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The Impact of Bilateral Eye Movements on Frontal-Midline Theta

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Abstract

The bilateral eye-movement manipulation facilitates cognition on a range of cognitive tasks, including executive functions tasks that require a high level of mental effort and sustained attentional-control. The aim of the current study was to investigate the relationship between bilateral eye-movements (BEMs) and frontal-midline theta (FMT) activity, a well-established electroencephalogram (EEG) marker for increased attentional-control. Participants were randomly assigned to either a 30 s central-control condition or a 30 s BEM condition and had their resting-state brain activity recorded before and after the 30 s manipulation task. EEG data from 60 participants was utilized for analysis. Analyses determined that BEMs had a significant impact on positive and negative mood compared to the control group. Changes in FMT power were calculated before and after exposure to post visual manipulation and displayed a general increase in FMT for the BEM condition and a general decrease for the control condition.

In addition, analysis of the theta frequency band for lateral electrode sites revealed significant effects at frontal and parietal brain regions after the visual manipulation. The BEM condition demonstrated an increase in frontal theta power and decrease in posterior theta power pre versus post manipulation when compare to the center-control condition. These findings offer support for the occurrence of a neural change after exposure to BEMs.

The Impact of Bilateral Eye Movements on Frontal-Midline Theta

Executing rapid bilateral eye-movements is a manipulation that has gained increasing attention in recent years due to its effects on cognition. Research on bilateral eye-movements (BEMs) has demonstrated its effects on cognition in areas such as memory, attention, and creativity, among others (e.g., Christman, Garvey, Propper, & Phaneuf, 2003; Lyle & Martin, 2010; Shobe, Ross, & Fleck, 2009). However, research exploring the impact of BEMs on cognition is mixed, with results varying depending on consistency of handedness (e.g., consistent versus inconsistent handed; Brunye, Mahoney, Augustyn, & Taylor, 2009; Lyle, Hanaver-Torrez, Hacklander, & Edlin, 2012; Lyle, Logan, & Roediger, 2008; Parker & Dagnall; 2010), as well as whether eye movements were horizontal or vertical (Christman *et* al., 2003; Lyle *et* al., 2008). More importantly, there is a shortage of neuroimaging research clarifying the impact of BEMs on brain activity (c.f., Propper, Pierce, Geisler, Christman & Bellardo, 2007; Samara, Elzinga, Slagter, & Nieuwenhuis, 2011).

Several theories have been generated that aim to explain the cognitive and emotional effects that occur following BEMs (e.g., Barrowcliff, Gray, Freeman, & Macculloch, 2004; Christman *et* al., 2003; Edlin & Lyle, 2013; Stickgold, 2002). For example, the *Saccade Induced Cognitive Enhancement (SICE) Theory* (Edlin & Lyle, 2013) suggests that BEMs facilitate cognition for executive function tasks that require a high degree of top-down attentional control (goal-driven selective attention)(Edlin & Lyle, 2013) due to the executive control required to execute BEMs. The aim of the current study is to empirically evaluate the SICE theory following BEMs. To do so, electrophysiological activity before versus after participants engage in BEMs will be evaluated for changes in frontal-midline theta (FMT). FMT is an established EEG marker of executive attention and working memory (Gevins *et* al., 1998; Gevins, Smith, McEvoy, & Yu, 1997), and will allow a direct test of the SICE theory.

The BEM manipulation is typically implemented using 30 s of rapid eye movements performed by participants tracking a dot visually that alternates in location between the left and right sides of a computer screen every 500 ms (Christman *et* al., 2003; see also Lyle & Edlin, 2015; Shobe, Ross, & Fleck, 2009). BEMs have been used in clinical settings such as during therapy for PTSD. According to the *Adaptive Information Processing Model* (AIP; Shapiro & Solomon, 1995), BEMs facilitate the processing and alleviation of distressing memories (Shapiro, 1989). Shapiro's model postulates that internal and external triggers can elicit the original perceptions of a distressing memory thereby inducing psychosomatic symptoms (e.g., high anxiety, nightmares, intrusive thoughts; Solomon & Shapiro, 2008). According to the AIP model (Solomon & Shapiro, 2008), the bilateral stimulation in EMDR therapies allows the individual to access previously stored dysfunctional information and to link the distressing memory with information from other memory networks thereby enabling new associations. The reduction in distressing memory symptoms of PTSD following BEMs has been supported in various studies (e.g., Lee & Drummond, 2008; Lilley, Andrade, Turpin, Sabin-Farrell, & Holmes, 2009).

In addition to Shapiro's model explaining the effects of BEMs in a clinical application (AIP; Shapiro, 2001), theories explaining the underlying effects of BEMs on cognition have been proposed and include the *Inter-hemispheric Interaction Theory* (IHI) (Christman *et* al., 2003) and the SICE theory (Edlin & Lyle, 2013). According to the IHI theory of enhancement proposed by Christman and colleagues (Christman *et* al., 2003), superior episodic memory retrieval following BEMs is the result of increased coordination between the cerebral hemispheres via the corpus callosum. The assumption is that BEMs equalize activation levels of the hemispheres allowing them to work together more efficiently. Prior research indicates that the left versus right hemispheres are specialized in episodic memory encoding and retrieval, as proposed by the *Hemispheric Encoding/Retrieval Asymmetry (HERA) Model* (Tulving, Kapur, Craik, Moscovitch, & Houle, 1994), and thus increased interaction between hemispheres should lead to enhanced episodic memory retrieval. Lastly, Christman et al. (2003) assert that significant increases in interhemispheric EEG coordination found during REM sleep (e.g.,Barcaro *et* al., 1989; Dumermuth & Lehman, 1981) link BEMs and IHI, particularly due to the finding that the vast majority of eye movements during REM sleep are horizontal (Hansotia *et* al., 1990).

To test the IHI theory of cognitive enhancement following BEMs, Christman and colleagues (Christman *et* al., 2003) conducted two experiments exploring the impact of BEMs on memory retrieval. In Experiment 1, participants viewed 36 words on a computer screen for 5 s each during a study phase. Then, participants engaged in 30 s of BEMs or a central-control condition and was followed by a recognition task and a word-fragment completion task that were administered to test episodic and implicit memory. Results revealed that only participants in the horizontal saccadic eye movement group showed a significant improvement in distinguishing old from new test items on the recognition task compared to other groups tested in the research (central-control condition, horizontal smooth pursuit, vertical saccades, and vertical smooth pursuit) (Christman *et* al., 2003). Analyses showed no significant differences in the number of completed word fragments in the word-fragment completion task among any of the conditions, indicating that BEMs have no effect on memory retrieval for implicit memories.

In an attempt to extend the findings of Experiment 1, in Experiment 2 Christman et al. (2003) asked participants to write down unusual events that happened every day in a journal for six days. One week after submitting their journal entries, participants were assigned to participate in one of two conditions before recall; a 30 s BEM condition or a 30 s central-control condition. Participants in the BEM condition recalled significantly more journal entries and produced fewer false recalls than the central-control condition. The results of Experiment 2 suggest that BEMs increased episodic memory retrieval for real-life events in addition to the lab-based word lists used in Experiment 1. However, because hemispheric activation or interaction was not measured for either experiment the observed memory enhancement, it is unknown if performance following BEMs correlated with a change in IHI.

In subsequent research exploring the neural correlates of BEMs, Propper and colleagues (Propper *et* al., 2007) used EEG to measure potential changes in coordination between the hemispheres after participants were exposed to BEMs. Propper et al. (2007) examined gamma activity (35-54 Hz) due to their association with the processing of episodic memories (Babiloni *et* al., 2010). Examination of homologous frontal sites FP1 and FP2 were also chosen because of their associations with episodic memory. Their findings indicate that engaging in BEMs led to a decrease in the correlation of gamma power between the two frontal electrode sites compared to a central-control condition. The researchers acknowledged the discrepancy between their findings and the IHI hypothesis and stated that changes in brain activity do not always translate into changes in cognitive function (Propper *et* al., 2007). According to Propper et al. (2007), interhemispheric coherence indicates that the two hemispheres are doing similar things, and interhemispheric interaction indicates that two hemispheres are performing coordinated, but not necessarily similar things. The authors assert that a decrease in interhemispheric coherence does not necessarily indicate a reduction in IHI (Propper *et* al., 2007), as was seen in prior research using bimanual motor tasks in which participants showed significant increases in coordination of their left and right hands (IHI), but decreases of gamma-band interhemispheric coherence between the hemispheres (Gerloff & Andres, 2002).

As a direct follow up, Samara *et* al. (2011) tested the IHI hypothesis and highlighted methodological limitations of Propper et al.'s (2007) original exploration of IHI. First, because Propper et al.'s research lacked a memory task, any changes in EEG coherence could not be related to memory performance changes. Also, EEG signals were only compared between one pair of prefrontal electrodes without exploring other symmetrical scalp regions. Samara et al. (2011) hypothesized that if the IHI theory is supported then an interhemispheric increase in coherence (a measure of hemispheric functional connectivity) should occur following the BEM condition compared to the central-control. An additional hypothesis predicted that if IHI does indeed enhance episodic memory retrieval then performance on the free recall task should be more accurate following the BEM condition, when compared to the central-control condition.

To address the aforementioned limitations, Samara et al. (2011) presented a study list of neutral and emotional words to 14 young adults who came to the lab for two separate sessions a week apart. In one session, participants were assigned to a 30 s BEM condition and in the other session to a 30 s central-control condition; conditions were counterbalanced across participants in this within-subjects experiment. After a 4 min pre-condition baseline EEG data recording in which participants alternated each minute between eyes open and eyes closed, the BEM or central-control manipulation began. After the manipulation, a post-condition baseline EEG recording of 4 minutes, alternating between eyes closed and eyes open took place. Lastly, participants were asked to recall as many words as they could from the study list within 5 min.

EEG results showed no evidence of a significant increase in EEG coherence across 12 sets of electrode pairs after BEMs, thus failing to support the IHI hypothesis. However, one pair of frontal electrodes (FT7 and FT8) showed a decrease in alpha band (8-13 Hz) coherence after BEMs. Samara et al. (2011) presume that since alpha coherence has previously been shown to be reduced during a cognitive task versus a resting state (Nunez, 2000), perhaps less coherence in the alpha frequency band at frontal electrode reflects brain states related to decreased arousal or cognitive processing. Interestingly, behavioral data indicated a significant increase in recall of emotional words for the BEM condition compared to the central-control condition. This set of findings suggests that IHI may not be the critical change in brain activity associated with retrieval enhancement and that this cognitive enhancement may be the result of other underlying mechanisms.

To further test the IHI theory , Lyle and Martin (2010) utilized a letter matching task to differentiate the impact of BEMs on intrahemispheric processing versus interhemispheric processing. In this task, participants were asked to fixate on a cross in the middle of the computer screen and indicate when the bottom letter matched the top letter that appeared by pressing the letter “h”. The authors reasoned that if the target and a matching letter probe are presented in the same visual field (intrahemispheric trials), then the two letters are processed within the same hemisphere and IHI is not necessary to detect the match. In contrast, if the target and a matching probe are presented in different visual fields (interhemispheric trials), they are processed in different hemispheres and IHI is necessary for match detection. Participants completed two experimental blocks after the central-control manipulation and two experimental blocks after the BEM manipulation. The two manipulations were counterbalanced and separated by a 15-minute interval that consisted of unrelated questionnaires. Lyle and Martin predicted that if engaging in BEMs facilitates IHI, enhanced performance in response time and accuracy in interhemispheric trials should occur following BEMs. In contrast to predictions of IHI, accuracy on intrahemispheric trials was significantly greater following BEMs than a central-control, but accuracy on interhemispheric trials did not differ significantly between conditions.

Lyle and Martin (2010 suggest that bilateral saccades may not facilitate IHI, but instead propose that BEMs cause in an increase in attentional-control and prepares participants for executive control tasks that follow. Rather than an increase in IHI as proposed by Christman et al. (2003), perhaps an increase in top-down attentional control is the mechanism that underlies the cognitive enhancement found in within-hemisphere trials and not between-hemisphere trials. In addition, Lyle and Martin (2010) proposed that a conceivable neural basis for such an enhancement is the saccade-induced activation that occurs during BEMs in the bilateral frontal eye fields (Corbetta *et* al., 1998), a region that is also involved in the allocation of attention (Corbetta & Shulman, 2002) and thus may affect subsequent attentional processing.

Further investigation of the top-down attentional control hypothesis proposed by Lyle and Martin (2010) was conducted by Edlin and Lyle (2013) who measured the effects of BEMs on the three attentional networks: alerting, orienting, and executive control. Participants engaged in BEMs or a central-control fixation and then began the revised attention network test (ANT-R: Fan *et* al., 2009). In the ANT-R, participants were asked to indicate the direction a target arrow was pointing, trial-by-trial. Trials varied based on whether the target arrow was surrounded by congruent (arrows that match the direction of the target) or incongruent (arrows that do not match the direction of the target) flankers. Responding quickly on trials containing incongruent flankers requires ignoring distracting stimuli by resolving conflict which demands a high level of attentional control, the basis of executive control. Simply responding during trials that contain congruent flankers requires orienting (information from sensory input) and alerting (maintaining awareness), a lower level of attentional control. Results showed that the RTs for trials containing incongruent flankers were significantly faster following BEMs than a central-control condition, and no differences were found in RTs between groups for trials containing congruent flankers. Therefore, BEMs reduced RTs whenever there was incongruent input that required greater attentional control to overcome the mismatch, an indication that BEMs specifically enhanced the subsequent operation of the executive function network (Edlin & Lyle, 2013).

The purpose of the present research was to measure the electrophysiological effects of BEMs on the frontal-midline region of the brain. Frontal-midline theta (FMT) is defined as rhythmic waves at a frequency of 4-8 Hz measured at electrode Fz reflecting activity of dense projections from Brodmann's Areas 8, 9, 24, 32, and 33 to the frontal-midline region (Gevins *et* al., 1997; Ishii *et* al., 2014; Pizzagalli, Oakes, & Davidson., 2003). Interestingly and relevant to the current study, voluntary eye movements and visual attention are linked to the same Brodmann's areas (Allman, Hakeem, Erwin, Nimchinsky, & Hof, 2001; Purves *et* al., 2001; Squire *et* al., 2012). Moreover, increases in FMT have been associated with increased attention (Asada, Fukuda, Tsunoda, Yamaguchi, & Tonoike, 1999), task difficulty (Gevins, Smith, McEvoy, & Yu, 1997; Smith, Gevins, Brown, Karnik, & Du, 2001), and memory load (Tesche & Karhu, 2000) which are components of the cognitive tasks that have been affected by BEMs in prior research (Lyle & Edlin, 2015; Martin & Lyle, 2010).

Additionally, increases in FMT during episodic memory retrieval tasks (Addante, Watrous, Yonelinas, Ekstrom, & Ranganath, 2011; Gruber, Tsivilis, Giabbiconi, & Muller, 2008) and in working memory tasks have been reported (Gevins *et* al., 1997; Gevins *et* al., 1998; Hsieh, Ekstrom, & Ranganath; 2011; Roberts, Hsieh, & Ranganath, 2013). In one study that explored the relation between FMT and task difficulty, Gevins and colleagues (Gevins *et* al., 1998) examined the sensitivity of EEG measures to variations in working memory load as defined by task difficulty and mental effort. Working memory is defined as the limited capacity for holding information in mind for several seconds in the context of the cognitive activity (Baddely & Hitch, 1974). Participants performed a consecutive letter matching task that asked them to indicate whether the letter presented in the current trial matched a letter presented in a previous trial on a computer screen. The task contained two versions, a spatial version (the location of letter) and a verbal version (the identity of the letter), and three levels of difficulty totaling 6 combinations of test conditions. The low-load (LL) difficulty level asked participants to compare the current stimulus with the one from the previous trial, the moderate-load (ML) difficulty level asked participants to compare the current stimulus with the stimulus presented two trials ago, and the high-load (HL) difficulty level asked participants to compare the current stimulus with the one presented three trials ago. Each task load level required increased mental effort and focus to overcome interfering information. Concurrent EEG measurements of the theta (4-7 Hz), alpha (8-12 Hz) and beta (13-30 Hz) bands were obtained and electrophysiological results showed a significant increase of FMT as task difficulty increased, with the greatest theta activity during the HL task (Gevins *et* al. 1997). Furthermore, no between-task differences (spatial versus verbal) in theta activity were observed. The researchers concluded that increases in FMT activity are influenced by variations in working memory load and sustained mental effort (Gevins *et* al., 1997; Gundel & Wilson, 1992; Smith, Gevins, Brown, Karnik, & Du, 2001; Yamamoto & Matsuoka, 1990). Further support for this conclusion comes from Smith *et* al. (2001), a study in which task load was manipulated and increased task difficulty was associated with an increase in FMT. This set of findings imply that FMT activity may be regulated by the activation of information maintained in working memory, suggesting a meaningful relationship with cognition. Relevant to the current investigation, increases in FMT activity resulting from sustained attentional control may be associated with the enhanced cognition that occurs following BEMs.

In addition to studies that have shown the appearance of FMT to be more pronounced during the performance of attention demanding tasks (Gevins *et* al., 1997; Mizuki, Tanaka, Isozaki, Nishijima, & Inanaga, 1980; Kubota *et* al., 2000), other investigations have shown a strong link between FMT activity and lower trait anxiety (Inanaga, 1998) and lower state anxiety (Suetsugi, 2000). To explore if any link exists between the appearance of FMT and a significant change in self-report anxiety measures, behavioral measures of personality and affect were administered to use as possible covariates in the analyses.

The present research explored differences in FMT in resting-state EEG activity recorded before and after participants completed 30 s of BEMs or 30 s of a central-control manipulation. Comparable to the method applied by Samara et al. (2011), a 4-min baseline recording, alternating in 1-min intervals between eyes open and eyes closed was recorded before exposure to either the BEM or central-control manipulation followed by a 4-min post recording using the same recording sequence. The change in FMT was compared between the BEM group and central-control group to test the hypothesis that participants in the BEM condition would show a greater increase in FMT after the manipulation than participants in the central-control condition.

Method

Participants

Ninety-one undergraduate psychology students from Stockton University participated in the research for course credit. Exclusion criteria included a history of traumatic brain injury or neurological disorder, epilepsy, a history of mental health disorder and/or current use of medications for the treatment of mental health disorders, and substance use/addiction in the past year.. Sixteen participants did not have usable EEG data and were also excluded from the analysis. Lastly, only participants who scored a 70 or higher on the Edinburgh Handedness Inventory (EHI; Oldfield, 1971) were classified as strongly right-handed and were included in the analysis. Those who scored below 70 on the EHI were classified as weak-handed and were excluded from analysis (*n*=15), leaving 60 participants (6 females, 54 males) for data analysis. Demographics and data from self-report measures of personality and affect for the remaining participants are provided by condition in Table 1.

Materials

The Positive and Negative Affect Schedule (PANAS; Watson, Clark, & Tellegan, 1988). The PANAS is comprised of 20 emotional descriptors, 10 which assess negative affect (NA; e.g., hostile or nervous) and 10 which assess positive affect (PA; e.g., enthusiastic or attentive). Respondents indicate to what extent they have felt this way during the past week using a 5-point Likert scale. Watson et al. (1988) have provided evidence demonstrating that the PA and NA scales are valid assessments of positive and negative affect. For the PA Scale, the Cronbach's alpha coefficient ranged from .86 to .90 and for the NA Scale was between .84 and .87. In addition, over an 8-week time period test-retest reliabilities (.68 for PA and .71 for NA) indicate that the PANAS is a reliable measure of trait affect and possesses strong concurrent validity for measures that include general distress and dysfunction, depression, and state anxiety (Watson et al., 1988).

Positive and Negative Affect Scale-Brief (PANAS–B; Thompson, 2007). The PANAS-Brief is a 10-item version of the PANAS (Watson *et* al., 1988) and contains 10 emotional descriptors, 5 which assess NA (e.g., upset or afraid) and 5 which assess PA (e.g., inspired or attentive). Respondents indicate to what extent they feel this way right now using a 5-point Likert scale.

Schizotypal Personality Questionnaire-Brief (SPQ-B; Raine & Benishay, 1995). The SPQ-B is a 22 item self-report measure of schizotypal personality characteristics based on the original SPQ (Raine, 1991), a self-report scale modeled on the DSM-III-R criteria for schizotypal personality disorder. The SPQ-B contains three factors modeled after the three components of schizophrenia and include: cognitive-perceptual (e.g., ideas of reference, magical thinking, unusual perceptual experiences, and paranoid ideation), interpersonal deficits (e.g., social anxiety, no close friends, blunted affect, and paranoid ideation) and disorganization (e.g., odd behavior, odd speech). Raine and Benishay (1995) provided evidence supporting the effectiveness of the SPQ-B using four different samples of undergraduate students. Test-retest reliability across the four samples averaged 0.76 and SPQ-B scores indicated criterion validity by correlating with independent clinical ratings of schizotypal traits on the Diagnostic and Statistical Manual of Mental Disorders–III-Revised (DSM-III-R; Raine & Benishay, 1995).

The Ten Item Personality Inventory (TIPI; Gosling, Rentfrow, & Swann, 2003). The TIPI is a brief measure of the Big Five personality traits. Respondents indicate on a 7-point Likert scale how strongly they “agree” or “disagree” with 10 items that are then used to generate scores on the big-five domains: Openness, Conscientiousness, Extraversion, Agreeableness, and Emotional Stability (e.g., “I see myself as calm and emotionally stable”). Two of the ten items on the assessment are used to generate each of the component scores. Test-retest reliability (.72) indicates that the TIPI is a dependable measure of the Big Five personality traits in situations where there are time constraints (Gosling *et* al., 2003).

Edinburg Handedness Inventory (EHI; Oldfield, 1971). Handedness was verified by the EHI. Participants are asked to indicate their hand preference for 10 different activities (writing, drawing, using a spoon, opening jars, brushing teeth, throwing, combing hair, using scissors, using a knife without a fork, and striking a match) by choosing from the following responses (with the corresponding scoring): Always Left (-10), Usually Left (-5), No Preference (0), Usually Right (5), or Always Right (+10). Handedness scores for participants range from -100 (dominantly left-handed) to 100 (dominantly right-handed).

EEG.

High-density EEG data were recorded using a 129-channel HydroCel Geodesic Sensor Net, with Cz reference (Electrical Geodesics, Inc.). Sensor impedance levels were below 50 KΩ, appropriate for use with the Net Amps 300 high-impedance amplifier. Data were sampled at 250 Hz, and filtered using an analog .1 – 100 Hz bandpass filter. Resting-state EEG data were recorded from each participant using Net Station 4.2 software. Data from the 19 channels in the 10-20 electrode system of placement were exported from Net Station for artifact removal and data reduction using Neuroguide 2.6.5 (Applied Neuroscience, Inc.; Thatcher, 2015). Data were down-sampled to 128 Hz and re-referenced to linked mastoids. Each participant's EEG record was visually inspected for artifact and segments of clean EGG data were selected for additional processing.

Fast Fourier Transformation (FFT) was performed on the data using 2 s epochs (.5 Hz resolution, cosine taper window) and a 75% overlapping sliding window to reduce the effects of FFT. FFT was computed for the following frequency bands: delta (1.0 – 4.0 Hz), theta (4.0 – 8.0 Hz), alpha (8.0 – 12.0 Hz), beta (12.5 – 25.0 Hz) and gamma (30.0 – 50.0 Hz). EEG power for each of the 19 electrodes in the 10-20 electrode system was determined for each of the frequency bands before and after exposure to the manipulation (BEM or central-control).

Procedure

The procedure for the present research was approved by Stockton University's Institutional Review Board. Participants began by giving written informed consent for their participation in the project. The consent form was followed by the demographics form. Participants were then asked to complete the PANAS (Watson *et* al., 1988), TIPI (Gosling *et* al., 2003), and the SPQ-B (Raine & Benishay, 1995) prior to the EEG portion of the experiment; the order of the questionnaires was counterbalanced across participants. After the questionnaires were completed, the EEG net was applied. A mild solution of distilled water and potassium chloride was used as a conductance medium.

During the EEG recording, participants began by having their resting brain activity recorded for 4 minutes, alternating back and forth between 1 minute eyes-closed and 1 minute eyes-open recordings. During these recordings participants were asked to sit in a relaxed position and not to think about anything in particular. After recording resting brain activity, half of the participants engaged in a BEM manipulation lasting for 30 seconds (experimental condition). In the BEM condition, participants were asked to track a moving circle as it shifted back and forth between the left and right sides of the computer screen, switching in location every .5 seconds (see Christman *et* al., 2003). The other half of the participants engaged in a central-control manipulation. In this task, participants were asked to view a circle in the center of the computer screen that randomly changed color two times per second. This control task offered visual stimulation but did not involve eye movements. Random assignment was used to assign each participant to either the experimental or control condition. After the 30-second manipulation (experimental or control), participants' brain activity was recorded again for 4 minutes using the same sequence as in the pre-manipulation recording. Immediately after the post-manipulation recording, participants completed the PANAS-Brief (Thompson, 2007), followed by the EHI (Oldfield, 1971).

Finally, the EEG net was removed and participants were thanked for their involvement in the research.

Results

Analysis Overview

Prior to analysis, EEG and behavioral data were screened for missing data, outliers, and normality. No violations of normality, nor the presence of outliers was noted. Because PANAS and PANAS-Brief scores had different scales, these scores were converted to Z scores prior to analysis. Because resting-state EEG was recorded under eyes-open and eyes-closed recording conditions, analyses were conducted separately for three different recording conditions: eyes-closed, eyes-open, and combined (collapsed across eyes-open and eyes-closed recordings). In addition, to incorporate electrodes from across the scalp, two ANOVAs were conducted for each of the recording conditions: one that focused on midline electrode locations and the other that focused on lateral electrode locations.

To directly test my hypothesis regarding frontal midline theta, a 2 x 2 mixed model analysis of variance was conducted to measure differences in theta power at electrode Fz, with visual manipulation (BEM versus central-control) as a between-subjects variable and time (pre and post) as the within-subjects variable. Additionally two separate supplemental 2 x 2 mixed model ANOVA's were conducted to measure differences in positive and negative PANAS scores with visual manipulation (BEM versus central-control) as a between subjects variable and time (pre versus post) as the within subjects variable.

In order to explore differences in the distribution of absolute power in the theta frequency band in the midline region in more depth, a 2 x 2 x 3 mixed model analysis of variance was performed with visual manipulation (BEM versus central-control) as a between-subjects variable and time (pre and post) and anterior-posterior (AP) electrode location (electrodes Fz, Cz, and Pz) as within-subjects variables to analyze (see Figure 1 for the electrode layout used in the analyses).

Lastly, to explore differences in the distribution of absolute theta power at lateral electrode locations, a 2 x 2 x 5 x 2 mixed model analysis of variance with visual manipulation (BEMs versus central-control) as a between-subjects variable and time (pre and post), anterior-posterior (AP) electrode location (frontal pole, frontal, central, parietal, and occipital), and hemisphere (left and right) as the within-subjects variables.

All analyses were conducted as two-tailed tests and were Greenhouse-Geisser corrected. Because of the importance in the present research on exploring differences between the BEM and center-control conditions, only significant interactions with condition as a variable were discussed further.

Analyses

First, a 2 x 2 mixed model analysis of variance with visual manipulation and time as independent variables was conducted to directly test my hypothesis that the BEM group would display a significant increase in FMT at electrode Fz pre versus post when compared to a central-control condition but failed to reveal a significant Time x Condition interaction for each eyes-open, eyes-closed, and combined recording condition analyses (see Table 2). However, plots for combined (see Figure 2) eyes-closed (see Figure 3) and eyes-open (see Figure 4) analysis showed a general trend supporting my hypothesis; namely the BEM group showed an increase in

FMT from pre to post manipulation and the central-control group showed a decrease in FMT from pre to post manipulation (see Table 3 for electrode power means by condition). Two supplemental analyses were conducted using pre and post PANAS scores to determine if BEMs had a significant impact on positive and negative mood compared to a control group. The results of a 2 (Time: pre versus post) x 2 (Condition: BEM versus central-control) mixed-model ANOVA examining changes in negative mood revealed a significant Time x Condition interaction ($F(1,58) = 4.698$, $p = .034$, $\eta_p^2 = .075$) (see Table 4 & Figure 5); differences between groups for positive mood were not significant, but displayed a general increase from pre to post for the BEM group and a decrease for the central-control group (see Table 5 & Figure 6).

Subsequently, a mixed model analysis of variance of the midline region revealed no significant interactions or differences between visual manipulation groups in the distribution of theta power collapsed across recording conditions (see Table 6). To more closely examine any group differences in theta power for separately by recording condition, a 2 x 2 x 3 (Condition x Time x AP) mixed model analysis of variance was conducted for eyes closed and separately for eyes open data for the midline electrode locations; however, these analyses also failed to revealed significant condition or interaction effects (see Table 7 for eyes-closed results; see Table 8 for eyes-open results).

However, a mixed model analysis of variance investigating lateral electrode locations showed a significant Time x AP x Condition interaction ($F(1,58) = 4.511$, $p = .006$, $\eta_p^2 = .072$) (see Table 9). Follow- up analyses were utilized to determine which electrode locations differed between conditions. A 2 x 2 x 2 mixed model ANOVA was conducted for each of the five anterior-posterior locations using condition as a between-subjects variable and time and hemisphere as within-subjects variables. These analyses revealed a significant Time x Condition interaction for frontal electrode pair F3-F4 (F(1,58) = 8.095, p = .006, η_p^2 = .122) and parietal electrode pair P3-P4 (F(1,58) = 10.911, p = .002, η_p^2 = .158) (see figure 7,8 & Table 10). No significant group differences were found for other lateral electrode pairs (frontal pole, central, and occipital).

Again, in order to more closely examine group differences for eyes closed and eyes open data, a 2 x 2 x 5 x 2 (Condition x Time x AP x Hemisphere) mixed analysis of variance was conducted for lateral electrode locations for each recording condition. Results revealed a significant Time x AP x Condition interaction for the eyes-closed recoding condition F(1,58) = 4.632, p = .006, η_p^2 = .074) (see Table 11). The results of follow-up analyses matched those found in the combined recording analyses, namely a significant Time x Condition interaction for the frontal electrode location (F3-F4; F(1,58) = 11.644, p = .001, η_p^2 = .167) and the parietal electrode location (P3-P4; F(1,58) = 10.944, p = .002, η_p^2 = .159) respectively. No significant interactions for eyes closed data were found for the other anterior-posterior locations (frontal pole, central, and occipital; see Table 12). Additionally, no significant interactions or visual manipulation effects for the eyes-open recoding condition for the lateral electrode locations were observed (see Table 13).

Discussion

The results of the present study did not reveal statistically significant differences in FMT between the BEM condition and the central-control condition. Although not statistically significant, pre versus post FMT plots for combined and eyes-closed recording conditions trended in the predicted direction; that is that the BEM group showed an increase in FMT from pre to post and the central-control group showed a decrease. These plots correspond with the change in mean FMT power from pre to post in both conditions. Additionally, the BEM group showed a general increase in positive mood and a statistically significant decrease in negative mood, and the central-control group again showed the opposite affect; namely a decrease in positive mood and a statistically significant increase in negative mood.

Exploratory analyses did not reveal significant differences at the midline region (Fz, Cz, Pz) between the BEM group and the central-control group in any of the recording conditions: eyes-closed, eyes-open, or combined. However, a significant effect was found at frontal and parietal lateral electrode locations for both combined and eyes-closed recording conditions; specifically the BEM group displayed an increase from pre to post in frontal theta power (F3-F4) and a decrease in parietal theta power (P3-P4), whereas the central-control group showed an opposite effect. For the central-control group a decrease from pre to post in frontal theta activity and an increase in parietal theta activity was observed.

The current study supports previous findings that variations in task load are reflected in changes in the distribution of absolute power in the theta frequency band over frontal regions (Gevins et. al, 1998). Increasing task loads requires greater demands of attentional-control and mental effort and are supported here by the general trend of the BEM group that showed an increase in FMT power from pre to post and the central-control group that showed a decrease in FMT. More specifically, the BEM group engaged in 30 s of bilateral-eye movements which requires a higher level of attentional-control stemming from the alerting attentional network (maintaining awareness) and the orienting attentional network (prioritizing sensory input) than the central-control condition, in which participants were simply required to maintain awareness (alerting) of a dot changing color in the center of the screen, a lower level of attentional-control.

Edlin and Lyle (2013) proposed that executing the 30 s BEM manipulation produces an increase in attentional control and prepares participants for executive control tasks that follow. This hypothesis was supported by their findings that the execution of BEMs leads to shorter RTs during incongruent trials of the ANT-R task compared to a central-control group and, as the authors concluded, that BEMs enhanced the executive function network due to the top-down attentional control required to execute BEMs (Edlin & Lyle, 2013; Edlin & Lyle 2014). The current study revealed a general increase in FMT occurring after the execution of BEMs compared to the central-control condition, and adds support that executing BEMs facilitates attention and may prime cognition for performance on subsequent memory, attention, and creativity tasks (e.g., Christman, Garvey, Propper, & Phaneuf, 2003; Lyle & Martin, 2010; Shobe, Ross, & Fleck, 2009). However, while variations in attentional-control between the two conditions reflected general changes in the distribution of FMT power, the current study suggests that the FMT effects may be more apparent during more challenging task-related demands of the executive function network that require greater working memory load and sustained mental effort (Gevins *et* al., 1997; Gevins et. al, 1998; Gundel & Wilson, 1992; Smith, Gevins, Brown, Karnik, & Du, 2001; Yamamoto & Matsuoka, 1990).

One of the aims of the current study was to contribute to the shortage of resting state EEG research exploring the neural mechanisms following BEMs. To date, no other study has specifically explored the effects of BEMs on FMT, an established EEG marker of executive attention. Previous EEG research has attempted to explain BEMs by testing the IHI hypothesis which states that BEMs equalize activation levels of the hemispheres thus allowing for superior episodic memory retrieval (Christman *et* al., 2003). Propper et al. (2008) explored gamma activity at electrode sites FP1 and FP2 due to their association with the processing of episodic memories (Babiloni *et* al., 2010). Contrary to the IHI theory, Propper et al. (2008) found that BEMs led to a decrease in gamma coherence between frontal pole electrode pair FP1 and FP2. No other homologous electrode sites were examined. Moreover, a follow up investigation of BEMs to address the limitations of examining a single electrode pair in the aforementioned study was performed by Samara et al. (2011) and tested the IHI hypothesis by exploring EEG coherence across 12 sets of electrode pairs for 6 standard frequency bands (theta, alpha, lower beta, higher beta, lower gamma, & higher gamma). Again, EEG results from 14 participants of this study showed no evidence of a significant increase in EEG coherence across the electrode pairs after BEMs, thus failing to support the IHI hypothesis. These findings suggest that interhemispheric interaction may not be the mechanism linked with the cognitive enhancement found after exposure to BEMs.

Moreover, the data in the current study suggest that exposure to BEMs is somehow associated with a change in resting-state theta activity in frontal regions. The main significant findings indicate an increase in theta power in the BEM group at lateral frontal regions (F3-F4) and a significant decrease in theta power at lateral parietal regions (P3-P4). The increase in theta power at frontal regions in the BEM group coincides with studies that link the frontal eye fields with shifting attention via voluntary eye movements (Schall, 2004) and others that indicate the dorsal frontoparietal regions are the site of top-down signals for voluntary attentional control (Corbetta, Kincade, Ollinger, McAvoy, & Shulman, 2000; Hopfinger, Buonocore, & Mangun 2000; Shulman *et* al. 2002). The observed changes in frontal theta power due to the differing demands in attentional-control between the conditions in the present study demonstrates a strong relationship between attention and voluntary eye movements as components of the frontoparietal attention network. In addition, the significant decrease in theta power in the BEM group at lateral parietal locations that occurred concurrently with the increase in frontal theta power coincides with fMRI studies that showed that decreases in activity in the temporoparietal junction (TPJ) during voluntary control of attention along with increases in activity in the intraparietal sulcus (IP) and the FEF during a visual motion detection task occurred concurrently (Shulman *et* al., 2003). Recent studies have suggested that dorsal frontoparietal regions are involved in directing attention based on goals or expectations, whereas regions in the TPJ are activated by subsequent target detection, particularly if the target is unexpected and requires attention to be reoriented (Corbetta *et* al. 2000; Linden *et* al. 1999; Macaluso, Frith, & Driver, 2002; Marois, Leung, & Gore, 2000). The nature of the BEM task aligns closely with these studies in that it is a visual manipulation consisting of expected shifts of visual attention alternating from left to right every 500 ms for 30 s without any reorientation of attention. The present results open up the possibility that the attentional control necessary to perform 30 s of BEMs, preparing participants for executive control tasks that follow, is reflected by theta power changes in resting-state brain activity in frontal and parietal regions, thereby supporting the *Saccade Induced Cognitive Enhancement (SICE) Theory* (Edlin & Lyle, 2013).

Former EEG investigations of resting-state brain activity, a state of wakeful rest without cognitive task demands, have suggested marked differences in EEG between eyes-closed versus eyes-open resting states (Chen, Feng, Zhao, Yin, & Wang, 2007; Kounios *et* al., 2007). EEG data in the current study underscored differences in eyes-closed versus eyes-open resting state brain activity and showed significant differences between the BEM condition and the central-control condition at frontal and parietal lateral electrode locations for eyes-closed recording conditions but not in eyes-open recordings. The differences in theta power at frontal regions during eyes-closed recordings is consistent with the findings in Chen et al. (2007) that revealed a significant reduction in theta power from eyes-closed to eyes-open states at the fronto-central area. With an increase in FMT and overall theta activity at the frontal region after execution of BEMs, the results of this study demonstrate pronounced differences in eyes-closed resting-state recordings between the BEM group and the central-control condition, not evident in the eyes-open recording condition.

The BEM condition showed increased frontal theta activity concurrently with a significant reduction in negative mood thereby supporting research that reports individuals exhibiting greater theta activity tend to have lower state and trait anxiety scores (Inanaga, 1998). Likewise, EEG research has shown that FMT positively correlated with subjective reports of positive emotion and inversely correlated with the appearance of mind wandering and negative rumination (Aftanas & Golocheikine, 2001). Perhaps the observed positive influence that BEMs had on affect and mood can be attributed to the sustained attention required to properly execute BEMs, leaving little room for mind wandering or intrusive thoughts. Conversely the central-control condition showed a significant increase in negative mood and may be the result of the low attentional demands of the task itself. This notion has been supported by a behavioral study that displayed a significant reduction in emotional valence associated with negative autobiographical memories following BEMs when compared to a central-control condition (Barrowcliff *et* al., 2004)

There were several limitations in the present research. While duration effects of BEMs were found in a study by Shobe et al. (2009) that showed a BEM effect on creativity measures of originality lasting between 4-6 minutes, it should be noted that there was a 4-minute delay between the BEM manipulation and administration of the post-manipulation self-report measure of mood. It is unknown if the time lapse may have weakened the eye-movement effect. Future research may consider administering the post-manipulation self-report measure of mood immediately after the experimental or control task, potentially revealing a stronger effect of BEMs on mood. A final limitation of the current study was that the investigation was limited to the theta frequency band. Previous studies have shown that the alpha frequency band is associated with visual attention (Kounios *et* al., 2007), and thus future investigations exploring absolute power across all frequency bands would provide a meaningful contribution to the literature examining the neural mechanisms of BEMs. Due to the low task demands of resting-state EEG, research containing challenging attentional demands of the executive function network following BEMs will potentially reveal more prominent FMT effects and shed light on the relationship between BEMs and the cognitive enhancement that follows.

In conclusion, the current study suggests that various degrees of attentional-control are reflected by changes in FMT, and the heightened attentional-control that follows from BEMs appear to increase theta power at frontal brain regions and reduce negative mood. Resting-state EEG data from this study make a meaningful contribution to our understanding of the differences between eyes-closed versus eyes-open brain activity following a visual attention task. In order to better test the cognitive enhancement that occurs after BEMs, future EEG studies should implement executive control tasks following BEMs that measure its ability to facilitate cognition in the executive function network.

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TABLE 1. ***Age and self-report measures of personality and affect.***

Condition	Control (*n* = 28)		Eye Movement (*n* = 32)	
	M	SD	M	SD
Age	20.21	3.47	19.61	1.93
SPQ Total	7.68	4.88	6.97	4.12
PANAS Positive	32.81	4.84	34.23	5.47
PANAS Negative	18.71	5.18	19.48	6.70
Extraversion	4.32	1.41	4.65	1.56
Agreeableness	4.88	.86	5.13	1.02
Conscientiousness	5.79	.98	6.16	.81
Emotional Stability	4.88	1.33	4.73	1.20
Openness	5.50	1.16	5.53	1.20
P-Brief Positive	12.04	4.65	14.06	4.69
P-Brief Negative	6.21	1.66	5.52	1.38
Handedness	90.71	9.10	90.00	10.33

TABLE 2.

ANOVA Exploring differences in Theta Power for Time (Overall Pre versus Overall Post) by Electrode Location (Midline Electrode: Fz) by Condition (Eye-Movement Versus Control) Comparisons

Type	**Source**	***SS***	***df***	***MS***	***F***	***p***	***ES***
Overall	Time x Condition	.019	1	.019	1.727	.194	.029
Closed	Time x Condition	.045	1	.045	2.523	.118	.042
Open	Time x Condition	.001	1	.001	.070	.793	.001

TABLE 3. Mean Z-scores and Standard Deviations for FMT power at electrode Fz across recording conditions.

Condition	**Overall**		**Closed**		**Open**	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**
Control	**1.133**	**1.113**	**1.061**	**1.041**	**1.177**	**1.171**
	(.082)	**(.081)**	**(.087)**	**(.091)**	**(.081)**	**(.077)**
BEM	**1.151**	**1.18**	**1.100**	**1.156**	**1.197**	**1.201**
	(.077)	**(.076)**	**(.081)**	**(.085)**	**(.076)**	**(.072)**

TABLE 4.

ANOVA's Exploring differences in Positive and Negative Mood for Time (Pre versus Post) by Condition (Eye-Movement Versus Control) Comparisons

Type	**Source**	***SS***	***df***	***MS***	***F***	***p***	***ES***
Negative	**Time x Condition**	**2.978**	**1**	**2.978**	**4.698**	**.034**	**.075**
Positive	Time x Condition	.306	1	.306	.589	.446	.010

TABLE 5. Mean Z-scores and Standard Deviations for Positive and Negative Affect.

Condition	**Positive**		**Negative**	
	Pre	**Post**	**Pre**	**Post**
Control	**-.088**	**-.256**	**-.162**	**.279**
	(.187)	**(.189)**	**(.192)**	**(.198)**
BEM	**.144**	**.178**	**0.013**	**-.203**
	(.175)	**(.177)**	**(.179)**	**(.185)**

TABLE 6.

ANOVA Exploring differences in Theta Power for Time (Overall Pre versus Overall Post) by Electrode Location (Midline Electrode: Fz, Cz, and Pz) by Condition (Eye-Movement Versus Control) Comparisons

Source	***SS***	***df***	***MS***	***F***	***p***	***ES***
Condition	.395	1	.395	.570	.453	.010
Time	.026	1	.026	.591	.445	.010
Time x Condition	.057	1	.057	1.322	.255	.022
AP	68.082	1.997	34.092	59.989	.000	.508
AP x Condition	.164	1.997	.082	.144	.865	.002
Time x AP	.144	1.929	.075	7.787	.173	030
Time x AP x Condition	.115	1.929	.059	1.419	.246	.024

TABLE 7.

ANOVA Exploring differences in Theta Power for Time (Pre-Closed versus Post-Closed) by Electrode Location (Midline Electrode: Fz, Cz, and Pz) by Condition (Eye-Movement Versus Control) Comparisons

Source	***SS***	***df***	***MS***	***F***	***p***	***ES***
Condition	.232	1	.232	.327	.570	.006
Time x Condition	.087	1	.087	1.823	.182	.003
AP x Condition	.185	1.995	.093	.140	.869	.002
Time X AP x Condition	.219	1.910	.115	1.977	.145	.033

TABLE 8.

ANOVA Exploring differences in Theta Power for Time (Pre-Open versus Post-Open) by Electrode Location (Midline Electrode: Fz, Cz, and Pz) by Condition (Eye-Movement Versus Control) Comparisons

Source	***SS***	***df***	***MS***	***F***	***p***	***ES***
Condition	.737	1	.737	1.125	.293	.019
Time x Condition	.028	1	.028	.561	.457	.010
AP x Condition	.331	1.991	.166	.336	.714	.006
Time X AP x Condition	.026	1.990	.347	.348	.706	.006

TABLE 9.

ANOVA Exploring Differences in Theta Power between Conditions (Eye-movement versus Control) for Time (Overall Pre versus Overall Post) by Electrode Location (Anterior-Posterior), by Hemisphere

Source	***SS***	***df***	***MS***	***F***	***p***	***ES***
Condition	.163	1	.163	.265	.608	.005
Time	.005	1	.005	.336	.564	.006
Time x Condition	.010	1	.010	.689	.410	.012
AP	441.579	2.794	158.037	111.546	.000	.658
AP x Condition	3.196	2.794	1.144	.807	.484	.014
Hemi	10.435	1	10.435	21.809	.000	.273
Hemi X Condition	.045	1	.045	.094	.760	.002
Time x AP	.054	2.701	.020	.676	.553	.012
Time x AP x Condition	**.361**	**2.701**	**.134**	**4.511**	**.006**	**.072**
Time x Hemi	.012	1	.012	.589	.446	.010
Time x Hemi x Condition	.019	1	.019	.922	.341	.016
AP x Hemi	2.711	3.365	.806	2.300	.071	.038
AP x Hemi x Condition	.211	3.365	.063	.179	.928	.003
Time x AP x Hemi	.066	2.984	.022	1.812	.147	.030
Time X AP x Hemi X Condition	.049	2.984	.016	1.331	.266	.022

TABLE 10.

ANOVAs Exploring Group Differences in Theta Power between Conditions (Eye-movement versus Control) for Time (Overall Pre versus Overall Post) by Electrode Location (Anterior-Posterior)

Electrode Pair	**Source**	***SS***	***df***	***MS***	***F***	***p***	***ES***
FP1-FP2	Condition	.226	1	.226	.217	.643	.004
	Time x Condition	.015	1	.015	.549	.462	.009
F3-F4	Condition	.003	1	.003	.007	.934	.000
	Time x Condition	**.116**	**1**	**.116**	**8.095**	**.006**	**.122**
C3-C4	Condition	1.455	1	1.455	1.471	.230	.025
	Time x Condition	.059	1	.059	6.036	.017	.094
P3-P4	Condition	.234	1	.243	.320	.574	.005
	Time x Condition	**.181**	**1**	**.181**	**10.911**	**.002**	**.158**
O1-O2	Condition	1.432	1	1.432	1.068	.306	.018
	Time x Condition	0.00	1	0.00	.006	.938	.000

TABLE 11.

ANOVA Exploring Differences in Theta Power between Conditions (Eye-movement versus Control) for Time (Pre-Closed Versus Post-Closed) by Electrode Location (Anterior-Posterior), by Hemisphere

Source	***SS***	***df***	***MS***	***F***	***p***	***ES***
Condition	.158	1	.158	.258	.614	.004
Time x Condition	.004	1	.004	.205	.653	.004
AP x Condition	3.283	2.732	1.202	.757	.508	.013
Hemi x Condition	.100	1	.100	.212	.647	.004
Time x AP x Condition	**.586**	**2.668**	**.220**	**4.632**	**.006**	**.074**
Time x Hemi x Condition	.009	1	.009	.234	.630	.004
AP x Hemi x Condition	.102	3.330	.030	.085	.976	.001
Time x AP x Hemi x Condition	.122	3.101	.040	2.006	.113	.033

TABLE 12.

ANOVAs Exploring Group Differences in Theta Power between Conditions (Eye-movement versus Control) for Time (Pre-Closed versus Post-Closed) by Electrode Location (Anterior-Posterior)

Electrode Pair Source		***SS***	***df***	***MS***	***F***	***p***	***ES***
FP1-FP2	Condition	.621	1	.621	.515	.476	.009
	Time x Condition	.055	1	.055	1.489	.227	.025
F3-F4	Condition	.002	1	.002	.005	.946	.000
	Time x Condition	**.187**	**1**	**.187**	**11.644**	**.001**	**.167**
C3-C4	Condition	1.643	1	1.643	1.656	.203	.028
	Time x Condition	.035	1	.035	2.439	.124	.040
P3-P4	Condition	.085	1	.085	.105	.747	.002
	Time x Condition	**.309**	**1**	**.309**	**10.944**	**.002**	**.159**
O1-O2	Condition	1.091	1	1.091	.759	.387	.013
	Time x Condition	.004	1	.004	.072	.789	.001

TABLE 13.

ANOVA Exploring Differences in Theta Power between Conditions (Eye-movement versus Control) for Time (Pre-Open versus Post-Open) by Electrode Location (Anterior-Posterior), by Hemisphere

Source	***SS***	***df***	***MS***	***F***	***p***	***ES***
Condition	.215	1	.215	.336	.565	.006
Time x Condition	.015	1	.015	.1.036	.313	.018
AP x Condition	3.335	2.773	1.203	.888	.442	.015
Hemi x Condition	.046	1	.046	.102	.751	.002
Time x AP x Condition	.183	3.018	.061	2.336	.075	.039
Time x Hemi x Condition	.020	1	.020	.882	.351	.015
AP x Hemi x Condition	.406	3.419	.119	.339	.823	.006
Time x AP x Hemi x Condition	.038	3.111	.012	.681	570	.012

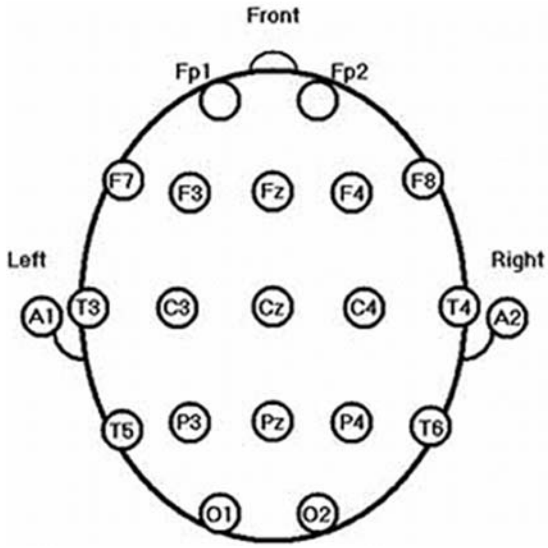

Figure 1. Electrode Layout. 21 electrode sites of the International 10-20 System.

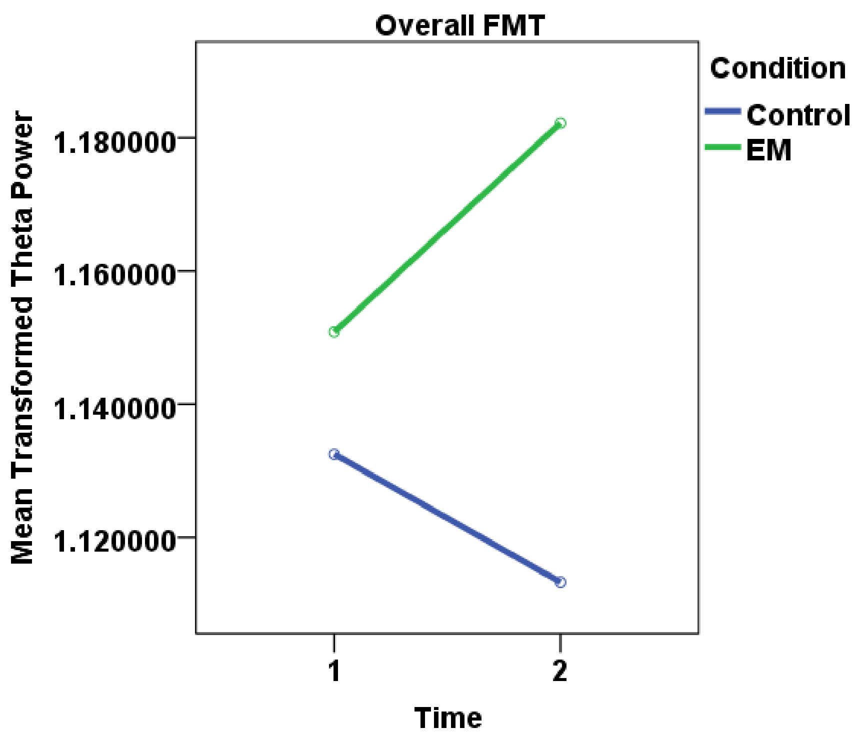

Figure 2. Raw theta power scores were log transformed and standardized. This figure illustrates a general increase for the BEM condition and a general decrease for the central-control condition in FMT power from pre to post.

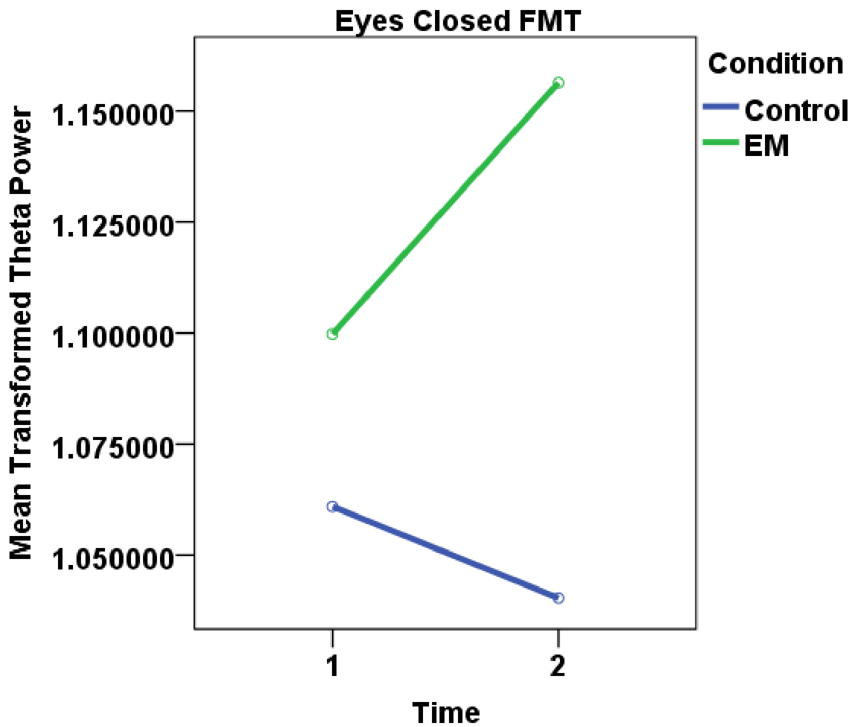

Figure 3. Raw theta power scores were log transformed and standardized. This figure illustrates a general increase for the BEM condition and a general decrease for the central-control condition in FMT power from pre to post during eyes closed recordings.

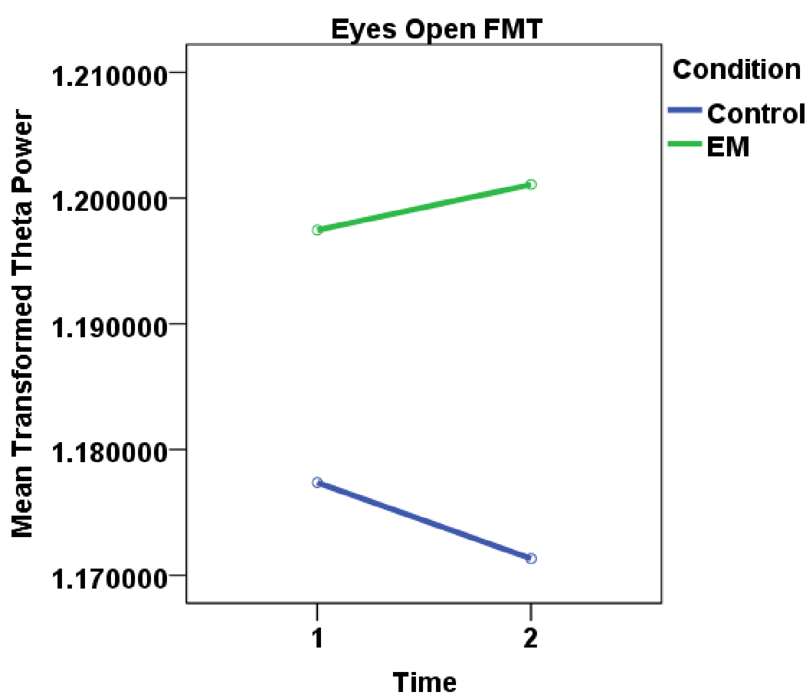

Figure 4. Raw theta power scores were log transformed and standardized. This figure illustrates a general increase for the BEM condition and a general decrease for the central-control condition in FMT power from pre to post during eyes open recordings.

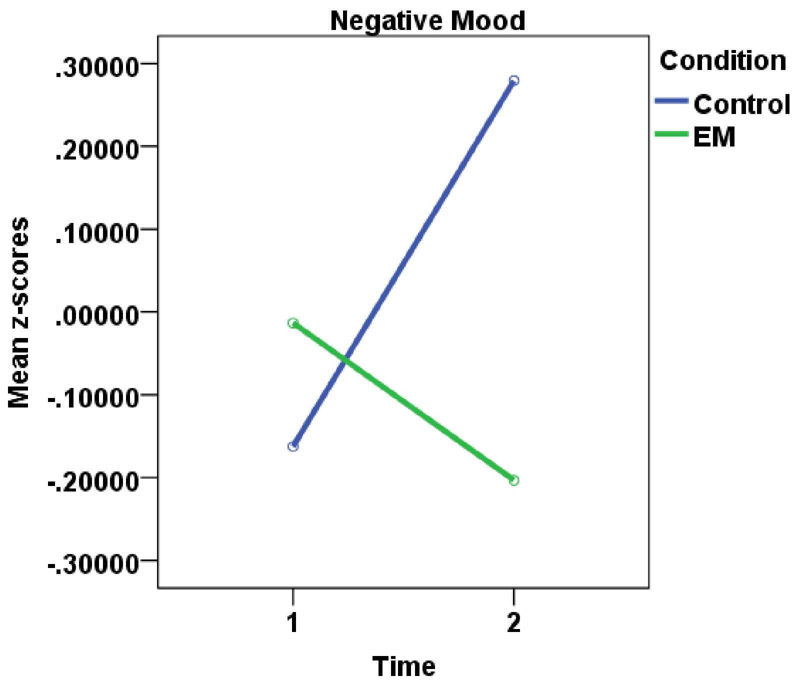

Figure 5. Raw PANAS and P-Brief scores were standardized. This figure illustrates a significant decrease in negative mood for the BEM condition and a significant increase for the central-control condition.

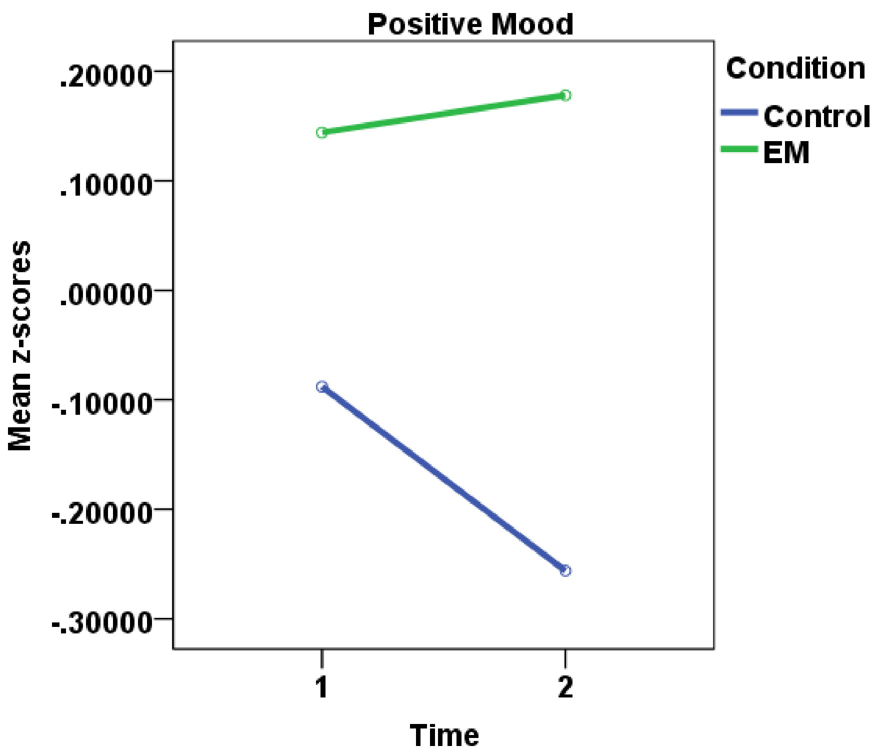

Figure 6. Raw PANAS and P-Brief scores were standardized. This figure illustrates a general increase in positive mood for the BEM condition and a general decrease for the central-control condition.

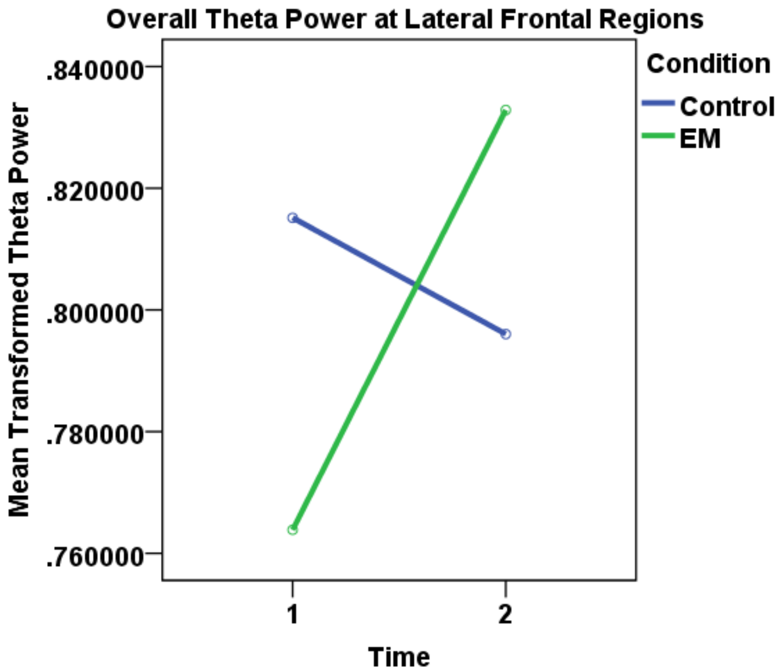

Figure 7. Raw theta power scores were log transformed and standardized. This figure illustrates a significant increase for the BEM condition and a significant decrease for the central-control condition in overall theta power from pre to post at frontal electrode pair F3-F4.

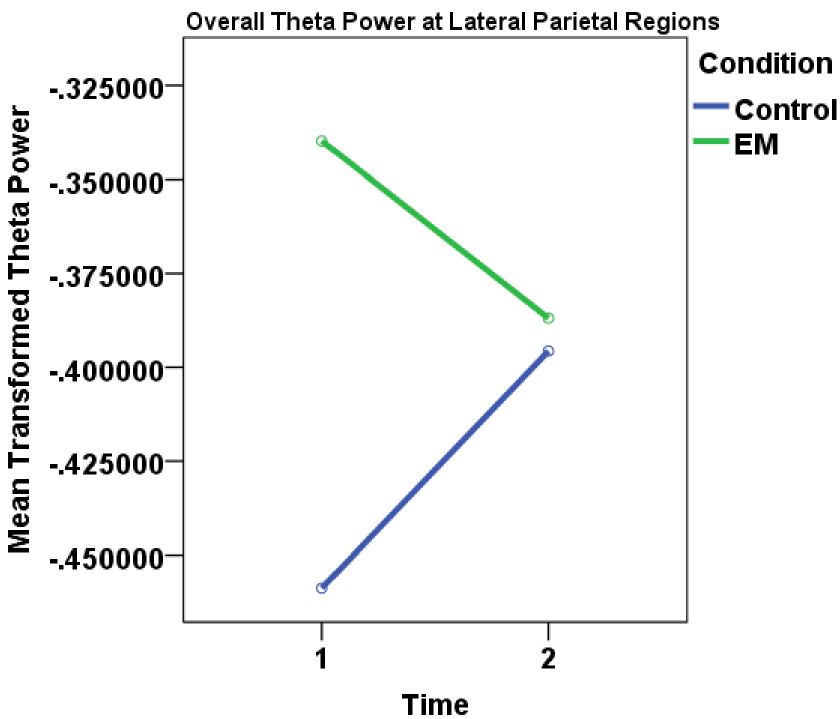

Figure 8. Raw theta power scores were log transformed and standardized. This figure illustrates a significant decrease for the BEM condition and a significant increase for the central-control condition in overall theta power from pre to post at parietal electrode pair P3-P4.

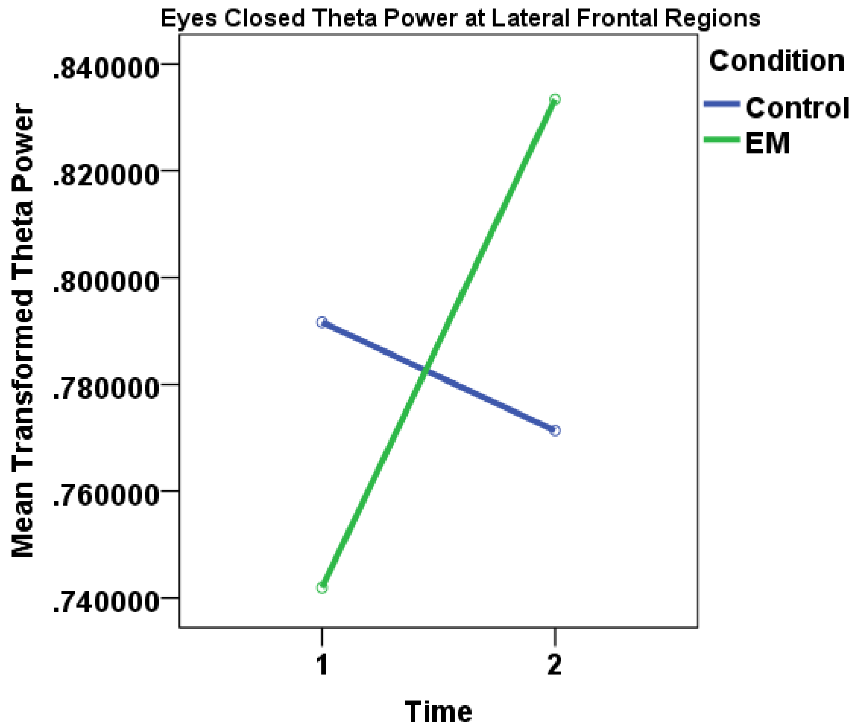

Figure 9. Raw theta power scores were log transformed and standardized. This figure illustrates a significant increase for the BEM condition and a significant decrease for the central-control condition in eyes closed theta power from pre to post at frontal electrode pair F3-F4.

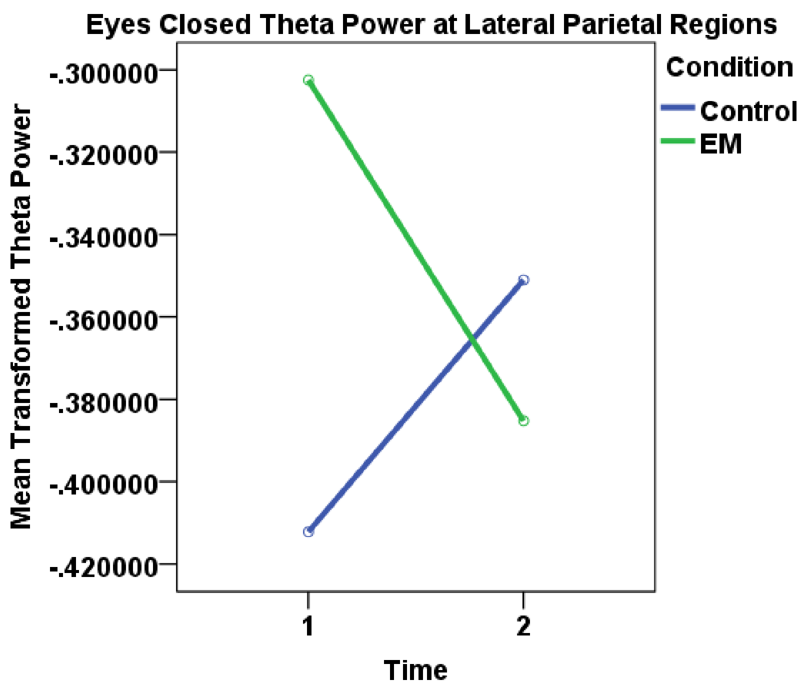

Figure 10. Raw theta power scores were log transformed and standardized. This figure illustrates a significant decrease for the BEM condition and a significant increase for the central-control condition in eyes closed theta power from pre to post at parietal electrode pair P3-P4.