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Electrical Brain Activity and The Examinee's Level of Effort During Performance Validity Tasks

Roselia Juan

Stephen F. Austin State University, juanr@jacks.sfasu.edu

ELECTRICAL BRAIN ACTIVITY AND THE EXAMINEE'S LEVEL OF EFFORT DURING PERFORMANCE VALIDITY TASKS

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Roselia Juan, B.S.

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APPROVED:

Luis E. Aguerrevere, Ph.D., Thesis Director

Frankie Clark, Ph.D., Committee Member/Program Director

Daniel McCleary, Ph.D., Committee Member

Nathan Sparkman, Ph.D., Committee Member

Elaine Turner, Ph.D., Committee Member

Pauline M. Sampson, Ph.D.
Dean of Research and Graduate Studies

Abstract

Many people who intend to obtain benefits from an assessment may resort to performing poorly on assessments. Previous literature has found that cognitive deficits and long-term symptomatic complaints are reported by individuals with mild Traumatic Brain Injuries. Limited studies have investigated how brain activity measured via Quantitative Electroencephalography (QEEG) relates to mental effort during cognitive tasks. The purpose of this study was to investigate electrical brain activity, as measured by Peak (PK) frequency, on frontal brain areas (i.e. locations F3-F4) in individuals giving poor mental effort. Measures of effort, in this study, include the Test of Memory Malingering, Rey 15-Item Test, and the Rey-Osterrieth Complex Figure. A significant difference was found for the Rey-15 task in F4-F3 Beta PK Frequency asymmetry, indicating that groups differed in the asymmetry scores at the frontal areas. The results suggest that PK was only able to be related to effort when participants completed relatively easy tasks, and this was represented by asymmetry on PK Frequency for Beta on the Frontal Lobe.

Keywords: EEG, Beta Peak Frequency, Effort, Performance Validity Tests, TBI

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CHAPTER I

Introduction

Deficits in cognitive functioning are commonly reported in people sustaining head trauma. Traumatic Brain Injuries (TBI), which occur after an external force disrupts the brain, is a significant health concern in the United States affecting 1.4 million to 3 million individuals yearly (McCrea, 2008). Roughly, 70-90% of all cases are considered mild in severity (mTBI). The most common deficits reported from mTBI include difficulties with attention and concentration, memory, learning, coordination, and judgment/problem solving (Rimel, Giordani, Barth, Boll, & Jane, 1981; Rabinowitz & Levin, 2014). Approximately 15-20% of mTBI cases report long-term (more than a week) symptomatic complaints. However, these cognitive difficulties resolve within three months (Ryan & Warden, 2003).

Unfortunately, some individuals exaggerate or fake symptoms to obtain accommodations, resources, or monetary compensation without truly needing it. In 2002, researchers conducted a survey with 131 members of the American Board of Clinical Neuropsychology (ABCN) to investigate an annual base rate of malingering cases (Mittenberg, Patton, Canyock, & Codit, 2002). Out of 33,000 clinical cases identified, prevalence rates for malingering showed 29% of those cases were due to personal injury, 30% disability or worker's compensation, 19% criminal cases, and 8% medical or psychiatric cases. From the reported rates in personal injury litigation cases, 38.5%

account for individuals seeking compensation for mild head injuries (Mittenberg et al., 2002). Research also suggests that external incentives and other financial compensation motivates people to intentionally exaggerate or fabricate deficits (Belanger, Curtiss, Demery, Lebowitz, & Vanderploeg, 2005; Binder & Rohling, 1996; Binder, Rohling, & Larrabee, 1997). This gives rise to the personal intention of false symptomology, such that in compensation-seeking neuropsychological patients, about 40% of cases are considered to be giving poor effort during examinations (Larrabee, 2003). Therefore, it is up to the evaluators to provide an accurate diagnosis by taking into consideration several factors that could affect the evaluative procedure. Typical assessment protocol for poor effort incorporate measures of performance validity tests (PVTs).

Quantitative Electroencephalography (QEEG) is a noninvasive procedure used to record and quantify synaptic excitation of neurons at specific points of a person's scalp (Dubey & Pathak, 2010; Koberda, Moses, Koberda, & Koberda, 2013). The EEG activity of a person's brain signal is categorized into four frequency bands: delta, theta, alpha, and beta. These frequencies are observed at different rates, with beta waves being the fastest and involved in concentration (Butnik, 2005). Researchers have found a positive correlation between mental effort and left beta power during attentional tasks (Howells, Stein, & Russell, 2010). Therefore, it is possible that a relationship in electrical brain activity and poor mental effort could be represented by Beta power on the frontal lobes. The purpose of this study is to investigate frontal lobe electrical brain activity (via Beta Peak Frequency [PK]) in relation to the level of effort expressed by individuals when performing PVTs. Results of this study are important for School Psychologists because the effectiveness of interventions and treatment is influenced by poor effort during examinations.

CHAPTER II

Literature Review

Traumatic Brain Injury (TBI)

Traumatic brain injury (TBI) is defined as a blow or jolt to the head causing a disruption in the normal functioning of the brain (Center for Disease Control and Prevention [CDC], 2016). In the United States, TBI is a major health concern. The most recent national estimates reported that in 2013 alone, 2.8 million TBI-related cases resulted in emergency room visits, hospitalizations, or death (Taylor, Bell, Breiding, & Xu, 2017). This number was an increase from 2010 data with 2.5 million cases (Faul, Xu, Wald, Coronado, & Dellinger, 2010) and from 2003 with 1.5 million cases (Rutland-Brown, Langlois, Thomas, & Xi, 2006). Moreover approximately 500,000 children under the age of 15 suffer from a TBI each year (Keenan & Bratton, 2006). More recently, Thurman (2014) reported epidemiological rates of TBI in children and youth (<20 years old) at 691 per 100,000 TBI cases.

While numerous situations can lead to head injuries, the primary leading causes of TBI incidents in people of all ages are due to motor vehicle accidents, falls, bicycle and sports-related accidents, and physical assault (Faul et al., 2010; Langlois, Rutland-Brown, & Wald, 2006). From these, motor vehicle accidents and falls are the primary TBI related causes of death (Coronado et al., 2011). In adolescents and adults ages 15-44 years, the leading causes of TBI are due to assaults, falls, and automobile accidents

(CDC, 2016). In youth 5-14 years, injuries caused by being struck by/or against an object (34.9%) and falls (35.1%) account for TBI visits to the emergency department.

Anatomically, the human brain is surrounded by cerebral spinal fluid underneath several protective layers, including the skull and meninges (Blennow, Hardy, & Zetterberg, 2012). When an injury to the head occurs, it can cause the shaking or disruption of the brain within its protective layers. Research suggests that the specific force required for a TBI, or the exact mechanism of TBI is not completely understood to date (Cullum & Thompson, 1997; McCarthy & Kosofsky, 2015). However, the inertial forces (acceleration/deceleration forces) applied during this type of craniocerebral trauma have the potential to alter the brain structure and disrupt its function (McCarthy & Kosofsky, 2015), as well as disrupt a person's level of consciousness and neuropsychological functioning (Thurman, Coronado, & Selassie, 2007). Because the nature and extent of the injury can vary with individual, physiological and somatic symptoms are assessed to determine the severity of each case.

Measurement of TBI Severity. Measurement of TBI severity is composed of several characteristics including level of consciousness, physical symptoms, and neuroimaging abnormalities (Lee & Newberg, 2005; Teasdale & Jennett, 1974). More specifically, morphologic changes taken into consideration in the classification of TBI severity are: loss of consciousness (LOC), focal neurophysiological signs, and posttraumatic amnesia (PTA). Although there is not one specific valid measurement system used to clinically evaluate head injuries, the preferred and widely used instrument of choice for measuring level of consciousness is the Glasgow Coma Scale (GCS; Barlow, 2012). The GCS system is used for individuals first suspected of having sustained a TBI. It is a standard rating scale that focuses on measurements of consciousness to assess the ocular, verbal, and motor responses of the affected individual (Teasdale, Murray, Parker, & Jennett, 1979). Scores for eye movement (1-4), verbal response (1-5), and motor response (1-6) comprise the rating scale upon physical evaluation. The summed score of each domain, which is rated on a scale of 3-15, is used to obtain the degree of severity (Risdall & Menon, 2011). TBI classification lies on a continuum of categories including mild, moderate, and severe. A lower score also constitutes a lower degree of consciousness. Individuals with severe TBI (GCS 3-8) are often unconscious and unable to follow commands (Ghajar, 2000). Those with moderate TBI (GCS 9-13) are often lethargic at the time of evaluation and can have a LOC of 30 minutes or more. Individuals classified with mTBI (GCS 13-15) can result in a LOC for 30 minutes or less and often tend to be responsive following the injury. In a similar system of evaluation, the American Congress of Rehabilitation Medicine (1993) established diagnostic criteria based on different markers. Posttraumatic amnesia (PTA) is referred to as being disoriented to time and place, and a reduced memory and ability for attending to environmental cues after a TBI occurs (Mysiw, Fugate & Clinchot, 2007). PTA also typically correlates to a GCS score. When PTA occurs for less than 24 hours, it is classified as a mild injury, and moderate to severe if it occurs for longer than

24 hours (Carroll et al., 2004). For this study, the focus will remain on the least severe classification of brain injuries known as mTBI**.**

Mild Traumatic Brain Injury (mTBI)

The definition commonly found in the literature defines a mTBI as (1) an alteration or LOC for no more 30 minutes; (2) Post-traumatic amnesia (PTA) for less than 24 hours; (3) a GCS score of 13-15; and (4) no skull fracture or abnormalities on structural brain injury. The majority of all TBI cases in hospitals and assessment centers are considered mild in severity. The term ‘concussion’ is commonly found throughout literature involving sports injuries and is used synonymously for mTBI. In reviewing 121 articles on TBI incidence, Cassidy et al. (2004) found that 70-90% of all TBI cases are mild and yield a total of approximately 600 mild cases in 100,000 per year. Concordantly, a population-based study conducted by Selassie and colleagues (2013) identified that about 93% of all sport-related TBI cases who presented to hospitals and emergency departments were considered mild in severity. Sports-related injuries and bicycle injuries are the most common cause of concussions in children and adolescents, while falls and car accidents represent the majority of mTBI in the adult population (Ropper & Gorson, 2007). In the U.S., the main causes of adolescent males suffering concussions are mainly due to car accidents and sports (Cassidy et al., 2004).

Consequences to an individual’s cognitive abilities depend on the impact of the injury on the brain’s anatomical structure and can potentially produce immediate changes to a person’s behavioral, emotional, and motor function. Immediate effects of a person’s cognition after an mTBI are described throughout the literature and have been found to resolve within a few weeks to months. Cognitive deficits can result in difficulties with attention and concentration, learning, coordination, memory, and judgment/problem solving (Rimel et al., 1981; Rabinowitz & Levin, 2014). From these, the most commonly identified deficiencies are memory and concentration (Iverson, 2005).

Neuropsychological assessments are used as a performance-based measure of cognitive abilities in people having sustained TBIs. These assessments measure memory, attention, processing speed, reasoning, judgment, and problem-solving (Harvey, 2012). Leininger, Grambling, Farrell, Kreutzer, and Peck (1990) compared symptomatic complaints in individuals with mTBI to healthy controls at one and twenty-two months post-injury. They found that mTBI individuals ($N = 53$) performed significantly worse on neuropsychological assessments of attention when compared to the healthy controls ($N = 23$). People with mTBI showed poorer performance than uninjured controls on several neuropsychological tests including deficits in tests of reasoning, information processing, and verbal learning. Mathias, Beall, and Bigler (2004) matched a control group of healthy participants ($N = 40$) with mTBI patients ($N = 40$) and had them undergo tasks involving attention, non-verbal fluency, and verbal memory. Results showed that mTBI patients have a slower ability to switch attention and were less accurate in their responses than the healthy participants. Within the adolescent population, student-athletes who suffered concussions showed declined memory and increased symptom reporting 36 hours post-injury, but showed no difficulties 5-10 days after the injury (Lovell et al., 2003).

Dikmen, Machamer, and Temkin (2001) matched trauma participants and mTBI patients to investigate neuropsychological impairments at one-month and one-year post-injury. Trauma participants were those who sustained an injury to the body, but not the head. Of the measures utilized (i.e., visual attention, auditory attention/concentration, memory, performance IQ), only memory performance on the Selective Reminding Test Sum of Recall was significantly worse ($p < .001$) than the trauma participants and one-month post-injury. No other significant differences were observed for one-month post-injury. Mild memory difficulties were observed one-year post-injury in mTBI participants as well. These scores indicate that overall, individuals having sustained a mTBI do not typically differ in their cognitive functioning from trauma or healthy individuals. At about four days post-injury, Landre, Poppe, Davis, Schmaus, and Hobbs (2006) investigated cognitive functioning in mTBI hospitalized patients and other-trauma patients and found that participants with mTBI showed poor performance on cognitive measures when compared to the other group. However, they also found no differences on post-concussive symptom reports between the two groups.

In short, mTBI constitutes the most common of TBI severities and occurs in 70-90% of all TBI cases. Few studies have found mTBI patients significantly differ on neuropsychological assessments following an mTBI diagnosis. Several studies conducted with mTBI patients, healthy controls, and even TBI patients with external psychological history, have concluded that in most cases, mTBI should resolve within three months of an impact to the head (Binder et al., 1997; Iverson, 2005).

Poor Effort

Iverson (2006) defined a person's underperformance behavior during testing as poor effort. Interpretation of poor effort is geared toward identifying whether a person is purposefully performing below what they are capable. One popular method used in the detection of poor effort and motivation are performance validity tests (PVTs). PVTs rely on 'below chance' scores to depict suboptimal effort from true mild-moderate cognitive impairment (Larrabee, 2003). The below chance scores are typically lower scores than the established cutoff scores for typical performance of a person with true mTBI. Most PVTs are forced-choice tests (FCTs). These FCTs are performance-based assessment methods used to identify people exaggerating deficits or giving poor effort during evaluations. They are popular in testing cognitive-impairment due to their low level of difficulty.

During the administration of FCTs, individuals are presented with a series of trials and are asked to choose between two alternatives, with one choice being correct and the other incorrect (Frederick & Speed, 2007). From there, the total number of correct responses is typically scored to obtain the test result. Scores are interpreted by comparing the result to the probability of the number of correct answers expected for guessing (Frederick & Speed, 2007). The probability for a person choosing a correct response on forced-choice tests is 50%. That is, a person who has no memory of certain stimuli has a 50% chance level of correct performance on an FCT (Iverson & Binder, 2000). Thus, scoring below this probability is referred to as below-chance performance, signifying that this score is not based on a random or chance occurrence, but rather the intentional avoidance of choosing the correct response (Bianchini, Mathias, & Greve, 2001).

Forced choice PVTs and cut off scores have been utilized to detect poor effort or exaggeration of cognitive impairment symptoms. Setting the floor at the 50^{th} percentile has proven to be the best hit rate when comparing cases with mTBI versus poor effort (Backhaus, Fichtenberg, & Hanks, 2004). Research suggests that individuals who fail effort testing are likely to be misdiagnosed as having severe cognitive impairment (Lange, Pancholi, Bhagwat, Anderson-Barnes, & French, 2012). For this reason, measures that detect effort and motivation during an evaluation can help reduce the number of misdiagnoses. The most common measures by clinical practices of response bias are the TOMM and Rey 15-Item test (Sharland & Gfeller, 2007; Slick Tan, Strauss, & Hultsch, 2004).

Common Performance Validity Tests

Test of Memory Malingering (TOMM). The TOMM was developed as a recognition memory task to assess whether an individual is falsifying symptoms of memory impairment during evaluations (Tombaugh, 1996). It is one of the most frequently administered PVTs in the detection of poor effort due to its ability to work with a variety of individuals regardless of age, education, or mild cognitive impairment.

Gervais, Rohling, Green, and Ford (2004) investigated the TOMM and compared it to other PVTs when administered to claimants referred for personal injury disability. About half of the claimants scored between 45-49, while the other half of the claimants scored below the PVT's cut-off score. Their study suggests that the TOMM is visual and supports the specificity rates for level of difficulty, such that claimants with lower cognitive ability may be more likely fail other test measures of memory than the TOMM. It can also serve to identify performance ability on other measures of cognitive ability. Constantinou, Bauer, Ashendorf, Fisher, and McCaffrey (2004) found that poor performance on the TOMM predicts worse performance on other measures of cognitive abilities. Specifically, the TOMM has been validated and deemed appropriate to use with neurologically impaired patients, as there appears to be a 97% accurate performance on the TOMM (Tombaugh, 1997). Merten, Bossink, and Schmand (2007) also used the TOMM to understand how nonlitigant patients with neurocognitive deficits scored on the TOMM. At least 70% or more of the patients passed the TOMM, which suggests its usefulness for individuals with overt cognitive symptoms. Cut-off scores have been derived from tests that researchers have cross-validated with clinical populations with moderate TBI (Iverson, Slick, & Franzen, 2000; Mathias, Greve, Bianchi, Houston & Crouch, 2002). These scores were later validated by Haber and Fichtenberg (2006) who conducted a replication study with TOMM data from 50 participants.

Rey 15-Item Test (Rey-15). The Rey-15 shows less sensitivity and specificity than the TOMM (Vallabhajosula & van Gorp, 2001), however research conducted with practitioners indicate that its use is the second most commonly used after the TOMM (Slick et al., 2004). The Rey-15 has been found valuable when given to individuals with brain injuries, thus validating its' use for individuals with cognitive impairment. In their study, Taylor and colleagues found that all five of individuals with severe brain injury obtained perfect (15/15) scores on the Rey-15 (Taylor, Kreutzer, & West, 2003). Although injuries to the brain can portray difficulties in memory and concentration for some individuals, the Rey-15 is easily recalled by individuals with severe memory issues (Rey, 1964). The Rey-15 is used to detect suboptimal effort and complaints of memory impairment (Nelson et al., 2003). To measure poor effort, the typical cut-off is a score less than 9 out of 15 (Lezak, 1995). The development of Rey-15 item and the established cut-off scores have demonstrated the ability to detect tendencies in individuals who show optimal effort on measures of neuropsychological tests (Specificity) but low ability to detect all people that give sub-optimal effort (i.e. Sensitivity).

Quantitative Electroencephalography

Electroencephalography is referred to as a neurophysiological imaging technique used to measure and record electrical human brain wave activity (Dubey & Pathak, 2010). The non-invasive electroencephalogram (EEG) procedure utilizes electrodes to obtain and record neuronal activity from the scalp. This technique began in the early 1920's, but showed great improvement when Berger (1969) successfully recorded his son's brain signals. The EEG measures synaptic excitation of neurons resulting in typical brainwave patterns with an amplitude of 5-100 uV and 1-40hz frequency (Scherg, Ille, Bornfleth, & Berg, 2002). Today, quantitative EEG (QEEG) is based on the mathematical processing of standard recorded electroencephalography, which allows researchers to quantify data and gather numerical measures (e.g., frequency, amplitude, coherence, power, peak frequency, etc.) for data analysis (Koberda et al., 2013).

Electrode Placement. QEEG neuronal signals are typically obtained by placing electrodes on different regions of the head. The electrodes are positioned along a person's scalp according to the International 10-20 system (see Figure 1; Ferreira et al., 2008). The International 10-20 system utilizes standardized nomenclature and was defined by Jasper (1958) as a system used to describe the external skull locations of the EEG electrodes corresponding to anatomical landmarks underlying the cerebral cortex of the human brain. The '10' and '20' of the internationally accepted system refers to the electrode placement between two anatomical points in percentage form. The EEG scalp electrodes are positioned at 10% or 20% intervals of total front-to-back or right-to-left of the cranial skull (see: Trans Cranial Technologies, 2012). The electrodes are placed at each lobe of the cranial skull and are labeled using a letter respective to the lobe they overlie (F for Frontal, T for Temporal, T for Temporal, P for Parietal, and O for Occipital). Although there is no Central lobe, the 'C' is used for identification purposes, as such the A for earlobe electrodes. While each letter identifies a specific lobe, a number is used to differentiate between left and right hemispheres. Odd numbers correspond to the left hemisphere, while even numbers are specific to the right hemisphere. The 'z' (zero) is used for electrodes placed on the midline.

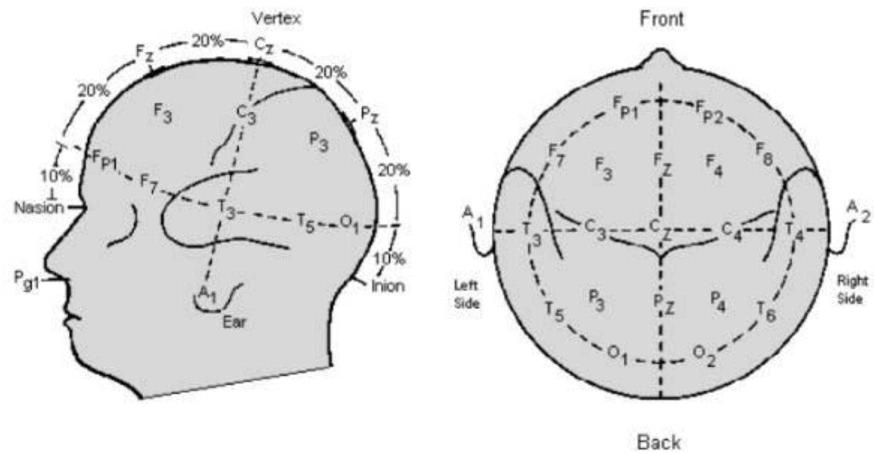

Figure 1. Electrode placement according to the International 10-20 system as seen from the left and above the head. A, earlobe; C, central; F, frontal; F_p, frontal polar; O, occipital; P, parietal; P_g, nasopharyngeal. (From Ferreira et al. Human-machine interfaces based on EMG and EEG applied to robotic systems. Journal of NeuroEngineering and Rehabilitation 2008, 5:10.)

QEEG Activity. Electrical wave signals are divided into frequency bands on a slow to fast hertz continuum (Hammond, 2006). Brain waveform activity is unique to each individual, but researchers categorize brain waves into four frequency bands: Delta, Theta, Alpha, and Beta. Delta (0.5 Hz – 4 Hz) waves represent slow wave activity associated with deep sleep and unconsciousness (Simon & Emmons, 1956). Theta (4 – 8 Hz) wave activity is associated with drowsiness or a mental dream-like state, but research has shown that these waves also retrieve and encode during working memory (Butnik, 2005). Alpha (8 – 13 Hz) waves have been associated with a relaxed state of mind, but are ready to respond when needed (Hammond, 2006). Alpha waves are commonly observed in the posterior and occipital regions and tend to have an amplitude peak-peak of 50 uV (Teplan, 2002). Alpha activity is typically diminished during activities requiring thinking or calculation and induced when a person closes his or her eyes. Beta (> 13 Hz) bands are the fastest in frequency and smallest in amplitude and are typically involved during an awake state-of-mind and during focused concentration (Butnik, 2005). This wave activity has been typically found in the anterior frontal regions of the brain. Beta has been associated with active thinking (Dietrich & Kanso, 2010), while a subset of Beta (12 – 15 Hz) has been related to attentional levels. Increased Beta activity has also been associated with internal mental tasks and is suggested to be useful in measuring cognitive and emotional processes. (Ray & Cole, 1985b).

QEEG indicators of mTBI. Research involving EEG has recently been used to investigate electrophysiological activity changes in individuals having sustained mTBIs, Generally, the literature shows that mTBI can cause electrophysiological changes with reduced Theta power, reduced Alpha and Beta Frequency amplitude, reduced fast Beta power, and increased Gamma amplitude activity (Tebano et al., 1988; Montgomery, Fenton, McClelland, MacFlynn, & Rutherford, 1991; Thatcher, Biver, McAlaster, Camacho, & Salazar, 1998). Recordings from EEGs in individuals having suffered from mTBI show an initial decrease in Alpha Frequency, but in weeks or months post-injury, a gradual increase is shown, suggesting that a person's level of Alpha Frequency returns to a person's pre-injury Alpha frequency (as cited in Thompson, 2006). At about six days after a mTBI injury, patients showed an increase in power of slow Alpha (8-10 cps) and a reduction in fast Alpha (10.5-13.5 cps) and reduction of fast Beta (20-35 cps) compared to normal controls (Tebano et al., 1988). In Korn, Golan, Melamed, Pascual-Marqui, and

Friedman (2005), changes in QEEG activity six months post-TBI showed higher Delta band (1.5-5 Hz) and lower power in Alpha (8.5 – 12 Hz) activity.

Moreover, studies involving concussive symptomology suggest that QEEG is 96% high sensitive in identifying brain related symptomology of PCS (Duff, 2004). The efficacy of QEEG as a possible indicator of PCS was proven by Linden (2015). His case study regarded the neuromodulation training of a 17-year-old female athlete suffering from post-concussion headaches symptoms. The QEEG data obtained showed abnormal Theta/Beta EFG ratios in the right frontal (F4) regions of the brain showing before concussion (F4 = 2.84, Cz= 5.3) in 2005 to post-concussion (F4 = 3.4; Cz = 4.61) in 2009. Teel, Ray, Geronimo, and Slobounov (2014) investigated levels of cognitive performance in seven clinical asymptomatic concussed participants within eight days after injury in comparison to thirteen participants in a control group. The EEG data showed abnormal electrical activity in the concussed group with a significant increase in coherence ($p < .05$) in baseline data and cognitive data. On memory, Thorton (2003) examined QEEG variables during memory tasks in mTBI participants when compared to normal individuals. Memory functioning was found to be predominately positively correlated with phase and coherence in Beta 1 and Beta 2 frequencies, and negatively correlated with Beta 1 and Beta 2 activity levels at specific locations. In 2009, Kumar, Rao, Chandramouli, and Pillai investigated deficits in working memory among mTBI and healthy individuals. Results showed EEG poor coherence between the frontal-temporal and temporal-parietal regions.

QEEG Attentional Indicators During Tasks. Researchers have found that Beta activity and Alpha activity relate to attentional processes. Ray and Cole (1985a) investigated the effects of attentional demands during cognitive and emotional tasks, and found that Beta activity reflected both cognitive and emotional processes. Moreover, researchers have found a positive correlation between mental effort and left Beta power during attentional tasks (Howells, Stein, & Russell, 2010). In other studies, Alpha activity was used to understand attentional processes. Osaka (1984) studied Peak Alpha Frequency during cognitive tasks. He found an increase in Peak Alpha Frequency in the left hemisphere over the right hemisphere during arithmetic tasks, and vice versa for visuo-spatial task with an increase in the right hemisphere rather than left hemisphere. Schmidt and colleagues asked individuals to memorize visual figures as they recorded Peak Alpha Frequency in healthy adults and adults with mild cognitive impairments and found no statistical differences in groups (Schmidt, Anghinah, Basile, Forlenza, & Gattaz, 2009). While Peak Alpha Frequency has been studied, Beta activity remains an important concept in understanding attention during cognitive tasks.

Cognitive Effort and EEG. Cognitive (mental) effort is defined as the total energy expended by the brain when information is presented (Fairclough & Mulder, 2012; Kirschner & Kirschner, 2012). Researchers have found EEG correlates in the measure of sustained attention and can be used to provide good physiological understanding for vigilance (Gale, 1977). However, limited studies have investigated EEG patterns of mental effort during cognitive tasks. Perhaps one the closest studies to investigating mental effort in relation to EEG activity was provided by Nguyen and Zeng (2017). The researchers concluded in their study that Beta power at Fz appeared to estimate effort. Other researchers have found a correlation between EEG engagement and task demands, such that task engagement correlated with task workload (Berka et al., 2007).

In summary, EEG data has been utilized to quantify patterns of brainwave activities. Brainwave activity in individuals having sustained a mTBI are noticed in Alpha, Theta, and Beta waves. In relation to cognitive deficits, QEEG recordings have determined differences in the frontal and the temporal regions in individuals with cognitive limitations when compared to healthy individuals. Additionally, researchers have found that attentional measures of Beta and Alpha are related to task performance. Few researchers have attempted to look at task engagement as a method to understand effortful concentrations. While Beta activity has been related to task performance and attentional factors, no studies investigating Beta activity and in relation to cognitive impairment or deficits were found. There were also no studies found that investigated patterns of Beta High Peak Frequency activity as a measure of poor effort.

Study Rationale and Purpose

Treatment, interventions, and financial compensation are typical outcomes of psychological and psychoeducational assessment. Thus, if the effectiveness of these interventions is influenced by poor effort during assessments, it is important for examiners to identify inaccurate representations of symptomology. To help interpret an individual's level of effort, particularly in cases where poor effort is suspected, PVTs have been developed to assist evaluators. Among those measures, the most commonly used are the TOMM and the Rey-15 tests. These tests are also neuropsychological assessments that have been widely used in a variety of evaluations. The current literature on electrophysiological evidence related to cognitive effort is limited, but emerging technology (e.g., EEG) has recently created an opportunity for researchers to investigate electrical activity in relation to task engagement and mental effort (Berka et al., 2007; Nguyen & Zeng, 2017). In fact, previous studies purport Beta activity has been related to task performance and attentional factors (Howells et al., 2010; Ray & Cole, 1985). While Alpha PK Frequency activity has been researched in relation to mental tasks, no studies investigating Beta PK Frequency activity and in relation to cognitive effort were found. Based on the current literature, it is possible that QEEG data can provide diagnosticians with empirical evidence of electrophysiological activity that correlate with brain activity during tasks. However, more research is needed to identify specific attentional brain patterns related to mental effort.

Purpose

The purpose of this study was to investigate electrical brain activity in relation to the cognitive mental effort expressed by individuals when performing memory-based performance validity tests (PVTs).

Hypotheses

I. Participants in the Poor Effort group will score lower on all three measures when compared to the Full Effort group.

II. Participants in the Poor Effort group will show lower Beta PK frequency at F3 and F4 locations than the Good Effort group on all three measures.

CHAPTER III

Method

Participants

Data was collected from forty-two undergraduate and graduate students from a rural Southwestern University in the United States. Participants were screened on arrival using a multi-item personal wellness self-report questionnaire. Participants were screened for the following inclusion criteria: (1) students enrolled in upper level education (e.g., Juniors, Seniors, or Graduate students) eligible for class extra credit, (2) no history of seizures, (3) no metal body implants in brain or skull, (3) hairstyles that permitted access to frontal areas of the scalp (i.e., no dreadlocks). Exclusionary criteria involved (1) being younger than 18 years of age, (2) self-reported history of brain injury with a classification of Moderate to Severe, and (3) self-reported episodes of epilepsy or seizures in the past 12 months, and (4) having metal body implants in brain or skull. Participants were recruited via SONA systems for Stephen F. Austin State University (SFASU).

The final sample was composed of forty-two participants (Female: n= 40). The mean age was 23.74 years old (SD = 5.14). The majority of the sample was primarily Caucasian (59.5%), followed by Hispanic (23.8%), African American (14.3%), and Other (2.4%). No participants were excluded for the preliminary results. No participants reported a history of head injuries resulting in a loss of consciousness. No participants reported a history of seizures or body metal implants in brain or skull. A visual analysis was conducted to determine exclusions and was based on epoch variables with each reading. This study was approved by the SFASU Institutional Review Board (IRB).

Measures

Test of Memory Malingering. The Test of Memory Malingering (TOMM: Tombaugh, 1996) is a visual recognition test that uses pictures of common objects as stimuli. The TOMM was utilized to measure cognitive strategies during a visual recognition memory task. It consists of two learning trials and one retention trial. For this study, Trial 1 of the TOMM was administered. Participants were presented with 50 individual line drawings (phase 1) and was immediately followed by the presentation of 50 pairs of line drawings, each containing one item previously presented (target) and one item that was not previously presented (distractor). The 50-line stimulus drawings were presented for 3 seconds each while simultaneously recording the participant's brain activity. Once Trial 1 was complete, the EEG recording ended and the participants were presented with 50 pairs of line drawings and they were asked to identify the target item. Participants were told whether each item they selected was correct or incorrect. Responses for the target variable were counted correctly, while responses for the distractor item were counted incorrectly.

Rey-15 Item Test. The Rey 15-Item test is a Visual Memory Test that is used as a measure to detect malingering memory deficits (Rey, 1964). It consists of 15 figures (3 columns x 5 rows) on one page that is presented to individuals for 10 seconds and then the participant is asked to immediately reproduce the figures from memory. The 15 items are categorically broken into 3 items in each set. For this study, participants were asked to study the 15 different figures while simultaneously recording their brain activity. The EEG recording ended, and participants were asked to draw what they remembered. The Rey-15 Item test was scored in the total number of figures obtained correctly. Poor performance indicated when a person reproduces less than nine items correctly (Lezak, 1995).

Rey-Osterrieth Complex Figure. The Rey-Osterrieth Complex Figure (ROCF; Osterrieth, 1944; Rey, 1941) is a measure of both visual perceptual and visual memory. In this study, the ROCF was used as a non-PVT memory comparison test. The ROCF was used in this study to determine cognitive effort exerted while memorizing a figure. For the purpose of this study, participants were asked to scan the stimulus for two minutes, while simultaneously recording their brainwaves. The stimulus was collected, and participants were asked to draw the figure from memory (Immediately Free Recall with zero-minute delay). The figure was scored according to the Mayo Clinic's adaption of the Osterrieth Scoring System (Osterrieth, 1944).

Electrophysiological Markers

Brainwave activity was obtained using the BrainMaster Discovery 24E hardware, from BrainMaster Technologies, Inc. This hardware system is typically used in the clinical and research communities. The BrainMaster is a high-quality hardware that incorporates 24 channels using the 10-20 International System. It uses low-noise DC-sensitive amplifiers, 24-bit analog-to-digital converters, and an optically and magnetically isolated USB interface. It is a choice for multi-channel EEG. This 24-channel system is composed of 22 channels connected to an electrode cap, plus two channels connected to reference points (earlobes). Together, the BrainMaster Discovery 24E conducts 256 samples per second, with 24-bit resolution, and an amplifier bandwidth from DC (0.000 Hz) to 80 Hz. QEEG data was recorded from two electrodes (F3, F4) placed on the skull using the 10/20 system, with ground reference electrodes placed on the earlobes. The NeuroGuide software from Applied Neuroscience Inc. (see: appliedneuroscience.com) was used to clean the QEEG data from artifacts by using the z-scored FFT method. The NeuroGuide Software functions as a digital signal processing QEEG tool to edit, quantify, and analyze data. After cleaning artifact data, approximately 60 seconds of TOMM QEEG and ROCF QEEG data and a minimum of 3 seconds for the Rey-15 clean data was analyzed. Beta Peak frequency was studied in the following frequency band: Beta (12.6 to 18 Hz).

Procedure

Study Location and Informed Consent. This study was conducted in the Human Neuroscience Laboratory (HNL), Room 105, of the Human Services Department at SFASU. The HNL was fully equipped with computer equipment and private rooms for high-quality QEEG recordings. Informed consent was obtained from all participants at the beginning of each session. Participants were informed about the nature of the study and the implications involved in voluntarily completing the study.

Prescreening. A prescreening questionnaire was verbally administered to obtain demographic, medical, and head injury history. Brain injury questions included history of hitting one's head resulting in a bump, bruise, or scratch; experiencing a concussion or losing consciousness; having a history of seizures; and having a history of psychiatric or neurodevelopmental disorder. Exclusions included a current history of seizures, and/or metal plates or implants in his or her skull. Once screening procedures were completed, the participants' scalp was prepared for QEEG recordings. The study took no longer than one hour to complete.

EEG Cap Placement. Qualifying participants were guided to the assessment room for the EEG cap placement procedure. The participants' scalp was combed and areas where the electrodes were placed were swabbed with rubbing alcohol to ensure cleanliness for a good reading of the scalp's signal. The electrode cap was placed using the 10-20 system. Electrode gel was added to the participant's scalp at the F3 and F4 locations and included the reference points at the earlobe. The locations were monitored for impedance and recorded in KwOhms. The 20-minute setup concluded with the EEG cap being connected to the BrainMaster Discovery 24E hardware system. Participants were instructed to relax and sit comfortably during each recording. A baseline EEG 3-minute recording was obtained with the participants' eyes opened. After this, the vignette instructions were introduced.

Group Vignette Randomization. The participants were randomized into one of two groups and each participant was unaware of the group assignment. The experimenter was also unaware of the instructions that each participant received. Participants were randomized into two groups: Poor Effort (experimental) and Good Effort (control). Participants in both groups received a vignette retrieved and adapted from Suhr and Boyer (1999). The vignette was adapted for the control group as the participants were instructed to give their full effort rather than simulate brain damage. A disclaimer was added to the bottom of each scenario which explained that participants must complete the study as indicated by the vignette in order to receive credit for their participation. Each participant received a sealed envelope and were asked to read the vignette carefully because they were to follow it the rest of the study. They were also asked not to reveal the instructions to the experimenter. The vignette for the experimental condition read:

> *Imagine that you were in a car accident in which another driver hit your car. You were knocked unconscious and woke up in the hospital. You were kept overnight for observation. The doctors told you that you experienced a concussion. Try to imagine that a year after the accident, you are involved in a lawsuit against the driver of the other car. If you are found to have experienced significant injuries as a result of the accident, you are likely to receive a bigger settlement. You have decided to fake or exaggerate symptoms of a brain injury in order to increase the settlement you will receive. As a part of the lawsuit, you are required to undergo cognitive testing to determine whether or not you have experienced a brain injury. If you can successfully convince the examiner that you have experienced significant brain damage, you are likely to get a better settlement. If the examiner*

detects that you are faking, you are likely to lose the lawsuit. You are about to take a series of cognitive tests that would be used in such a situation. I would like you to simulate brain damage, but in a believable way, such that your examiner cannot tell that you are attempting to fake a brain injury.

Study disclaimer: If you are not able to correctly follow the instructions, or convince the researcher, you will not receive credit for your participation in class or via SONA Systems.

The vignette for the control condition read:

Imagine that you were in a car accident in which another driver hit your car. You were knocked unconscious, and woke up in the hospital. You were kept overnight for observation. The doctors told you that you experienced a concussion. As a part of a routine assessment, you are required to undergo cognitive testing to determine whether, or not you have experienced a brain injury. You are about to take a series of cognitive tests that would be used in such a situation. I would like you to complete the tasks giving your full effort, such that no brain injury will be detected.

Study disclaimer: If you are not able to correctly follow the instructions or convince the researcher that you are giving full effort, you will not receive credit for your participation in class or via SONA Systems.

Performance Validity Tasks (PVTs). The PVTs were administered under randomized conditions to each participant. Following the presentation of the vignette, the participants were administered the cognitive tasks. The tasks presented included the TOMM, Rey-15, and ROCF. QEEG recordings were recorded during the presentation of each of the tasks. The TOMM QEEG recording was approximately 3 minutes, the Rey-15 about 10 seconds, and the ROCF was a 2-minute recording. Once the cognitive tasks were completed, the electrode cap was removed, and the participant's scalp was cleaned from the electrode gel residue.

Participant Deception and Debriefing. Deception was used as part of this study. In order to maintain a valid and reliable study, participants were made to believe that they must complete the study in a certain fashion in order to receive credit. The vignette the participants received stated that would not receive credit if they did not correctly follow the instructions provided. For this study, task performance was an important aspect that relied on the effort put forth by the participants.   Nonetheless, every participant received credit regardless of his or her performance. Participants were debriefed regarding the purpose and nature of the study and the importance of their participation. Finally, participants were asked to explain their strategies for simulating cognitive impairment and asked to fill out a Post-Study Questionnaire (see Appendix A). They were dismissed with contact information regarding the results of the study, along with resources should they feel the need to seek services for participant discomfort.

Research Design

This study is a between-group experimental design measuring the independent variable (*condition: Poor Effort, Good Effort)* and the dependent variables (*task* *performance: TOMM score, Rey-15 score, ROCF score; Mental effort: Beta Peak Frequency brain activity*). Performance strategy techniques were measured by the scores obtained from the TOMM, the ROCF, and the Rey-15 Test, along with personal anecdotes and survey responses obtained at debriefing. Data were analyzed and interpreted using the IBM SPSS Statistics for Windows, version 25 (IBM Corp., Armonk, N.Y., USA). Several Independent samples *t*-tests were used to analyze results. Statistically significant results were analyzed at an alpha level of $p < .05$ and $p < .001$.

CHAPTER IV

Results

Preliminary Descriptive Statistics

The total number of participants was *N*= 42. The majority of the sample consisted of Female participants (95.2%, *n* = 40) with a *Mage* = 23.74 years old (*SD* = 5.14). The sample was primarily Caucasian (59.5%, *n* = 25), followed by Hispanic (23.8%, *n* = 10), African American (14.3%, *n* = 6), and Other (2.4%, *n* = 1). The sample consisted of mainly upper undergraduate classmen and graduate students. College Juniors (19.0%, *n* = 8), Seniors (66.7%, *n* = 28), Graduate students (11.9%, *n* =5) and Post Bachelorette (2.4%, *n* =1) were involved. Participants were randomly assigned to either a Poor Effort group (*N* = 20) or a Good Effort Group (*N* = 22). Descriptive statistics were evaluated for age, gender, ethnicity, and education to determine if the groups significantly differed on demographic characteristics. Analysis of variance (ANOVA) indicated no significant group differences in age F (1,40) = .119; p = .732, gender, F (1,40) = .005; p = .947, Ethnicity F (1,40) = 1.28; p = .266, or Education F (1,40) = 1.49; p = .230. There were also no significant differences in gender across group conditions, X^2 (1, N = 42) = 0.01, $p > .05$, student classification, X^2 (3, N = 42) = 1.75, $p > .05$, or age X^2 (13, N = 42) = 11.33, p > .05.

Comparisons Without Exclusions

First, independent *t*-tests were conducted to determine group differences in PVT scores. As expected, the Poor Effort group scored significantly lower than the Good Effort group on all the tests (see Table 1). As observed in Table 1, individuals in the Poor Effort group scored much lower than the Good Effort group on the TOMM $t(40) = -11.28$, $p < .001$), Rey-15 $t(40) = -6.05$, $p < .001$, and the ROCF $t(40) = -4.73$, $p < .001$).

Table 1

Group Analysis on Test per Group Without Exclusions

Variables	Poor Effort (*N* = 20)	Good Effort (*N* = 22)		
	M (SD)	*M (SD)*	*t*	*p*
TOMM	25.60 (9.51)	48.82 (1.62)	-11.28	.000**
Rey-15	6.45 (3.65)	12.82 (3.17)	-6.05	.000**
ROCF	11.70 (7.12)	21.18 (5.86)	-4.73	.000**

Note: ** significant scores observed between groups and PVT scores

Second, independent samples *t*-tests were performed to determine a statistically significant association in Beta PK frequency between the Poor Effort group and Good Effort group. During the Rey-15, participants in the Poor Effort group ($N = 20$, $M = -0.23$, $SD = .70$) showed statistically significant lower Beta PK F4-F3 asymmetry than the than the Good Effort group ($N = 22$, $M = 0.13$, $SD = .38$), $t(40) = -2.10$, $p < .05$). Group comparisons did not demonstrate statistical significance in Beta PK frequency at the F3 or F4 locations for any of the PVTs, as seen on Table 2.

Table 2

Group Analysis for QEEG Beta High Peak Frequency per Group Without Exclusions

Variables		Poor Effort (*N* = 20)	Good Effort (*N* = 22)		
Task	Location	*M (SD)*	*M (SD)*	*t*	*p*
TOMM	*F3*	17.87 (.75)	17.71 (.15)	.71	.482
	F4	17.94 (.71)	17.85 (.78)	.41	.688
	F4-F3	.07 (.25)	0.14 (.39)	-.67	.506
Rey-15	*F3*	18.05 (.74)	16.31 (5.34)	1.44	.158
	F4	17.81 (.65)	16.44 (5.39)	1.13	.265
	F4-F3	-0.23 (.70)	0.13 (.38)	-2.10	.042*
ROCF	*F3*	17.89 (.60)	17.88 (.65)	0.06	.952
	F4	17.87 (.55)	17.94 (.70)	-0.36	.721
	F4-F3	-0.02 (.39)	0.06 (.24)	-0.84	.404

Note: * significant scores observed between groups and High Peak Frequency variables

Establishing Cutoffs

A decision to determine participant insufficient effort from sufficient effort was made. As a measure of effort, PVTs adhere to cutoff scores to determine whether a person is giving poor effort, faking or exaggerating symptomology. PVT scores in this study indicate some participant's test scores to not reflect the study's main objective. Performance scores were compared to previously researched cutoffs for each PVT and applied to the current data. The TOMM cutoff criterion was set at 45/50 (Bauer, L., O'Bryant, Lynch, McCaffrey, & Fisher, 2007; Gavett et al., 2005). For the Rey-15, scores below 9 were considered evidence of insufficient effort (Lezak, 1995). For the ROCT, a cutoff score in the 16th percentile was set based on previous research by Maghsoodi (2011).

PVT scores were transformed into a dichotomous variable of Pass/Fail scores. A frequency table (Table 3) presents the number of individuals in each group that passed or failed each test by condition according to established cutoff scores. As can be seen, only one person was incorrectly classified by the TOMM. With the Rey-15, six participants were incorrectly classified in the Poor Effort Group and five in the Good Effort Group. With the Rey-Figure, six participants were incorrectly classified in the Poor Effort Group and four in the Good Effort Group. Participants that did not meet the criterion for their particular group condition were excluded. Participants that passed the PVT in the Poor effort condition were excluded for each PVT. Participants that failed the PVT in the Good effort condition were excluded.

Table 3

PVT Pass/Fail Performance

Variables	Poor Effort (*N* = 20)	Good Effort (*N*= 22)
	Pass (Fail)	*Pass (Fail)*
TOMM	0 (20)	21 (1)
Rey-15	6 (14)	19 (3)
ROCF	6 (14)	18 (4)

*Note: The numbers of participants excluded were defined by previously researched cutoff scores for each PVT. Passed rate based on the 45/50 criterion on the TOMM, <9 on the Rey-15, and 16^{th} percentile on the ROCF.

Group Comparisons After Exclusions

In addition to excluding participants based on published cut-off scores, two participants in the Rey-15 group were excluded due to a high volume of artifacts resulting in no available QEEG data. To determine if exclusions influenced our previous results, independent sample *t*-tests were conducted to determine TOMM, Rey-15 and ROCF score differences between the groups. Similar to previous results, the Poor Effort group scored significantly lower than the Good Effort group on all the PVTs (see Table 4). A number of *t*-tests were also conducted to determine if the Poor Effort group and Good Effort groups had differences in Peak Frequency activities at areas F4 and F3. Results indicated that the groups only differed in the asymmetry scores at the frontal areas for the Rey-15 task. Beta PK F4-F3 asymmetry between the Poor Effort group (N = 14, M = -0.32, SD =0.73) showed lower Beta PK asymmetry on the Rey-15 than the Good Effort group (N = 18, M = 0.21, SD = 0.37), $t(29) = -2.63$, $p < .05$). No other statistical differences were observed, see Table 5.

Table 4

Group Comparisons on Test per Condition After Exclusions

Variable	Poor Effort		Good Effort			
	N	*M(SD)*	*N*	*M(SD)*	*t*	*P*
TOMM	20	25.60 (9.51)	21	49.05 (1.24)	-11.20	.000**
Rey 15	14	4.50 (2.28)	17	13.88 (1.73)	-13.04	.000**
ROCF	14	7.75 (3.89)	18	23.08 (4.12)	-10.71	.000**

Note: ** significant scores observed between groups and PVT scores. Exclusions were based on PVT published cut-off scores relating to Poor Effort. Two additional participants were excluded from the Rey 15 group due to unavailable QEEG data.

Table 5

Group Analysis for QEEG Beta High Peak Frequency After Exclusions

Variables		Poor Effort	Good Effort		
Task	Location	*M (SD)*	*M (SD)*	*t*	*p*
TOMM	*F3*	17.87 (.76)	17.73 (.73)	0.65	.521
	F4	17.94 (.71)	17.87 (.79)	0.31	.762
	F4-F3	0.07 (.25)	0.15 (.39)	-0.77	.449
Rey-15	*F3*	18.06 (.81)	17.89 (.82)	0.56	.580
	F4	17.74 (.70)	18.11 (.77)	-1.39	.176
	F4-F3	-0.32 (.73)	0.21 (.37)	-2.63	.013*
ROCF	*F3*	17.87 (.69)	17.93 (.56)	-0.27	.788
	F4	17.82 (.59)	17.97 (.64)	-.703	.487
	F4-F3	-0.05 (.43)	0.04 (.24)	-.80	.432

Note: Poor Effort (TOMM *N*= 20; Rey-15 *N*= 14; ROCF: *N*= 14), Good Effort (TOMM *N* = 21; Rey15 *N* =17; ROCF: N = 18). *significant scores observed between groups and High Peak Frequency variables.

Qualitative Analysis of Poor Effort Strategies

All participants (*N*= 42) differed by group in the strategies they reported using to meet study objective. Participants in the Poor Effort Group *(N* = 20) were compared to the Good Effort Group (*N* = 22) using independent samples *t*-tests. Participants in the Poor Effort group significantly reported *answering most/all item incorrectly* at a greater rate (*M* = .50, *SD* = .51) than the Good Effort group (*M* = .14, SD =-.35), $t(40) = 2.70$, $p < .01$). Participants in the Poor Effort group significantly reported *answering randomly* at a greater rate (*M* = .85, *SD* = .37) than the Good Effort group (*M* = .05, SD =-.21), $t(40) = 8.80$, $p < .01$). Participants in the Poor Effort group significantly reported *purposefully looking away from the task-relevant materials* during stimulus presentation at a greater rate (M = .40, SD = .50) than the Good Effort group (M = .09, SD =-.30), $t(40) = 2.46$, $p < .05$). Participants in the Poor Effort group significantly reported *taking longer than was necessary to respond* at a greater rate (M = .85, SD = .37) than the Good Effort group (M = .09, SD =-.30), $t(40) = 7.44$, $p < .01$). Participants in the Poor Effort group significantly reported *daydreaming during stimulus presentation* at a greater rate (M = .55, SD = .51) than the Good Effort group (M = .18, SD =-.40), $t(40) = 2.63$, $p < .05$). The Poor Effort group significantly reported *purposefully drawing a distorted figure* at a greater rate (M = .75, SD = .44) than the Good Effort group (M = .05, SD =-.21), $t(40) = 6.65$, $p < .01$).

On the other hand, participants in the Good Effort group (M = .68, SD = .48) significantly reported the use of *other* strategies, while no participant in the Poor Effort group (M = .00, SD = .00), $t(40) = -6.39$, $p < .01$), reported the use of other strategies. Participants who used other strategies reported that they gave their best, focused, and concentrated during the study. They also used cognitive strategies such as memorizing by association and repeating the name or object in their mind during stimulus presentation.

Further analysis of qualitative data focused on participants who met the cut-off criterion for the Rey-15. All participants agreed that an external factor (e.g., Class Credit) motivated their participation in this study. Participants in the Poor Effort Group rated their participation with less motivation and less willingness to provide their full effort in accomplishing the objective than the Good Effort Group, see Table 6.

Table 6

Rey-15 Group Differences in Motivating Factors by Percentage

Question	Poor Effort (*N* = 14)	Good Effort (*N* = 17)
	Percentage	*Percentage*
How important was it that you accomplish the instructed objective?		
Unimportant	-	-
Of Little Importance	7.1%	-
Moderately Important	14.3%	11.8%
Important	28.6%	17.6%
Very Important	50%	70.6%
How important was it that you give your full effort to accomplish the objective?		
Unimportant	-	-
Of Little Importance	7.1%	-
Moderately Important	-	-
Important	21.4%	11.8%
Very Important	71.4%	88.2%
How important is it for you to obtain class credit as a result of your participation in this study?		
Unimportant	-	-
Of Little Importance	-	-
Moderately Important	14.3%	-
Important	7.1%	5.9%
Very Important	78.6%	94.1%

*Note: Percentages reflect groups after exclusions on the Rey-15 given that this PVT reflected significant differences in brain activity.

CHAPTER V

Discussion

This study investigated frontal lobe (F3 and F4) Beta Peak Frequency (PK) brain activity and mental effort while performing memory-based performance validity tests (PVTs). To ensure effort, participants were randomly assigned to two group conditions: Good Effort and Poor Effort, based on TBI recovery scenario. First, this study hypothesized that participants in the Poor Effort group would score lower on all three PVTs when compared to the Full Effort group. As expected, groups performed differently in all PVTs and supported this hypothesis. However, some individuals in the Good Effort group scored below preestablished PVT cutoffs suggesting that not all participants in this group gave full effort during the task. Similarly, some individuals in the Poor Effort group scored above preestablished PVT cutoffs, suggesting that some individuals in this group did not completely follow the scenario. Thus, although these results suggest that while the TBI scenarios were effective in manipulating mental effort, some participants effort was not congruent with the expectations.

This study's main hypothesis aimed to determine if participants in the Poor Effort condition would show lower Beta PK Frequency at F3 and F4 locations than the Good Effort group on all three measures given. Because not all participant PVT scores were congruent with cutoff scores, this hypothesis was tested two ways: 1) Groups were analyzed including all participants regardless of performance, and 2) Groups were analyzed including only participants consistent with PVT cutoff scores. Results from both analyses did not support this hypothesis. In specific, the Poor Effort group showed F3 and F4 Beta PK frequency activity that was not statistically lower than the Good Effort Group while performing the PVTs. Hence, as participants were presented with a PVT stimulus, Beta PK frequency at the homologous sites (F3, F4) did not demonstrate significant differences between groups even when differences were observed by performance scores.

However, and very importantly, an asymmetry in frontal Beta PK activity was found to be statistically significant for the Rey-15. Beta PK frontal asymmetry was computed by subtracting Beta PK frequency at the right hemisphere (F4) from homologous the left hemispheric site (F3). Based on this computation, higher scores represent greater frontal activation asymmetry while positive scores indicate a greater right hemisphere task dominance. The Poor Effort group demonstrated a statistically significant negative score on Beta PK asymmetry. This result demonstrated that individuals in the Poor Effort group had significantly higher left frontal Beta PK activity, while individuals in the Good Effort group showed higher right frontal Beta PK activity while scanning the Rey-15. This study supported previous attempts investigating Beta in relationship to attention. Bigler (2014) outlined attentional networks, giving emphasis to the “Top-down” attention network located in the prefrontal cortex which requires effort. One study identified a positive correlation between mental effort and left Beta power during attentional tasks (Howells et al., 2010).

Previous studies have shown that EEG asymmetry is relatively important in emotional states. Resting asymmetries characterized by greater right than left frontal activity appear to be associated with traits and behaviors of withdrawal behaviors (Wheeler, Davidson, & Tomarken, 1993). Research investigating depressive states indicated low motivation yielded greater right frontal activation (Shaffer, Davidson, & Saron, 1983) and lower left frontal activation (Gotlib, 1998) in participants. Right frontal areas are said to mediate withdrawal motivation and/or negative affect, while left frontal areas mediate motivation and/or positive affect (Coan & Allen, 2004). In this study, participants placed in the Group Effort group showed greater right F4 Beta PK Frequency during the Rey 15, while the Poor Effort group showed greater left F3 Beta PK frequency during the Rey 15.

A caveat to previous studies is that they tend to focus on the Alpha Frequency F4-F3 asymmetry. As for this study, understanding asymmetry of Beta PK frequency F4-F3 would not be an indication of an emotional state, but rather how alertness is represented in individuals instructed to provided good or poor effort. To support the conclusion that Beta PK asymmetry is likely due to effort, and not an emotional state, it is important to recognize that the findings were only observed in the simplest PVT (the Rey-15). The Rey-15 has even proven effective for individuals with major depression (Lee et al., 2000). Moreover, as opposed to the TOMM or the Rey Figure, the Rey-15 is more likely to be a simple effort given that it is a quick and easy test that requires lower cognitive load and likely requires less metacognitive strategies. Similarly, its redundancy makes it an easy task and individuals are likely to underestimate the level of difficulty (Rey, 1964). Additionally, because ROCF is not a PVT measure of poor effort, in this study, it was used as a comparison for pure memory. When analyzing data, ROCF scores and Beta PK Frequency were not found to significantly correlate in the Good Effort group, indicating that Beta PK is also not an indicator of memory. However further research is needed to determine if PK Beta asymmetry is due to poor effort or some other emotional/cognitive state.

Limitations and Future Studies

Lack of statistical results on the TOMM or the ROCF may be due to the way individuals approached each task and the strategies participants seemed to use, which in turn may have not shown as Beta PK frequency. In this study participants were asked to imagine a scenario which urged them to provide effort based on an incentive. Participant motivation to complete each task as requested and the techniques used by each individual was recorded. Individuals in the Poor Effort group reported using strategies involving more behavioral performance strategies, rather than cognitive strategies. Participants in the Poor Effort group were observed to work slower and respond more incorrectly to PVTs. They also reported answering randomly, taking longer to respond, looking away from stimulus, and drawing distorted figures. Participants in the Good Effort group reported being more focused during the stimulus and reported that they used metacognitive strategies to remember the stimulus. They tended to report greater use of memory, concentration, association strategies, imagery, scanning and analysis of stimulus.

In cleaning data, many participants were excluded due PVT published cutoff scores indicative of poor effort. While the scenarios were relatively important in guiding the participants' external effort, the scenario may not have clearly specified the objective of the study. The objective of the study was to understand mental effort in terms of Beta PK frequency, yet the results indicate that participants may not have fully understood the context of the instructions provided, negating appropriate mental effort relative to the study. Another limitation involved the exploratory nature of the study, given a lack of literature evidencing a direct link between mental effort and PK was a limitation. While previous literature focus on Alpha brain activity relating to motivation and emotional states, future studies studying mental effort with Beta may be beneficial. While EEG is only an indication of brain activity, this study cannot infer the reason for seeing PK frequency. Future studies may use a task that simply requires pure effort. It is possible that additional factors beyond motivation had an effect in how participants completed the study.

The lack of male participants could also be considered a limitation in this study. This study involved the participation of nearly all female participants (*n* = 40), which may have influenced the results in terms of brain activity. Studies have shown that females tend to perform better on episodic memory and verbal tasks, while men perform better at visuospatial processing tasks, which have been typically associated with the right hemisphere (Kimura, 1996; Lewin, Wolgers, & Herlitz, 2001). Moreover, men have shown significant brain asymmetry in EEG activity for linguistic and visuo-spatial tasks when compared to females, who tend to show greater lateralization (Trotman & Hammond, 1979). In this study, male participants did not influence the results as determined by an additional analysis which excluded male participants. Future studies should include a larger sample of male participants in order to investigate whether sex differences play an effect in Beta PK.

Implications and Conclusions

School Psychologists work to intervene at individual and systems level to promote educational and psychological services. Because the effectiveness of interventions and treatment may be influenced by poor effort during psychoeducational evaluations, psychologists would benefit from understanding effort at the biological and neuronal level. Additionally, with the rapid growth of neuromodulation treatment techniques (i.e., tDCS, Neurofeedback, Biofeedback) as interventions for various psychological conditions, researchers within the area may be interested in the role of Beta PK in mental effort.

The current study investigated frontal lobe brain activity and mental effort while performing memory-based performance validity tests (PVT). Cognitive (mental) effort was defined as the total energy expended by the brain when information is presented (Fairclough & Mulder, 2012; Kirschner & Kirschner, 2012). Limited studies have investigated EEG patterns of mental effort during memory-based cognitive tasks.

Participants were randomized into Good Effort and Poor Effort Groups. As expected, participants in the Poor Effort group performed poorly on all PVTs as opposed to the Good Effort Group. However, in analyzing Beta PK asymmetry, only Beta PK asymmetry scores for the Rey-15 were significant. The results suggest that poor effort could be represented by asymmetry on PK Frequency for Beta on the Frontal Lobe.

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Appendix A

Post-Study Questionnaire

1) What was the instructed objective for this experiment?

2) How important was it that you accomplish this objective?

1	2	3	4	5
Unimportant	Of Little Importance	Moderately Important	Important	Very Important

3) How important was it that you gave your full effort into accomplishing this objective?

1	2	3	4	5
Unimportant	Of Little Importance	Moderately Important	Important	Very Important

6) What strategies did you use to accomplish today's objective? (check all that apply)

- o answered most/all items incorrectly
- o answered randomly
- o looked purposely away from the task-relevant materials (e.g., looked at pages, but not at pictures)
- o blurred vision so could not see stimulus during study or test phase
- o did not respond to some/all test items
- o took longer than was necessary to respond to test items
- o daydreamed while looking at the stimulus
- o purposely drew a distorted picture
- o other (please describe): ________________________________

5) Were you offered (extra) credit in your class for completing this study? If so, how much importance did it have on your performance today?

1	2	3	4	5
Unimportant	Of Little Importance	Moderately Important	Important	Very Important

VITA

After graduating from Central High School, Pollok, Texas, in 2009, Roselia entered Stephen F. Austin State University at Nacogdoches, Texas. She received the degree of Bachelor of Science in Psychology with a minor in Biology from Stephen F. Austin State University in December 2012. In September of 2015, she entered the Graduate School of Stephen F. Austin State University and received the degree of Master of Arts in School Psychology in May of 2019.

Permanent Address: 2100 North Raguet Street, Suite 302
P.O. Box 13019, SFA Station
Nacogdoches, Texas 75962

Publication Manual of the American Psychological Association (Sixth Edition)

This thesis was typed by Roselia Juan