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COMPARISON OF FIRST-TIME NEUROCOGNITIVE BASELINE COGNIGRAM ASSESSMENTS BETWEEN AMERICAN AND BRAZILIAN PROFESSIONAL BULL RIDING ATHLETES

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By

Peter Wang

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Abstract

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The purpose of this study was to compare the first-time neurocognitive concussion baseline outcomes, using the Cognigram assessment software, between American and Brazilian professional bull riders. The analysis was performed using the database provided by the Professional Bull Riding Association Sports Medicine staff. The Cognigram assessment measures and analyses four outcomes: Psychomotor Function, Attention, Learning, and Working Memory Speed. The study examined the test outcomes of 210 professional bull riders (150 American, 60 Brazilian). A one-way multivariate analysis of covariance (MANCOVA) was used to determine if there a significant difference in the four assessment outcomes when comparing the country of origin subject groups. The results of the analysis reported country of origin has a significant effect on the assessment outcomes, $F(8, 406) = 6.407$, $p < .001$, Wilks' $\Lambda = .788$, partial $\eta^2 = .112$. Post hoc analysis reported significant differences in three outcomes (Bonferroni correction, $\alpha = .012$): Psychomotor Function, $F(2, 206) = 21.25$, $p < .001$, partial $\eta^2 = .17$, Attention, $F(2, 206) = 18.90$, $p < .001$, partial $\eta^2 = .16$, and Working Memory Speed, $F(2, 206) = 7.70$, $p < .001$, partial $\eta^2 = .07$. Country of Origin did not have a significant effect on Learning, $F(2, 206) = 1.14$, $p = .321$, partial $\eta^2 = .01$. Extrinsic factors (Testing environment and format and familiarity of testing content) and intrinsic factors (time orientation and physical and

mental status at the time of testing) could have significant effects on the disparity between the two groups, affecting assessment outcomes. If cultural bias has a significant effect on Cognigram assessment outcomes, this poses a threat to the validity of the assessment toll; and this may contribute to an increase in the probability of under diagnosis of sport related concussions for Brazilian bull riders.

TABLE OF CONTENTS

Chapter 1: Introduction

Traumatic brain injuries (TBI) are defined by the American Association of Neurological Surgeons (2020) as a "blow or jolt to the head or a penetrating head injury that disrupts the normal function of the brain." The Centers for Disease Control and Prevention (CDC) has labeled TBI as a "serious public health concern" that affects a significant portion of the country's population every year (Centers for Disease Control and Prevention, 2020). The most recent statistics reported by the CDC state that there has been an increase of 53% of TBI-related emergency room visits, hospitalizations and death from 2006 to 2014 (Centers for Disease Control and Prevention, 2019). The total incidence of TBI-related injuries and morbidities in 2014 was approximately 2.87 million, with more than 837,000 cases involving minors. Of those cases, 49% were caused by falls and 17% were caused by being struck or collisions with an object. TBI may include the following diagnosed injuries: open injuries such as fractures or penetrations by an object, and closed injuries such as cerebral edema, intracranial hemorrhage, epidural and subdural hematomas, and concussions (American Academy of Orthopedic Surgeons, 2016). The term concussion describes a particular type of TBI. The most common definition used to describe the diagnosis of a concussion is: a head injury caused by biomechanical forces – caused by either a direct blow to the head or neck or indirectly by forces transferred through the body, a rapid onset of neurological deficits that resolves spontaneously, these deficits or changes in function are not caused by structural changes or injury, loss of consciousness may or may not be involved; and these "clinical signs and symptoms cannot be explained by drug, alcohol, or medication use, other injuries (such as cervical injuries, peripheral vestibular dysfunction, etc.) or other comorbidities (e.g. psychological factors or coexisting medical conditions)" (McCroy, et al, 2017, p. 11).

In the athletic setting, sport-related concussion (SRC) is the most prevalent type of TBI. SRC has also become the most prevalent form of head injury in sports. One reason for this increased diagnosis is the emphasis of testing and evaluations of SRC. In the past, SRC have been labeled minor injuries that just required rest or played through. Terms like "dinged" or "having your bell rung" were common terms that were used to describe SRC. There were no formal testing or objective evaluations; only subjective symptoms were reported or assesed. Symptoms are defined as subjective evidence of a disease or illness. They are described or reported by the patient. Examples of common SRC symptoms are: dizziness, nausea, sensitivity to light or sound, headache, pressure in the head, changes or disturbances in one's visual field, ringing in one's ears, loss of sense of taste or smell, and confusion. These types of changes in one's perception or status cannot be observed or measured by the healthcare provider or another third party. It must be self-reported by the patient and for their existence and level of intensity. Signs are defined as any objective evidence of disease or illness. Examples of signs would be: nystagmus (difficulty or altered ability to track with one's eyes), altered gait or walking, pupil size and shape (examined individually or compared bilaterally), vomiting, loss of consciousness, loss of short or long term memory, unusual or altered emotional state, slurred speech, discharge of fluid (blood and/or cerebral spinal fluid) from the ears or nose, and seizure. Organizations did not have official head injury protocols to evaluate these injuries, return to play or participation, or return to classroom. If athletes did not report symptoms, even with observable changes in balance or behavior, athletes would be allowed to return to participation based on their self-reported symptoms and health status.

With increased emphasis on objective testing and evaluations for SRC, the importance of developing and choosing the most appropriate protocol includes choosing the most appropriate cognitive evaluation tool for one's population and clinical setting. Variables such as cost, equipment needed, staffing, and language accessibility are important factors that will affect the validity and reliability of one's SRC testing program. Testing validity refers to the ability of the test or tool to measure what it is intended to measure. Testing reliability refers to the ability of the test or tool to accurately measure each time that it is used, between different subjects and test administrators.

This study examines the use of the SRC testing tool Cognigram Computerized Assessment Tool (CCAT), previously known as CogSport and Axon Computerized Cognitive Assessment Tool, used by the Professional Bull Riders Association (PBR) Sports Medicine Program as a part of their SRC testing protocol (Cogstate, 2020; R. Blyn, personal communication, January 3, 2020). The PBR is a professional sports organization that sponsors and produces bull riding competitions in the United States (US), Canada, Mexico, Australia, and Brazil (PBR, 2020). The primary locations of the competition venues are located in the US. However, the PBR does produce and host events in the other countries. The PBR also produces and manages minor league competitions in each of the countries listed previously, used to develop new athletes to the sport and athletes looking to qualify for the primary competition league – the PBR Cup series. This format is similar to professional baseball and basketball where there are lower level minor leagues for each sport that are used for player development and rehabilitation.

The significance of valid and reliable SRC testing affects the ability of healthcare providers to accurately diagnose patients. In an athletic setting, it is common for athletes to hide or under-report their sign and symptoms. The primary reason is to avoid being removed from competition. Once an athlete has been diagnosed with an SRC, he or she is immediately removed from competition that day and must be placed in the concussion recovery protocol. Concussion recovery protocols vary depending on the athlete's level of competition, age, sport, time of year, and guidelines established by each sport organization and medical oversight committee. In the state of California, high school athletes that are diagnosed with an SRC are removed from competition for a minimum of 7 days from the date of diagnosis. For a high school football player, that would require the athlete to be ineligible to participate for the remainder of event on the day of the injury and be unable to play for the next game. In other sports such as basketball or baseball where games or matches may be scheduled multiple times in one week, entering concussion protocol would require an athlete to be ineligible for multiple days of competition. Another reason why athletes are hesitant to report or try to hide SRC signs and symptoms is that they may be fearful of losing their starting position on the team. In the setting of professional athletics, these reasons for under-reporting or hiding signs and symptoms of SRC may be due to financial reasons. In the PBR, athletes can only earn money by: winning an event, earning a score that places the bull rider in the highest rankings (top five through ten depending on the size and competition format of the event) in points for the daily event section, daily round of competition, or event championship round (R. Blyn, personal communication, January 3, 2020). Being removed from competition prevents the athlete from having the potential to earn income. Unlike most other professional sporting organizations, the athletes in the PBR are not under contract with a team or organization that guarantees an income regardless of injury and loss of participation due to injury. The financial incentive to under-report or not disclose signs and symptoms of a possible SRC is significant for athletes in the PBR.

Without accurate diagnosis and treatment for SRC, athletes risk further short-term complications and increased risk of potential negative health outcomes (American Academy of Orthopedic Surgeons, 2017). Athletes who are suffering from an SRC without diagnosis, that continue to participate in competition, significantly increase the risk for Second Impact Syndrome (Prentice, 2020). Second Impact Syndrome is defined as “a life-threatening emergency that occurs as a result of rapid swelling of the brain following a second head impact occurring before the symptoms of a previous concussion has resolved.” Any type of force applied to the body, causing acceleration and deceleration of the brain within the skull, during this recovery period may induce this physiological response. The mortality rate of this condition is 50%. Another health complication that may occur when athletes hide possible SRC’s is the possibility that comorbidities may be present. Other comorbidities may include epidural hematomas, subdural hematomas, and internal hemorrhaging within the skull (Prentice, 2020). These comorbidities, if not diagnosed due to the athlete hiding their signs and symptoms of their SRC, could significantly jeopardize the health outcome.

Another short-term complication from undiagnosed SRC’s include prolonged episodes post-concussion syndrome (Prentice, 2020). Post-concussion syndrome is a condition where patients experience persistent signs and symptoms that mimic the ones experienced directly after injury. These signs and symptoms may include: headaches, memory deficits, poor attention span, irritability, problems controlling emotions, fatigue, sensitivity to light and/or noise, visual problems, anxiety, and depression. This condition may last weeks or months after the injury. In addition, patients who experience a concussion are four times more likely to suffer another.

The long-term complications of SRC’s were not identified until recently. Recent research has linked SRC injuries to possible later development of Chronic Traumatic

Encephalopathy (CTE) (Breton, et al., 2017). CTE is a progressive neurodegenerative disease associated with repetitive mild brain trauma that can only be diagnosed after the patient's death by autopsy (Breton, et al., 2017; Mayo Clinic, 2020). Possible signs and symptoms of CTE reported by patients prior to their death include: cognitive impairment or dysfunction, problems behavioral impulse control, depression, memory loss (short-term and/or long-term), emotional instability, suicidal tendencies or ideations, and substance abuse. Since diagnosis of CTE can only be confirmed by autopsy, research of its progression and pathology are limited at this time. Differential diagnoses for patients suspected to develop CTE include Dementia, Alzheimer's disease, and other neurological lesions or disease (Caixeta, et al., 2018).

Considering both acute and long-term health outcomes affected by SRC, the significance of valid and reliable concussion assessment becomes increasingly important. Accurate baseline assessments of athletes are necessary to properly diagnose SRC. These baselines assessment also play vital role in the evaluation and decision-making process of returning athletes to activity and competition. Inaccurate neurocognitive function assessment could allow athletes to return to sport-related activities when their brains have not fully recovered and healed. This could jeopardize their immediate and long-term health. Within a diverse, multicultural population such as the PBR, concussion assessment should be valid regardless of socio-cultural background. The purpose of this study is to examine the validity of the CCAT among different cultural groups. Is there a significant difference in first-time, concussion baseline assessments between American and Brazilian professional bull riders?

CHAPTER 2: LITERATURE REVIEW

This study will examine if there is a significant difference between cognitive concussion baselines testing results in professional bull riding athletes from the U.S. and Brazil. The literature review will: describe the unique sport of professional bull riding and the PBR organization, provide a comprehensive overview of concussion injuries, and describe current concussion baseline testing protocols and the tests used by the PBR Sports Medicine staff.

Sport-Related Concussions

In order to effectively diagnose SRC injuries, it is vital to accurately measure cognitive and neurological functions and processes prior to injury. Once an athlete is suspected of sustaining a SRC or other TBI, post-injury evaluations and testing will be conducted to determine if the athlete is experiencing neurological or cognitive dysfunction. Many times, concussions or other TBI may not be apparent or easily diagnosed without further testing and evaluations. Greater than 90% of SRC do not occur with the sign or symptom of loss of consciousness (LOC) (Ferry & DeCastro, 2020). Sign is defined by the Journal of the American Medical Association (2020) as "objective evidence of disease," observed by the health care provider. Symptom is defined as a subjective complaint by the patient, a "manifestation of disease apparent to the patient."

TBI may include any penetration or force applied to the head. This classification of injuries includes fractures, lacerations, internal hemorrhaging within the head, and concussions. As described in Chapter 1, concussions are often labeled as mild TBI (Mullally, 2017). The mechanism of injury for concussions is the "result of direct trauma, rapid acceleration-deceleration of the head such as 'whiplash' injury, or a blast injury commonly seen in military personnel serving in a war zone." The injury occurs not from the impact or direct force, but is caused by the movement of the brain within the skull. As demonstrated with sports such as football and bull riding where protective helmets are worn by athletes, concussions are still prevalent. Injuries from direct trauma or impact, such as fractures and lacerations, have been prevented by the protective equipment but the prevalence of concussions remains significant. Derived from the Latin "concussus" which means to shake violently, the rapid movement of the brain is the cause of the injury.

After the trauma to the brain, there is an alteration in mental status and neurological function believed to be caused by neurochemical changes. The stretching and contraction of the axons, cells that make up the brain, causes concentration changes of neurotransmitters, minerals - such as potassium and calcium, and lactate (Mullally, 2017). These chemical changes lead to the transient signs and symptoms observed or reported. Signs and symptoms of a concussion are any of the following: loss of consciousness, seizure, balance dysfunction, gait difficulties, motor incoordination, confusion or disorientation, blank or vacant look, amnesia – anterograde (post-injury memory loss) and/or retrograde (memory loss prior to injury), vision problems, headache, nausea or vomiting, increased emotional state or agitation, feeling of increased pressure in the head, sensitivity to light or sound, difficulty concentrating or feeling slow, and fatigue (McCrory, P, et al, 2016).

At this time, concussions cannot be diagnosed with traditional medical testing or imaging. Testing using X-ray, magnetic resonance imaging (MRI), or computer tomography is used to diagnose other TBI injuries such as fractures or internal hemorrhaging (Prentice, 2020). Concussion diagnosis can be made by the observation of altered mental status or neurological dysfunction such as loss of consciousness, seizure, balance impairment, or obvious mental impairment (Echemendia, et al. 2017). However, there is not a single gold standard test for SRC assessment and diagnosis. The current consensus regarding best practice guidelines for SRC assessment and diagnosis recommends a multifaceted approach that includes: self-reported symptoms checklist, medical history intake and clinical examination by a qualified healthcare provider, neurocognitive assessment, and baseline and post-injury assessments (Broglio, et al., 2014; McCrory, et al., 2017; Weber, et al., 2018).

Based on the best practice guidelines, neurocognitive assessment (pre-injury and post-injury) is an essential aspect of TBI evaluation and diagnosis and is included in the standard of care in sports medicine. Standard of care in the field of medicine is defined as the care provided being comparable to other reasonable, prudent healthcare practitioner's care under the same circumstances (Konin & Ray, 2019). This type of evaluation is a non-invasive measurement of brain function that quantifies the patient's: memory, attention span, language, reaction time, decision making, and visuospatial skills. This type of assessment can be performed using traditional testing methods that require written materials and a test administrator; or by using computerized testing programs that are supervised by qualified personnel. With the advancement of technology, computerized neurocognitive assessment has become the primary form of testing used to measure baseline neurocognitive function and evaluate SRC post-injury (Nelson et al., 2015).

Computer-based Neurocognitive Concussion Assessment

There are many advantages of computerized neurocognitive assessment over traditional pencil-paper assessments. Computerized testing provides: standardized and controlled stimulus during the presentation and testing protocol, consistent and efficient testing time and administration, increased sensitivity in evaluating and determining significant, small deficits that may be overlooked by the human assessment such as changes in reaction time, centralized storage of test data for analysis and research, and randomization of testing protocols and information (such as memory recall words or numbers) to ensure consistent testing validity McCrory et al., 2005) In addition, multiple tests may be administered at one time through the use of multiple computers, requiring only one test administrator to supervise the testing. Traditional pen and paper testing requires additional recruitment and training of qualified health care personnel in order to test large groups. Sports that may have large testing populations - such as football, track and field, crew, and soccer – would require significant time and human resources to efficiently test all subjects for pre-injury baselines.

With the integration of computerized neurocognitive assessment in the best practices protocol for SRC evaluations, one vital component is the use of baseline testing. Baseline testing is the assessment of neurocognitive function when the patient is “normal” – pre-injury status with assumed normal cognitive function.

The most widely used computerized neurocognitive assessment is the Immediate Post-Concussion Assessment and Cognitive Testing (ImPact). ImPact is a computerized neurocognitive assessment program that measures patient’s visual and verbal memory, reaction time, impulse control, attention, and visual processing speed and accuracy (McCroy, P. et al., 2005). According to Dessey et al. (2017), ImPact is the most widely concussion neurocognitive assessment in the U.S. and internationally. Their study reported that 93% of all organizations that use computerized testing are using ImPact. This includes a majority of high schools, collegiate, and professional sports organizations in the U.S. The PBR performed initial baseline testing using ImPact at the PBR World Finals in 1997 (R. Blyn, personal communication, January 3, 2020). However, the PBR Sports Medicine Program decided not to implement the computer assessment into their concussion protocol due to the significantly large number of invalid test scores. One reason given for the problems associated with this assessment was the language translation for the test was only available in Portuguese. The Brazilian bull riders speak and comprehend Brazilian Portuguese. Many of the Brazilian test subjects complained to the sports medicine staff that the instructions and testing questions were difficult to understand and found the test to be frustrating.

Following this initial trial, it was recommended to the PBR Sports Medicine staff by their consulting neurologist to investigate the computer neurocognitive assessment tool - Axon Computerized Cognitive Assessment Tool, currently called Cognigram (R. Blyn, personal communication, January 3, 2020). Cognigram is a computer based neurocognitive assessment tool that measures: reaction time, decision making, information processing, memory, and attention (McCrory, P. et al., 2005). These cognitive functions are measured using computer generated images of playing cards in four sub-tests. The language barriers experienced by Brazilian bull riders with the ImPact test assessments would be minimized by the Cognigram software through the use of simple image based testing of neurocognitive assessments. Language translation would only be required for the testing instructions that could be done by an in-person translator or a pre-recorded translation. The assessment is advertised as having “low practice effect, unaffected by language or culture” (Cogstate, 2021). Practice effect refers to the influence of repeated assessments or testing on the outcomes (McMillan & Schumacher, 2014). Practice effect describes the reliability of the assessment to measure consistent results, regardless of the subject’s memory of the test or testing protocol. The Cognigram neurocognitive assessment was adopted by the PBR Sports Medicine staff for use in the concussion protocol due to simplified testing instructions, use of images for assessment, minimal need for reading and language skills, and the significantly lower number of invalid test scores during its initial trial (R. Blyn, personal communication, January 3, 2020).

Valid and reliable neurocognitive assessments for baseline and post-injury evaluations are vital for the accurate diagnosis and return to activity decision making process (McCroy, et al., 2017). The acute and long-term health outcomes of patients with SRC are dependent on the accurate diagnosis of SRC. Prior history of concussion is a significant risk factor for higher incidence of future SRC's and correlated with the increased risk for post-concussion syndrome (Iverson, et al., 2017). Additionally, Second-impact syndrome is rare but often fatal short-term health complication. Chronic Traumatic Encephalopathy (CTE) is currently being researched as a possible long-term health outcome of SRC (Mullally, 2017).

Post-concussion syndrome describes the persistence of neurological signs and symptoms beyond 4 weeks post-injury of a SRC (O'Connor & Fincher, 2015; Starkey & Brown, 2015). These neurological deficits may be similar to those experienced by the patient post-injury, or, they may be different than the clinical manifestations of the initial injury. Diagnosis of post-concussion syndrome requires the same clinical evaluation and neurological assessment used to diagnose SRC. These signs and symptoms typically are exacerbated by physical activity and increased mental activity such as reading, studying, or other academic activities (McDonald, Burghart, & Nazir, 2016; Meehan, et al., 2013). Increased risk of post-concussion syndrome also occurs with TBI re-injury while recovering from the initial SRC. This highlights the value of neurocognitive assessment during the concussion recovery phase. Neurocognitive assessment is one part of the evaluation process that determines when patients have fully recovered from SRC. Neurological deficits measured post-injury must return to levels measured during baseline testing values.

Another acute health outcome that may occur if a patient suffers another TBI, while recovering from SRC, is Second-Impact Syndrome (O'Connor & Fincher, 2015; Starkey & Brown, 2015). Second-impact Syndrome (SIS) is a rare condition caused by a second traumatic impact to the head or body while the person is recovering from the initial concussion, causing a disturbance to the blood flow to the brain. It is believed that the body's autoregulation of blood is affected leading to increased intracranial vascular pressure and expansion. There is debate among researchers regarding the true incidence of SIS. The literature review by Engelhardt, Brauge, and Loiseau (2020) reported only five total cases that met the criteria for SIS. The mortality rate associated with SIS is reported to be 50%. Patients suffering from SIS will begin to significantly deteriorate two to five minutes after the second impact.

Chronic Traumatic Encephalopathy

First described by Dr. Harrison Martland in 1928, the term "punch drunk" was used to describe a progressive neurological deterioration of boxers (Castellani & Perry, 2017; Changa, Vietogoski, & Carmel, 2018; Lindsley, 2017). The signs and symptoms associated with the term included behavior, motor, and cognitive dysfunction that progressively worsened. During autopsy, cerebral microhaemorrhages were discovered, associated with the repeated trauma from punches (Changa, Vietogoski, & Carmel, 2018). In 1937, J.A. Millspaugh researched the condition and introduced the term "dementia pugilistica." The condition was later renamed chronic traumatic encephalopathy (CTE) in 1949 and included populations such as athletes in contact sports and military personnel, populations that experienced repeated head trauma. As diagnostic technology developed and improved, cerebral degeneration accompanied by abnormal protein deposits in histological studies refuted previous pathological assumption of cerebral microhaemorrhages (Goldfinger, et al., 2018; Changa, Vietogoski, & Carmel, 2018). Presently, CTE can only be diagnosed postmortem with the examination of the brain tissue. The diagnostic criteria for CTE is the specific distribution of hyperphosphorylated tau protein (a necessary protein found in the axons of neurons) in the brain, as well as atrophy in specific regions of the brain such as the cerebral cortex, temporal lobes, thalamus, and brain stem (Asken, et al., 2017). The specific distribution of phosphorylated tau that resemble tangles differentiates CTE from other taupathological conditions such as Alzheimer's (Lindsley, 2017; Asken, et al., 2017). CTE signs and symptoms mimic many other neurological disorders such as dementia, Parkinson's, and amyotrophic lateral sclerosis (ALS) (Lindsley, 2017). Patients may suffer from personality changes, speech and gait abnormalities, and mental health issues such as depression, anxiety, and suicidal indeations.

CTE gained attention in 2005 with publication of a case study by Omalu, et al. that presented a postmortem diagnosis of CTE in a retired National Football League (NFL) player (Lindsley, 2017; Omalu, et al, 2005). The patient exhibited CTE – like symptoms prior to death, and postmortem evaluation confirmed the diagnosis. Further studies were performed at autopsy of former NFL players; and widespread media attention focused on the possible link between CTE and repeated head injuries of professional football players. A study by Mez et al. in 2017 reported that 110 out of 111 deceased NFL subjects were diagnosed with CTE postmortem. The former football players and their families had agreed to donate their brains for continued research of this condition.

Currently, CTE research does not demonstrate significant correlation with TBI (Asken, et al., 2017; Lindsley, 2017; Mullally, 2017). A significant limitation of the current research is the targeted sampling of symptomatic subjects, which does not inform on the true epidemiological nature of the disease. Subjects of these studies had pre-existing CTE signs and symptoms prior to postmortem examination and a history of TBI (Mez, et al., 2017). Actual incidence and prevalence data for the general population does not exist at this time.

Other factors that complicate the causation relationship between TBI and CTE is the high incidence of drug use by NFL players. NFL players have reported significantly highly prevalence of opioid, alcohol, steroid, and other illicit drug use (Maese, 2017; Cottler, et al., 2011). The NFL does not disclose statistics to the public regarding violations of the substance abuse protocol. However, a survey of retired NFL players by Cottler et al. reported that 52% using opioids during their playing careers, with 71% reporting misuse. At the time of the survey, 7% of retired players were continuing to misuse opioids. Another study reported 89% of college athletes used alcohol to manage physical and mental health issues and 57% of world-class athletes reported using performance enhancing drugs (PEDs) (Carreathers, 2020). Substance abuse can also predispose patients to many of the signs and symptoms associated with CTE and other neurodegenerative diseases (American Psychology Association, 2013). Another debated topic regarding CTE is the correlation between CTE and suicide. Prior to 2010, suicide was not considered a clinical outcome of CTE (Iverson, 2016). Omalu et al. published an article in 2010 that reported suicide and suicidal ideations as one of the behavior profiles and clinical presentations associated with CTE. This assumption was based on the cause of death of 2 of the 3 cases presented by Dr. Omalu. Even if suicide and suicidal ideations were supported by the research, studies have reported that NFL players do not have a higher incidence of suicide than the general population (Iverson, 2019; Lehman, et al., 2016). The study by Lehman et al. (2016) compared the suicide mortality rate of retired NFL players and to the general population. Increased suicide mortality rate would support the notion of higher incidence of CTE within the population. This is specifically related to the postmortem evaluation required for diagnosis.

Assumptions of causality between TBI and CTE have been attributed to widespread media attention given to ongoing litigation, specifically the settlement between the NFL and the NFL Players Union (Asken, et al., 2017). At this time, there is no conclusive evidence of the causal relationship between TBI and CTE; however, this field of study is ongoing and the development of improved diagnostic methods is needed to investigate the relationship.

Factors Affecting Neurocognitive Assessment

The need for valid and reliable neurocognitive assessment is critical for accurate diagnosis and post-injury evaluation of SRC. Test administrators of neurocognitive concussion assessments must be aware of factors that may affect baseline and post-injury testing scores. These factors, if not recognized, may result in higher or lower scores for neurocognitive functions that may not be accurate. Without accurate measurement of these cognitive functions, the clinical diagnosis and post-injury assessments may be compromised, resulting in the possible under-diagnosis of SRC or premature medical release to resume activity when the patient is still recovering from the initial trauma. Native language, age, socioeconomic status (SES), sex/gender, previous psychiatric conditions such Attention-Deficit/Hyperactivity Disorder (ADHD), previous history of headaches or migranes, culture, and race/ethnicity have been shown to affect neurocognitive testing results (Abeare, et al., 2018; Cottle, et al., 2017; French, et al., 2019; Weber, et al., 2018; Houck, et al., 2018; Jones, et al., 2014; Daugherty, et al., 2017).

A study by Jones et al. (2014) examined the effect of native language (native English speakers and native Spanish speakers) and education on ImPact assessments scores in professional baseball players. When controlling for education, the study reported significant differences between the two populations in visual motor speed, reaction time, and visual memory outcomes ($P<0.05$). Education level did demonstrate correlation with all composite scores. This study was the only recent study that sampled a professional sport population within a similar age range of this study.

Age has been a widely recognized factor affecting computer-based neurocognitive SRC assessment. All assessment tools used to diagnose and evaluate SRC require new baseline assessments every year or every two years, depending on the age group of the subject (Daugherty, et al., 2017;Echemendia, et al., 2017; Cogstate, 2020; ImPact, 2021). Retesting neurocognitive baseline assessments annually increases validity of SRC post-injury evaluations when used as comparisons. The study by French et al. (2019) reported significant increases in verbal and visual memory, visual motor processing speed, and reaction time with increasing subject age range. In the study by Houck et al. (2018), researchers reported increased overall speed performance and memory during baseline testing using ImPact. Houck et al. (2018) also reported significant correlation between maternal SES and overall memory scores.

Previous history of mental health and psychological state during neurocognitive assessment can be significant factors affecting baseline testing outcomes. Previous history of anxiety and depression was reported to decrease visual memory composite scores (Weber, et al., 2018). Cottle et al. (2017) reported significant differences in visual motor speed with subjects that were previously diagnosed with ADHD. Decreased memory and speed performance among subjects with ADHD were also reported in the study by Houck, et al. (2018).

Houck et al. (2018) examined race/ethnicity as a factor affecting computer-based neurocognitive concussion baseline assessment. The researchers reported lower memory and speed performance ImPact baseline scores for Black/African American athletes versus White and Other Race/Ethnicity groups. Other studies also reported significant differences among populations of different cultures and nationalities; however, these studies utilized neuropsychological instruments not specific to SRC assessment such as Hopkins Verbal Learning Test and the Hooper Visual Organization Test (Daugherty et al., 2017; Araujo et al., 2019; Ostrosky-Solis et al., 2004).

One limitation regarding the published research regarding factors affecting computer-based neurocognitive testing is that studies predominantly focused on the use of ImPact (Abeare, et al., 2018; Cottle, et al., 2017; French, et al., 2019; Houck, et al., 2018; Jones, et al., 2014; Weber, et al., 2018). Due to the widespread use of ImPact across the various athletic competition levels as reported previously, it would be logical for studies examining computer-based neurocognitive assessment to report testing results for this specific testing program.

Another limitation of the research is the age demographics of the populations sampled. A significant majority of the populations tested using computer-based neurocognitive were school-age or college-age. There is a lack of research for populations above the age of 24. Computer-based neurocognitive concussion assessment in this age range is limited to professional athletes. The National College Athletic Association (NCAA) establishes age eligibility limits based on individual sports participation (NCAA, 2021). For most sports, student-athlete eligibility begins after high school graduation with a 12 month grace period. Participants are permitted 5 years to complete 4 years of competition. Exceptions are permitted based on religious or military service exemptions. This would place normal student-athlete age limitations at age 26. The lack of data regarding professional athletes is largely due to legal issues. SRC assessment data could be used for litigation against professional sports organizations as demonstrated by the NFL settlement. Studies that included sample populations beyond this age range have focused on geriatric populations, researching neurocognitive function of populations at high risk for Dementia, Alzheimer's, and other geriatric cognitive disorders (Araujo, et al., 2020; Goudsmit, et al., 2017; Ostrosky-Solís, et al., 2004).

The Sport of Professional Bull Riding

The sport of professional bull riding is unique due to the incidence and severity of injuries sustained during competition (PBR Sports Medicine, 2020). Based on the data collected and analyzed by the National Safety Council (2018), basketball has the highest incidence of injury (across all age groups) among organized sports, followed by football and soccer. With regard to SRC, hockey reported the highest percentage of SRC among diagnosed injuries at 12%. The second highest incidence of SRC involved Snowboarding – 10%, followed by football and lacrosse at 8%. However, according to the data provided by the National Collegiate Athletic Association (NCAA) Injury Surveillance Program (2014), men's wrestling had the highest incidence on SRC (10.92 per 10,000 athlete-exposures (AEs), followed by men's hockey (7.91 per 10,000 AEs), women's hockey (7.50 per 10,000 AEs), and football (6.71 per 10,000 AEs). At the professional level of competition, the National Football League (NFL) reported the average SRC rate per game at 0.58, while the National Hockey League (NHL) reported an average SRC rate per game at 0.025. A systematic review of the literature by Reisenauer & Stoneback (2020) reported injury rates for all rodeo competition events (timed events: Steer Wrestling, Barrel Racing, Calf Roping, and Team Roping; rough stock events: Saddle Bronc, Bareback Bronc, and Bull Riding) from 1990 to 2018. This study reported that up to 50% of all rodeo injuries occurred in the event of Bull Riding. This significantly high incidence of injury is due to the nature of the event. The size of the animal compared to the rider, the aggressive nature of the animals' behavior, the velocity and forces exerted on the rider during the ride, and the unpredictable and sometimes violent mechanism of the rider's dismount/escape from the bull after the ride are all factors that contribute to the increased injury rate. The researchers reported that head and neck injuries accounted for 27% of all injuries.

The injury statistics recorded by the PBR injury tracking software – Athletic Training Systems (ATS) – has been used since 2017. Yearly injury history reports report the following SRC injury statistics: 38 SRC's out of 157 total injuries in 2017 (24.2% of all injuries), 49 SRC's out of 245 total injuries in 2018 (20% of all injuries), 35 SRC's out of 216 in 2019 (16.2% of all injuries), and 37 SRC's out of 181 total injuries in 2020 (20.4% of all injuries). SRC's are the most prevalent injury diagnosed each year in the PBR.

The high incidence of injury, particularly with SRC, associated with bull riding can be attributed to the requirements of the sport. The average bull rider weighing 140 pounds must ride a bull, weighing on average at 1200 pounds, for eight seconds (R. Blyn, personal communication, January 3, 2020). Mechanisms of injury occur while mounting the bull prior to riding, during the ride, trying to dismount or being thrown from the animal, and moving away to safety after the ride. SRC can occur from striking the ground, being struck by the bull or along the fencing during the ride, or being struck or stepped on by the bull while on the ground. Being struck or stepped on by a bull has been compared being struck by small motor vehicle or having a small vehicle land on top of you.

The PBR is structured on a tier system, similar to professional baseball with the major league and it's tiered minor league system, where there is a premiere tour that selects 40 bull riders with the highest rankings based on points (PBR, 2020). Points are accrued through a system using points received for each completed ride and money earned for each event. The lower ranked bull riders ride on separate tours organized and produced by the PBR, similar to the minor league system in Major League Baseball in the U.S. There are two minor league tours that stage events throughout the year. The premiere tour is the only level of competition at this time that conducts SRC testing and evaluations. The medical coverage for the two other minor tours is provided by local Emergency Medical Systems (EMS) (R. Blyn, personal communication, January 3, 2020). The local EMS providers do not have access to the rider's medical history or concussion testing data. At the beginning of each season, the top 40 bull riders from the previous season are selected to start on the premiere tour. Concussion baseline testing is performed two days prior to competition. New baseline exams are performed every year per guidelines established by the medical board for the PBR. The medical board is comprised of the Medical Director – Dr. Tandy Freeman, M.D., the consulting Neurologist – Dr. Anthony G. Alessi, M.D., and the Director of Sports Medicine – Richard Blyn, A.T.C. Once the season begins, new bull riders who are lower ranked may be invited to compete on the premiere level as substitutes if a rider cannot compete due to illness, injury, and other acceptable reasons. These bull riders, who do not have current baselines for the year, will be tested at the event site by the sports medicine staff prior to competition.

Starting in 1992, the first full season of the PBR was comprised of athletes primarily from the U.S., with only one bull rider from Brazil and one from Australia (Professional Bull Riders Association, 2020). At the time of this study, the current demographic of the PBR is shown in Table 1. Table 2 compares the general characteristics for both countries.

Table 1
Country of Origin of Bull Riders 2020 Season

	U.S.	Brazil	Australia	Mexico	Canada
Total Number	224	81	59	40	31
Percentage	51.49%	18.62%	13.56%	9.20%	7.13%

Table 2
Comparison of Country Profiles

	United States	Brazil
Size (sq km)	9,833,517	8,515,770
Population (2019)	328,239,523	209,469,333
GDP (2019)	21.373 trillion (US$)	1.84 trillion (US$)
Poverty Rate (2018)	11.8 %	19.90 %
Life Expectancy (2018)	78.54	75.67
School Enrollment Primary Education (2011)	99.39	132.497
Literacy Rate (2018)	99.00 %	93.23 %

(World Bank, 2020)

Being similar in geographical size, Table 2 also presents similar statistics for life expectancy, literacy rates, and school enrollment. Significant differences can be seen comparing economic data, with Brazil reporting less than ten percent of the Gross Domestic Product (GDP) as the U.S and nearly double the poverty rate. These statistics demonstrate the significant income inequality experienced by the population. Income inequality has long plagued the country of Brazil. According to the report by the International Monetary Fund (IMF) in 2017 (Goes, & Karpowicz, 2017), Twenty-five percent of the population lived at or below the poverty level in the year 2004. The income gap did improve from 2004 to 2014, with the population poverty level reaching 8.5 %. However with the recent recession, Brazil's poverty level has increased to near 2004 levels as shown by Table 2. The age demographic of the Brazilian bull riders in the PBR coincides with their childhood and adolescence prior to the economic growth through the years of 2004 and 2014. According to staff of the PBR Sports Medicine team, bull riders grow up in rural areas in order to become bull riders (R. Blyn, personal communication, January 3, 2020). It would be rare for a bull rider to grow up in the city and have the opportunity to live near livestock and horses in order to practice and have the opportunity to become a bull rider. Growing up in these rural areas, income inequality, as well as disparities in education differs significantly.

CHAPTER 3: METHODOLOGY

The research design of this study is an ex post facto design, analyzing the data digitally stored in the existing PBR Sports Medicine Concussion Assessment Database. First-time baseline assessment results for the CCAT were collected for American and Brazilian bull riders. CCAT baseline assessments were included in the concussion protocol starting in October 2012. Cognigram software training for the PBR Sports Medicine staff occurred during the initial presentation of the software for purchase (R. Blyn, personal communication, January 3, 2020). The researcher created an original database using Microsoft Excel to include: anonymized subject identification coding, age at the time of testing, country of origin, test date, test duration, Processing Speed score, Attention score, Learning score, and Working Memory Speed score.

Subjects

The total number of subjects included in this study was 210 (N = 210). One hundred fifty subjects were from the U.S., and 60 subjects were from Brazil. The descriptive statistics for the subject population and measured outcomes are presented in Table 3.

Table 3

Descriptive Statistics of Subject's Conigram Scores

Measured Outcomes	Country of Origin	Mean	SD	n
Psychomotor Function				
	U.S.	95.422	8.4851	150
	Brazil	85.773	11.8883	60
	Total	92.665	10.5031	210
Attention				
	U.S.	96.810	8.5624	150
	Brazil	89.347	8.2861	60
	Total	94.678	9.1144	210
Learning				
	U.S.	97.779	8.3412	150
	Brazil	100.077	10.7462	60
	Total	98.436	9.1260	210
Working Memory Speed				
	U.S.	94.360	8.8910	150
	Brazil	88.680	9.5120	60
	Total	92.737	9.4081	210

Testing

CCAT baseline testing was conducted by the PBR Sports Medicine staff at the PBR competition venues. Concussion testing and evaluations were conducted in separate rooms provided by the PBR production staff (R. Blyn, personal communication, January 3, 2020). These rooms are normally adjacent to the assigned rooms for medical treatments and evaluations. This was done to provide a testing environment with minimal noise and interference by bystanders. Testing was performed using laptops purchased and maintained by the PBR Sports Medicine staff. Testing results are stored on cloud-based databases maintained by CogState Inc.

(Cogstate, 2020; R. Blyn, personal communication, January 3, 2020). Instructions for the assessment are given verbally by the test administrator and provided by the CCAT software program, using both audio and visual instructions. These instructions are provided in English to all English-speaking subjects, American and Brazilian. Non-English speaking subjects are given verbal instructions in Brazilian Portuguese by translators provided by the PBR administration.

Prior to assessment, the test administrator will complete the subject profile which includes the subject's name, date of birth, gender, type of sport, position or category within the specific sport category, and hand dominance (right or left-handed). After completion of the subject profile, the test administrator will select the type of assessment to be used, either baseline assessment or post-injury evaluation.

The first sub-test asks the subject to respond using the keyboard input when the playing card that is face down turns over. The subject must depress the "k" key to respond as quickly as possible. The card is turned over by the program at randomly selected delay intervals. After the subject responds, the card placed face up is removed and another card is presented face down to repeat the assessment. The sub-test ends once the assessment has been completed.

The second sub-test requires the subject to respond "yes" or "no" with the keyboard when the playing card presented face down is turned over and the subject must decide if the playing card displayed is the color red. The card presented may be either red or black in color. The subject must press the "k" key if their answer is "yes" or press the "d" key if their response is "no." The program also instructs the subject to respond as quickly as possible. The cards are turned over by the program at randomly selected delay intervals. After the subject responds, the card placed face up is removed and another card is presented face down to repeat the assessment. The sub-test ends once the assessment has been completed.

The third sub-test asks the subject “Have you seen this card before?” The subject is shown a card face down and the program turns the card face up at randomly selected delay intervals. The subject must determine if the card presented has been shown before. The card must match in both suit and face value. The program randomly selects cards to turn over and the subject must depress the “k” key if responding “yes” or depress the “d” key if the response is “no.” Subjects are asked to respond as quickly as possible. After the subject responds, the card placed face up is removed and another card is presented face down to repeat the assessment. The sub-test ends once the assessment has been completed.

The last sub-test asks the subject “Is this card the same as the previous card?” The test begins with the playing card face down. The program turns over the card at randomly selected delay intervals. The subject must determine if the presented playing card is the same, both in suit and face value, as the one right before. The program randomly selects cards to turn over and the subject must depress the “k” key if responding “yes” or depress the “d” key if the response is “no.” Subjects are asked to respond as quickly as possible. After the subject responds, the card placed face up is removed and another card is presented face down to repeat the assessment. The sub-test ends once the assessment has been completed. The Cognigram software provides subjects with a practice round for each subtest prior to actual testing.

Once all sub-tests have been completed, the software analyzes the data from assessment if the tests results are within the validity range. The first initial baseline assessment for each subject is compared to normative data based on the subject’s profile. This evaluation is used to determine if the subject understood the evaluation and to determine if the subject purposely scored low or incorrectly to affect possible future post-injury assessments. Subjects may significantly affect post-injury evaluations by intentionally scoring poorly on their baseline assessments. The reasoning for this behavior is to decrease the measured difference in post-injury assessment. If the subject is experiencing a deficit in neurocognitive function post-injury and intends to intentionally hide this deficit and deceive the test administrator, the subject would intentionally lower their baseline assessment. This process of intentionally lowering one's scores is termed "sandbagging" (Higgins, Denney, & Maerlander, 2017). As described previously, the motives to sandbag baseline assessments in the sport of bull riding is primarily financially based. Professional bull riders will resist being removed from competition, regardless of injury status.

Post-injury evaluation results are presented to the test administrator with the most recent baseline assessment for comparison. After the initial first baseline assessment, it is recommended that subjects be retested every year for a new baseline assessment. The new annual baseline assessment will be evaluated using normative data based on each subject's profile and previous baseline assessments to confirm validity.

Validity and Reliability

The Cognigram computer-based assessment states that the test is "sensitive and reliable" and is "unaffected by language, education, cultural background or practice" with "high test-retest validity" (Cogstate, 2021). A review of the literature supports the validity and reliability of the test. A basic definition of validity is the ability of a test to measure what it is intended to measure (Armstrong & Kraemer, 2016). The definition of reliability is the ability of the test to produce repeatable, consistent results. Louey et al. (2014) tested the sensitivity and specificity of the Cognigram test (previously named CogSport/Axon in the study). "Sensitivity is the ability of the test to identify correctly all screened individuals who actually have the disease"; while specificity is the ability of the test to identify correctly subjects that do have the disease or condition (Friis, 2018, p. 200-201). The study compared baseline and retest results from a sample of collegiate and professional Australian Football athletes. A portion of the sample population was retested post-injury from a SRC. Researchers evaluated baseline and retest data from subjects that were non-injured to assess Cognigram reliability. Researchers also evaluated baseline test and retest data for non-injured and injured subjects to determine Cognigram's sensitivity and specificity for assessing neurocognitive deficit post-injury. Injured subjects were also tested using ImPact and Automated Neuropsychological Assessment Metrics (ANAM) to produce normative data for comparison. These two assessment tools have been studied and proven to be valid and reliable tools for SRC evaluation. The study showed high reliability for overall test scores, as well as each subtest section of the assessment. SRC sensitivity for two or more subtest deficits in injured subjects was reported at 96.6%, higher sensitivity results than the normative data. There were no significant differences reported in specificity data when compared to the normative data (17.2%).

This supported the previous study by Collie et al. (2003) that compared Cognigram with normative data measured with the Digit Symbol Substitution Test (DSST) and Trail Making Test – Part B (TMT). Researchers in this study only tested non-injured subjects comprised of professional Australian football athletes and non-athlete volunteers. Cognigram baseline test and retest comparisons were analyzed for the two groups and compared with the normative data, reporting high to very reliability.

Reliability and validity of Cognigram was studied by Nelson et al. (2016) by comparing three computer-based neurocognitive assessments – ANAM, Cognigram, and ImPact. Subjects for the study were high school and collegiate athletes who were baseline tested using two of the three assessments. The subjects were divided into two groups: non-injured and injured during the study. All three testing protocols reported statistically similar moderate test-retest reliability. Test sensitivity analysis showed 47.6% (ANAM), 60.3% (Cognigram), and 67.8% (ImPact). These values were reported for 24 hour post-injury time intervals. The values decreased significantly for increased time intervals post-injury. The researchers concluded that all three neurocognitive assessments demonstrated moderate reliability and validity, providing limited clinical evaluation value. This supports the need for multiple assessment tools to evaluate SRC. Patients suffering from SRC may present with different signs and symptoms that may not demonstrate deficits measured by specific tests.

Analysis

A one-way multivariate analysis of covariance (MANCOVA) will be conducted for this study to determine if there is significant difference in initial baseline concussion assessment scores between the two subject groups (McMillan & Schumacher, 2014). The independent variables for this analysis will be the subjects' country of origin – United States or Brazil. The dependent variables are the four different analysis scores produced by the CCAT software: Processing Speed, Attention, Learning, and Working Memory Speed. The covariate for the analysis is the age of the subject, controlling for its effects on the subjects' cognitive function. First-time or initial baseline assessment scores for each subject were only used for the study. This initial assessment was the first experience every subject had with the CCAT. Yearly updated baseline assessments were excluded to eliminate the practice effect that would affect within subjects, internal validity (McMillan & Schumacher, 2014).

CHAPTER 4: RESULTS

Analysis 1 – Testing of Assumptions

The initial analysis of the data was performed using International Business Machines Corporation (IBM) Statistical Package for the Social Sciences (SPSS) version 27. Country of Origin was selected as the fixed factor or independent variable. Subject's Age was selected as the covariate in the analysis. The dependent variables were: Psychomotor Function, Attention, Learning, and Working Memory Speed. An initial analysis of the covariate was used to test the assumptions required for the final one-way MANCOVA analysis. Assumptions of the covariate are that it must be linearly correlated to the dependent variables and should not have a significant interaction with the independent variable – Country of Origin (Hinkle, Wiersma, & Jurs, 2003).

The initial multivariate analysis was completed using the custom model function within SPSS. The custom model included combining the independent variable – Country of Origin - with the covariate – Age. The assumption of homogeneity of covariance was satisfied with no significant results ($\alpha = .001$) for Box's Test (Box's M = 28.502, $F(10, 60791.495) = 2.773$, $p = .002$). The results of the analysis reported no significant interaction between the independent and covariate variable (Wilks' Lambda = .993, $F(4,203) = .374$, $p = .827$, partial $\eta 2 = .007$). In addition, when examining the interaction between the combined independent and covariate factor with each individual dependent variable, the analysis showed no significant interaction for each of the four dependent variables ($p > .05$).

Testing for homogeneity of variance was performed using Levene's Test of Equality of Error Variances. Results of the analysis are presented Table 4.

Table 4
Levene's Test of Equality of Error of Variances

	F	df1	df2	p
Psychomotor Function	7.375	1	208	.007
Attention	.300	1	208	.585
Learning	3.303	1	208	.071
Working Memory Speed	.002	1	208	.966

Note. This table tests the null hypothesis that the error variance of the dependent variable is equal across groups. Design: Intercept + Age + Country

Non-significant values ($p > .05$) for each dependent variable indicates equal variance for the measured outcome across the two independent groups (U.S. and Brazil). As shown in Table 5, Psychomotor Function was the only variable that showed a significant value ($p = .007$). In order to satisfy the assumption of homogeneity of variance, a second analysis was designed to control for the significant value.

Analysis 2 – Equal Subjects Populations

The second analysis was performed with the U.S. subjects randomly selected and assigned to two equally sized groups ($n = 75$). The independent variable of Country of Origin was comprised of: U.S. (group 1) ($n = 75$), U.S. (group 2) ($n = 75$), and Brazil ($n = 60$). The large sample size and equal sample size between the groups was recommended to lessen the possibility of committing a type 1 error in the analysis. Using the three-group format, a one-way MANCOVA analysis was performed again, first testing assumptions and then analyzing for significant differences between the groups when comparing each of the four test outputs.

Testing for assumptions, Box's Test of Equality of Covariance Matrices was not significant ($p > 0.001$). This would direct the researcher to examine the significance of Wilks' Λ

for Country*Age. When testing the assumptions of the MANCOVA, Wilks' Λ should not be significant; and the test between subjects for each test output using the same parameter (Country*Age) should also not be significant. The analysis reported p values greater than 0.05 for each of these values. However, Levene's Test of Equality of Error Variances did show a significant effect for the dependent variable – Psychomotor Function ($p = 0.016$). Since this analysis structured the independent variable into three groups that were similar in sample size, Levene's Test would not impact the final analysis.

The final one-way MANCOVA analysis was performed and there was a statistically significant difference between the Country of Origin groups when comparing all dependent variables controlling for age, $F(8, 406) = 6.407$, $p < .001$, Wilks' $\Lambda = .788$, partial $\eta^2 = .112$. When examining the tests between subjects for each dependent variable, the analysis reported that Country of Origin had statistically significant effect (using the Bonferroni correction for an $\alpha = .012$) on Psychomotor Function, $F(2, 206) = 21.25$, $p < .001$, partial $\eta^2 = .17$, Attention, $F(2, 206) = 18.90$, $p < .001$, partial $\eta^2 = .16$, and Working Memory Speed, $F(2, 206) = 7.70$, $p < .001$, partial $\eta^2 = .07$. Country of Origin did not have a significant effect on Learning, $F(2, 206) = 1.14$, $p = .321$, partial $\eta^2 = .01$.

The following graphs show the Estimated Marginal Means for each of the dependent variables (see Figures 1, 2, 3 and 4). For the dependent variable - Psychomotor Function (see Figure 1), the estimated marginal means are: U.S. Origin Group 1 (*M* = 94.51, *SD* = 7.74), U.S. Origin Group 2 (*M* = 96.33, *SD* = 9.13), and Brazil Origin Group 3 (*M* = 85.77, *SD* = 11.89). For the dependent variable - Attention, the estimated marginal means are: U.S. Origin Group1 (*M* = 95.70, *SD* = 8.59), U.S. Origin Group 2 (*M* = 97.92, *SD* = 8.45), and Brazil Origin Group 3 (*M* = 89.35, *SD* = 8.29). For the dependent variable – Learning, the estimated marginal means are: U.S. Origin Group 1 (*M* = 98.15, *SD* = 9.31), U.S. Origin Group 2 (*M* = 97.41, *SD* = 7.29), and Brazil Origin Group 3 (*M* = 100.08, *SD* = 10.75). For the dependent variable – Working Memory Speed, the estimated marginal means are: U.S. Origin Group 1 (*M* = 93.82, *SD* = 9.07), U.S. Origin Group 2 (*M* = 94.91, *SD* = 8.74) and Brazil Origin Group 3 (*M* = 88.68, *SD* = 9.51). The only assessment output where Brazilian subjects scored on average higher was Learning, though not statistically significant.

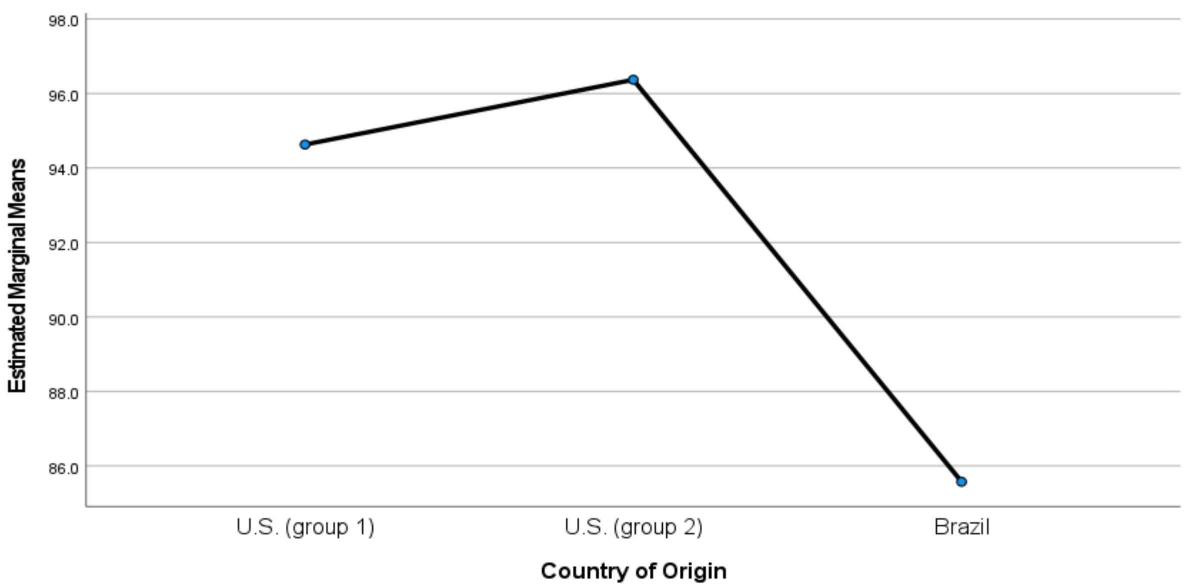

Figure 1. Estimated Marginal Means of Psychomotor Function
Note. Covariates appearing in the model are evaluated at the following values: Age = 25.27

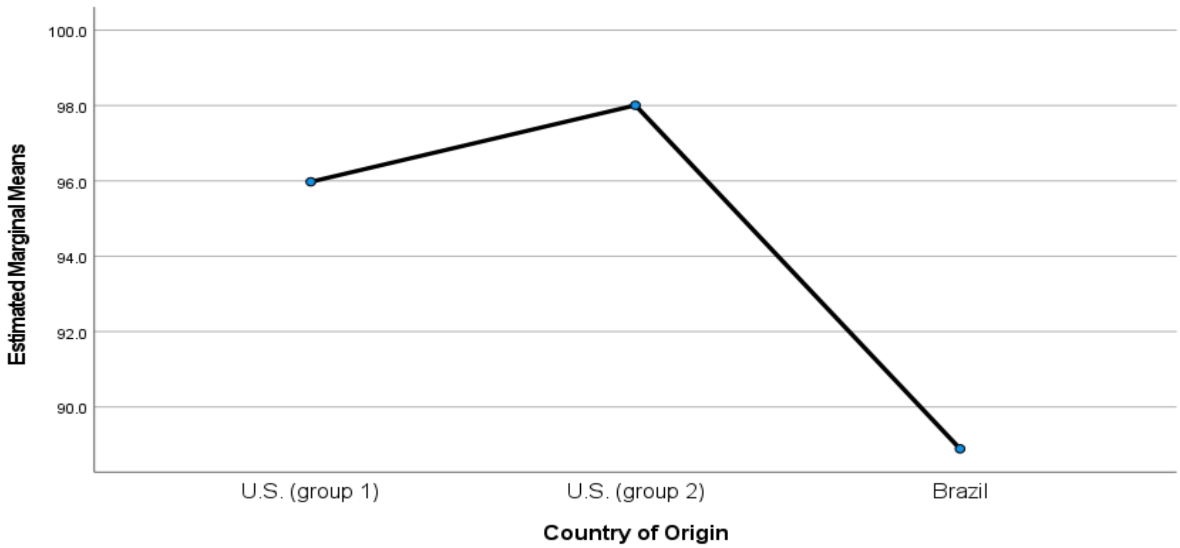

Figure 2. Estimated Marginal Means of Attention
Note. Covariates appearing in the model are evaluated at the following values: Age = 25.27.

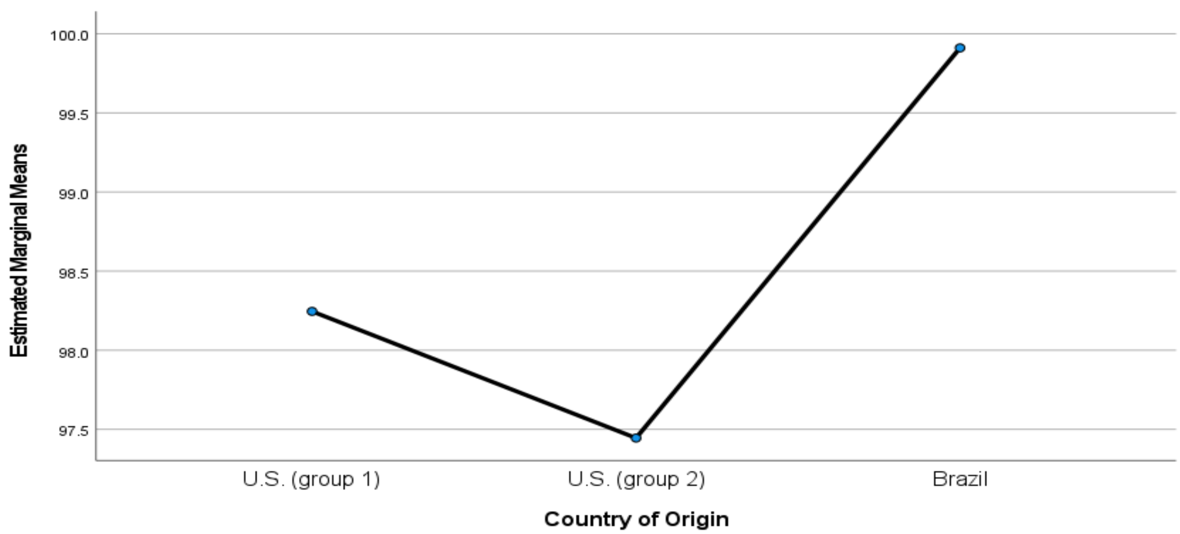

Figure 3. Estimated Marginal Means of Learning.
Note. Covariates appearing in the model are evaluated at the following values: Age = 25.27

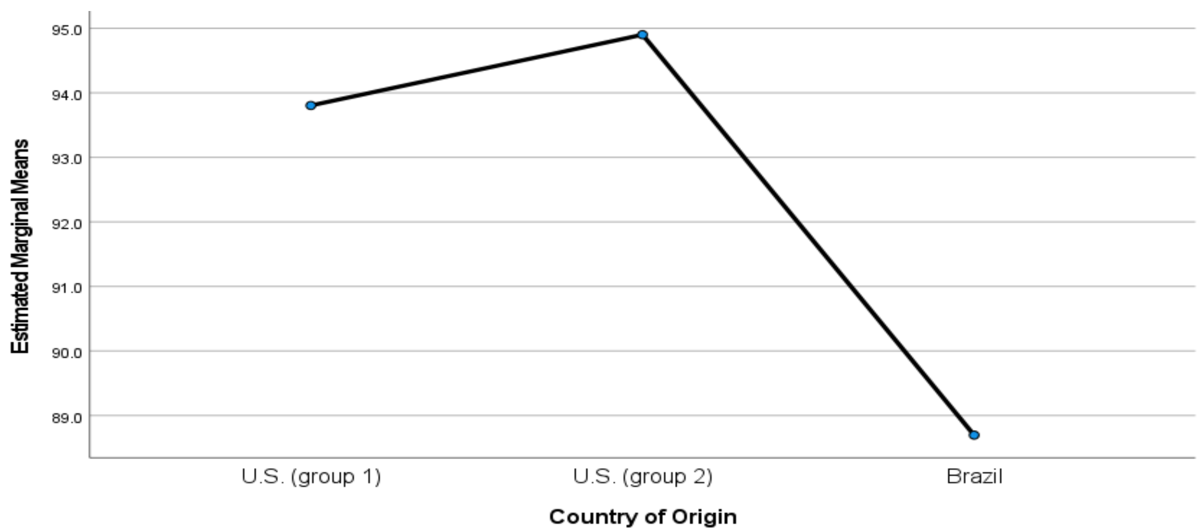

Figure 4. Estimated Marginal Means of Working Memory Speed.
Note. Covariates appearing in the model are evaluated at the following values: Age = 25.27

CHAPTER 5: DISCUSSION

The Cognigram computer-based assessment is marketed as a neurocognitive assessment that is not biased due to cultural or language. This characteristic was one of the primary deciding factors used for its selection by the PBR Sports Medicine Program (R. Blyn, personal communication, January 3, 2020). This assessment should provide a valid and reliable neurocognitive evaluation for determining a subject's normal baseline of cognitive function, and can be used to assess neurocognitive function after a TBI. By using images of playing cards to perform simple tasks, the computerized neurocognitive assessment should be valid and reliable assessment of neurocognitive function, regardless of the subject's cultural background or language skills. However, the analysis of first-time baseline assessments for two groups of athletes demonstrates a significant cultural bias against athletes from Brazil.

The factors contributing to cultural bias in neurocognitive testing can be divided into two groups, extrinsic and intrinsic factors. Extrinsic factors shown to influence testing validity and reliability are testing environment and format (written or computerized), familiarity of testing content, SES, and quality of schools and education (Daughtery et al., 2017; French et al., 2019; Houck et al., 2018; Jones et al., 2014, Ostrosky-Solís et al., 2004). Intrinsic factors that affect testing include: sex/gender, time orientation, native language, race/ethnicity, history of mental illness (anxiety, attention-deficit disorder, depression, etc.), physical and mental status at the time of testing, and education level (Ardila, 2005; Cottle et al., 2017; Goudsmit, et al., 2017; Weber et al., 2018). The database provided by the PBR Sports Medicine Program included only age, country of origin, and type of test (baseline evaluation or post-injury evaluation). With the limited information collected on the subjects, there are four possible factors that could influence the outcome of the assessment. Two are extrinsic factors and two are intrinsic. The extrinsic factors are familiarity of the testing content (playing cards) and testing format. The intrinsic factors are time orientation and test anxiety.

Intrinsic Factors

One intrinsic factor that is culturally different is time orientation. The U.S. majority culture is characterized as future oriented (Drench et al., 2012; Sue et al, 2019). This typically implies a significant importance on punctuality and management of time. This can also influence the speed in which tasks are completed. Instructions for a test that include the completion of a task as quickly as possible may be perceived differently by subjects from non-U.S. cultures (Ardila, 2005). Test subjects from the U.S. have become accustomed to the element of speed and being timed during testing. This is not as common in other cultures. The Cognigram assessment uses reaction time, specifically during the first subtest, to evaluate neurocognitive performance.

Brazil and other Latin American countries are generally past-present orientated (Sue et al, 2019). Past orientation tends to value elders and place high value on traditions (Drench et al., 2012; Sue et al, 2019). Cultures that are present orientated generally view time as something fluid and do not view time in traditional increments. Keeping schedules and the importance of time are not valued. This lack of importance regarding structured time increments may affect Brazilian test subjects' perception of time and speed during the test.

The second intrinsic factor that could have an effect on test performance is anxiety. Studies have reported that anxiety can have significant effect on testing performance (Fulton, 2016; Weber et al., 2018). The athletes from Brazil are tested not long after arriving in the U.S. The qualification format of the PBR is that athletes must qualify by ranking to compete at this level (PBR, 2021). Each country (U.S., Brazil, Canada, Mexico, and Australia) has its own minor league system of competition that determines bull riders' ranking. Once qualified, the bull rider is invited to compete in the U.S. at the primary competition level of the PBR. Bull riders from foreign countries typically have not competed in the U.S (R. Blyn, personal communication, January 3, 2020). It is not uncommon for foreign born bull riders to arrive into the U.S. for the first time on the day of the event, and immediately must report to the concussion testing area at the event for concussion baseline testing. Being in a completely foreign environment for the first time and interacting with individuals that do not speak your language can often lead to increased anxiety. This also coincides with added pressure to perform and compete at the highest level of one's sport.

Extrinsic Factors

Familiarity with playing cards is one possible factor that could affect testing results of the Cognigram test. The PBR Sports Medicine staff reported that they would have to define and explain the concept of playing card suites (Spades, Hearts, Clubs, and Diamonds) to Brazilian athletes and did not recall ever having to do this with U.S. athletes (R. Blyn, personal communication, January 3, 2020). This level of familiarity associated with country of origin can also be supported by playing card sales data. In 2021, playing card revenue sales for the U.S. was $669 million while sales for Brazil was only $181 million (Statista, 2021). Even though the population of Brazil is 64% of the U.S. population, playing cards sales for Brazil was 27% as compared to the sales in the U.S. Research supports the effect of familiarity of the testing content on memory testing performance, particularly processing speed (Coutanche et al., 2020; Yonelinas, 2002). Familiarity has a significant effect on recall. Subjects that have more experience playing card games are more familiar with the images on the playing cards and may have an advantage similar to repeated test bias – depending on the types of card games played previously. Playing cards require the test subject to recognize and remember the value, color, and suit for each individual card. The value of the card can be either a numerical value or a letter representing a face card (King, Queen, Jack, or Ace). Subjects are asked to process the image and remember the exact value, suit, and color when responding. The Cognigram assessment analyzes processing speed during all four sections of the testing. Test subjects are asked to respond as quickly as possible in all four subtests.

An example of a memory test that decreases the effect of familiarity is the Test of Memory and Learning second edition (TOMAL-2). The TOMAL-2 is a comprehensive standardized test for memory that is appropriate for subjects ages 5 through 59 years (Reynolds & Voress, 2007). The test consists of eight core subtests divided into two primary indexes – verbal memory (four subtests) and nonverbal memory (four subtests). The four subtests of nonverbal memory include facial memory, abstract visual memory, visual sequential memory, and memory of location. The facial memory subtest uses black and white images of faces that vary in age, gender, and ethnicity. The abstract visual memory subtest uses images of abstract figures. The visual sequential memory subtest uses images of random geometric patterns. The memory location subtest uses images of large black dots. These tests illustrate the use of images that decrease the likelihood of object familiarity. The use of images that are abstract in nature or based on geometric figures do not demonstrate any particular cultural bias.

The second extrinsic factor is testing format. The Cognigram is a computer-based test. As discussed earlier, Brazilian athletes typically grow up in rural areas of Brazil where the SES is significantly lower than their U.S. peers (Goes, & Karpowicz, 2017; R. Blyn, personal communication, January 3, 2020). This could lead to less familiarity or experience with computer-based testing. The U.S. has historically taken the lead in the use of information and communication technology (ICT) in the classroom (Pelgrum & Plomp, 1993). By 1993, the U.S. was the first and only country to implement computer usage in every classroom, at both elementary and secondary education levels. Recent surveys reported that 99% of Brazilian public schools having computers in the classroom (Brazilian Internet Steering Committee, 2019; Souza et al., 2017). However, these findings only represent schools in urban areas. Similar findings were reported for internet access in schools. Ninety-five percent of schools reported having access to the internet, but 26% of those schools had internet access with speeds less than 2 mbps. Eighty-three percent of students in urban areas had access to the internet, while only 40% of students had access to the internet in rural areas. Even with internet access, 52% reported using only their mobile phones for all educational activities. Without additional background information of each athlete, this can only be assumed due to general demographic knowledge of each country.

Learning

The only test output that did not show significant differences between the two groups was Learning. According to the Cognigram website (Cogstate, 2017), the domain of learning is primarily measured in the third subtest – asking the subject if they have seen the displayed card before. This section of the assessment is significantly longer in time, requiring the test subject to answer yes or no to numerous cards displayed. The subject must try to remember which cards have been shown throughout the test. The length of time and numerous chances to answer would allow the subjects to become familiar with the images. This could possibly be the reason for not having any significant differences between the groups. It is unclear how much of this testing output is measured during the other three subtests. The information provided by Cogstate was limited regarding detailed assessments for each test output.

Implications for Diagnosis

Computer-based neurocognitive assessment plays a significant role in the diagnosis of SRC, and the decision-making process for returning athletes to sport-related activity. Accurate assessments of normal neurocognitive function when the athletes are healthy are required to make an accurate diagnosis after a suspected SRC. Objective assessments may be the only measures that can be used for diagnosis if the athlete is trying to hide subjective symptoms to remain in competition. Because each individual that experiences a SRC may only have particular signs and symptoms, other objective testing - such as balance assessments and vestibular-ocular testing - may not show impairment.

The results of the study show there is a significant difference between U.S. and Brazilian athletes in three of the four subtests of the Cognigram assessment. Brazilian athletes scored significantly lower in the three test outputs: Psychomotor Function, Attention, and Working Memory Speed. If these testing variables are significantly lower due to cultural bias and not neurocognitive function, Brazilian athletes may not be diagnosed accurately after a TBI. Their impaired neurocognitive function may match the results of their baseline assessment and provide a false negative test score. Even if their neurocognitive impairment is lower than their inaccurate baseline assessment, the same baseline results will be used to determine when the athlete may return to sport-related activities. Test scores that are lower than their true values would allow these athletes to return to activity before neurocognitive function has normalized. This would place Brazilian athletes at greater risk of re-injury or other complications such as Second-Impact Syndrome.

Limitations of the Study

One primary limitation of this study is the lack of extensive demographic data for the subjects. Discussion of the possible contributing factors for the differences reported by this study are based on general assumptions about bull riders and cultural differences based on country of origin. These assumptions about education, SES, geographical background, and time spent in the U.S. were reported by PBR Sports Medicine staff based on their personal experience and history treating the athletes. Bull riders typically grow up in rural areas, come from low SES to middle class backgrounds, and have similar education levels (high school graduates). This study also assumes that Brazilian bull riders have not spent any significant time in the U.S. prior to concussion baseline testing at the event. The PBR Sports Medicine staff reported that Brazilian bull riders typically arrive for the first time in the U.S. when they qualify for the PBR competition. Most Brazilian athletes compete in the minor league competition level in their country of origin. However, the staff did report that a small number of Brazilian bull riders have competed in U.S. minor league bull riding events prior to qualifying. This may vary the level of acculturation and decrease the effect of cultural bias reported by the results of this study.

Another limitation of this study is the assumption that each subject is healthy and normal at the time of testing. Each subject is assumed to be healthy and not suffering from a SRC at the time of baseline testing. Due to the high incidence of SRC associated with the sport of bull riding, subjects may have a history of SRC injuries and may still be experiencing post-concussion symptoms at the time of testing. Subjects can qualify for the PBR throughout the season. Athletes competing at the minor league level may not have been evaluated for SRC injuries because the lack of medical services available. Minor league events are not required to have sports medicine services, only emergency medical services for transport (R. Blyn, personal communication, January 3, 2020).

Conclusion

The age-adjusted analysis of first-time baseline assessments for U.S. and Brazilian bull riders showed statistically significant differences in Psychomotor Function, Attention, and Working Memory Speed. Further research should be done to determine if these differences persisted in the following annual baseline testing. As the Brazilian athletes live and compete in the U.S., would these differences remain? Analysis of subsequent Cognigram assessments could be used to correlate test score outcomes. Do these differences normalize? Are these differences dependent upon time in the U.S., or the number of times an athlete has taken the assessment?

Future research could be done if additional information about each athlete is collected. Level of education, family SES, familiarity of playing cards, and mental health status are factors that could be included during the baseline assessment intake. This additional information could help determine which factors are contributing to the cultural bias. The use of additional testing protocols utilizing different images, such as the ChAMP, could be compared to the Cognigram assessment results. This would assess Cognigram's validity and reliability across different cultural groups.

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APPENDIX A

Results of Analysis 1

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Age	210	100.0%	0	0.0%	210	100.0%
Psychomotor Function	210	100.0%	0	0.0%	210	100.0%
Attention	210	100.0%	0	0.0%	210	100.0%
Learning	210	100.0%	0	0.0%	210	100.0%
Working Memory Speed	210	100.0%	0	0.0%	210	100.0%

Descriptives

			Statistic	Std. Error
Age	Mean		25.27	.323
	95% Confidence Interval for Mean	Lower Bound	24.63	
		Upper Bound	25.91	
	5% Trimmed Mean		24.99	
	Median		25.00	
	Variance		21.931	
	Std. Deviation		4.683	
	Minimum		18	
	Maximum		46	
	Range		28	
	Interquartile Range		6	
	Skewness		.966	.168
	Kurtosis		1.711	.334
Psychomotor Function	Mean		92.665	.7248
	95% Confidence Interval for Mean	Lower Bound	91.236	
		Upper Bound	94.094	
	5% Trimmed Mean		93.481	
	Median		95.000	
	Variance		110.315	
	Std. Deviation		10.5031	

	Minimum		48.0	
	Maximum		112.3	
	Range		64.3	
	Interquartile Range		12.5	
	Skewness		-1.431	.168
	Kurtosis		3.268	.334
Attention	Mean		94.678	.6290
	95% Confidence Interval for Mean	Lower Bound	93.438	
		Upper Bound	95.918	
	5% Trimmed Mean		95.139	
	Median		95.100	
	Variance		83.071	
	Std. Deviation		9.1144	
	Minimum		60.0	
	Maximum		111.9	
	Range		51.9	
	Interquartile Range		12.6	
	Skewness		-.757	.168
	Kurtosis		1.019	.334
Learning	Mean		98.436	.6298
	95% Confidence Interval for Mean	Lower Bound	97.194	
		Upper Bound	99.677	
	5% Trimmed Mean		98.156	
	Median		98.000	
	Variance		83.284	
	Std. Deviation		9.1260	
	Minimum		72.6	
	Maximum		138.0	
	Range		65.4	
	Interquartile Range		9.0	
	Skewness		.687	.168
	Kurtosis		2.266	.334
Working Memory Speed	Mean		92.737	.6492
	95% Confidence Interval for Mean	Lower Bound	91.457	
		Upper Bound	94.017	
	5% Trimmed Mean		92.690	
	Median		92.600	
	Variance		88.513	

	Std. Deviation	9.4081	
	Minimum	53.0	
	Maximum	120.3	
	Range	67.3	
	Interquartile Range	11.4	
	Skewness	-.098	.168
	Kurtosis	1.281	.334

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Age	.109	210	<.001	.944	210	<.001
Psychomotor Function	.132	210	<.001	.904	210	<.001
Attention	.058	210	.087	.967	210	<.001
Learning	.099	210	<.001	.961	210	<.001
Working Memory Speed	.048	210	.200*	.985	210	.028

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Between-Subjects Factors

		Value Label	N
Country of Origin	1	U.S.	150
	2	Brazil	60

Descriptive Statistics

	Country of Origin	Mean	Std. Deviation	N
Psychomotor Function	U.S.	95.422	8.4851	150
	Brazil	85.773	11.8883	60
	Total	92.665	10.5031	210
Attention	U.S.	96.810	8.5624	150
	Brazil	89.347	8.2861	60
	Total	94.678	9.1144	210
Learning	U.S.	97.779	8.3412	150
	Brazil	100.077	10.7462	60
	Total	98.436	9.1260	210
Working Memory Speed	U.S.	94.360	8.8910	150
	Brazil	88.680	9.5120	60

Total	92.737	9.4081	210

Box's Test of Equality of Covariance Matrices[a]

Box's M	28.502
F	2.773
df1	10
df2	60791.495
Sig.	.002

Tests the null hypothesis that the observed covariance matrices of the dependent variables are equal across groups.

a. Design: Intercept + Age + Country

Levene's Test of Equality of Error Variances[a]

	F	df1	df2	Sig.
Psychomotor Function	7.375	1	208	.007
Attention	.300	1	208	.585
Learning	3.303	1	208	.071
Working Memory Speed	.002	1	208	.966

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Design: Intercept + Age + Country

Tests of Between-Subjects Effects

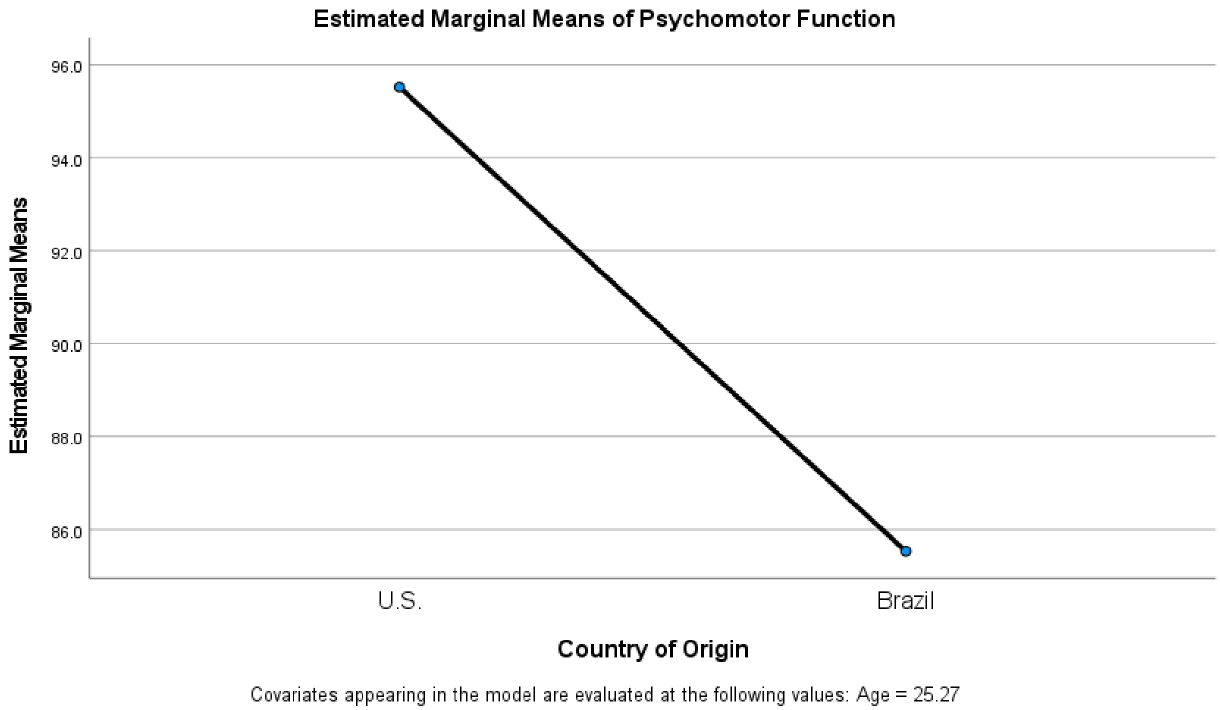
Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	Psychomotor Function	4027.558[a]	2	2013.779	21.907	<.001	.175
	Attention	2553.958[b]	2	1276.979	17.851	<.001	.147
	Learning	240.565[c]	2	120.283	1.450	.237	.014
	Working Memory Speed	1382.720[d]	2	691.360	8.361	<.001	.075
Intercept	Psychomotor Function	45060.783	1	45060.783	490.194	<.001	.703
	Attention	44772.385	1	44772.385	625.871	<.001	.751
	Learning	55063.731	1	55063.731	664.008	<.001	.762
	Working Memory Speed	48542.392	1	48542.392	587.050	<.001	.739
Age	Psychomotor Function	37.697	1	37.697	.410	.523	.002
	Attention	166.757	1	166.757	2.331	.128	.011
	Learning	14.376	1	14.376	.173	.678	.001
	Working Memory Speed	.045	1	.045	.001	.981	.000
Country	Psychomotor Function	3790.075	1	3790.075	41.230	<.001	.166
	Attention	2536.072	1	2536.072	35.452	<.001	.146
	Learning	166.293	1	166.293	2.005	.158	.010
	Working Memory Speed	1232.016	1	1232.016	14.899	<.001	.067
Error	Psychomotor Function	19028.338	207	91.924			
	Attention	14807.967	207	71.536			
	Learning	17165.737	207	82.926			
	Working Memory Speed	17116.551	207	82.689			
Total	Psychomotor Function	1826293.630	210				
	Attention	1899770.750	210				
	Learning	2052220.170	210				
	Working Memory Speed	1824536.580	210				
Corrected Total	Psychomotor Function	23055.896	209				
	Attention	17361.925	209				
	Learning	17406.302	209				
	Working Memory Speed	18499.270	209				

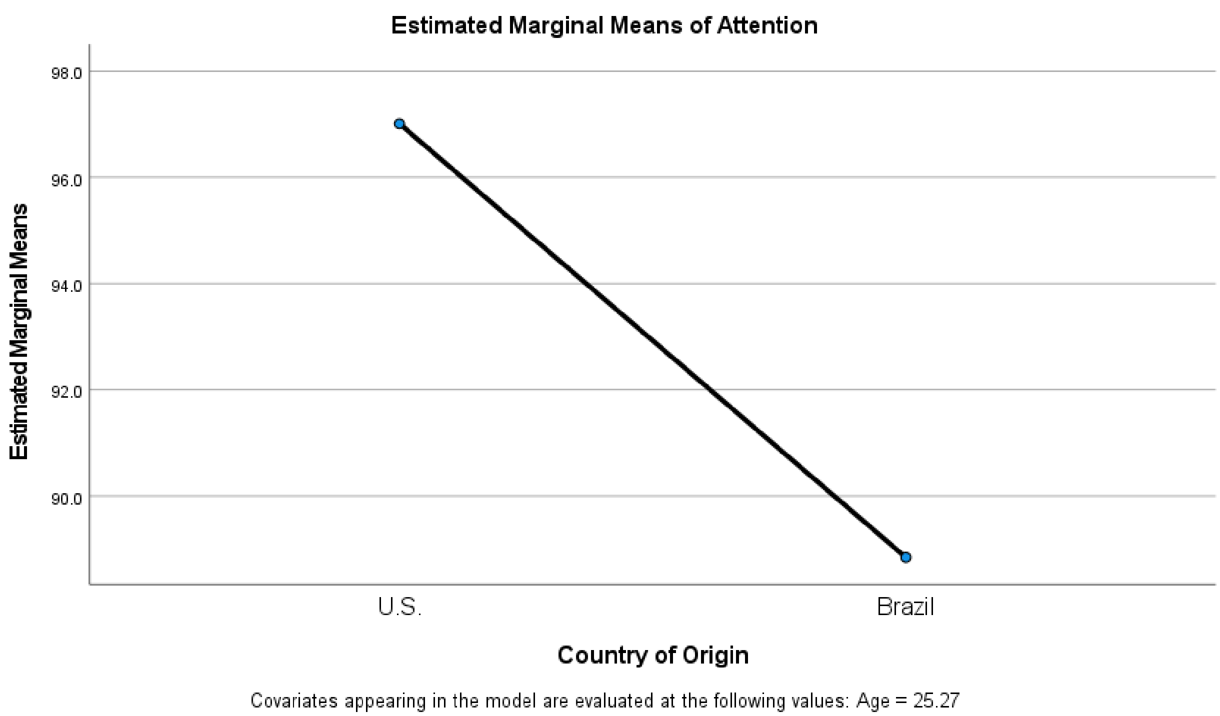
a. R Squared = .175 (Adjusted R Squared = .167)

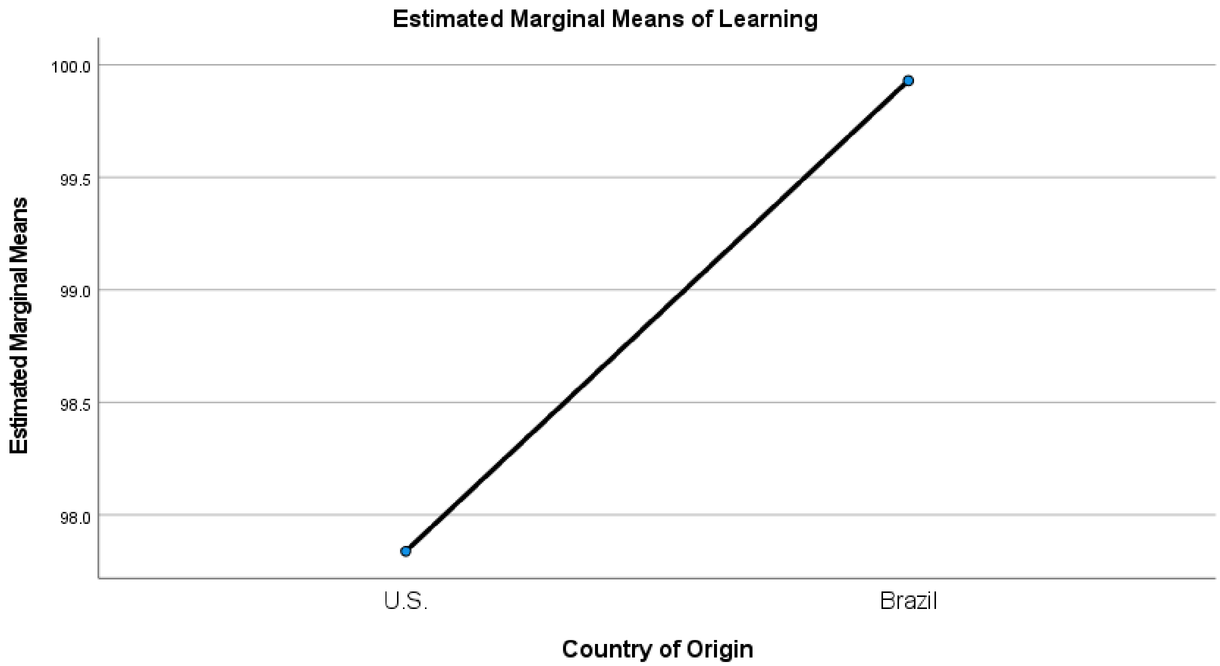
b. R Squared = .147 (Adjusted R Squared = .139)

c. R Squared = .014 (Adjusted R Squared = .004)

d. R Squared = .075 (Adjusted R Squared = .066)


Estimated Marginal Means of Psychomotor Function
96.0
94.0
92.0
90.0
88.0
86.0
Estimated Marginal Means
U.S.
Brazil
Country of Origin
Covariates appearing in the model are evaluated at the following values: Age = 25.27


Estimated Marginal Means of Attention
98.0
96.0
94.0
92.0
90.0
Estimated Marginal Means
U.S.
Brazil
Country of Origin
Covariates appearing in the model are evaluated at the following values: Age = 25.27



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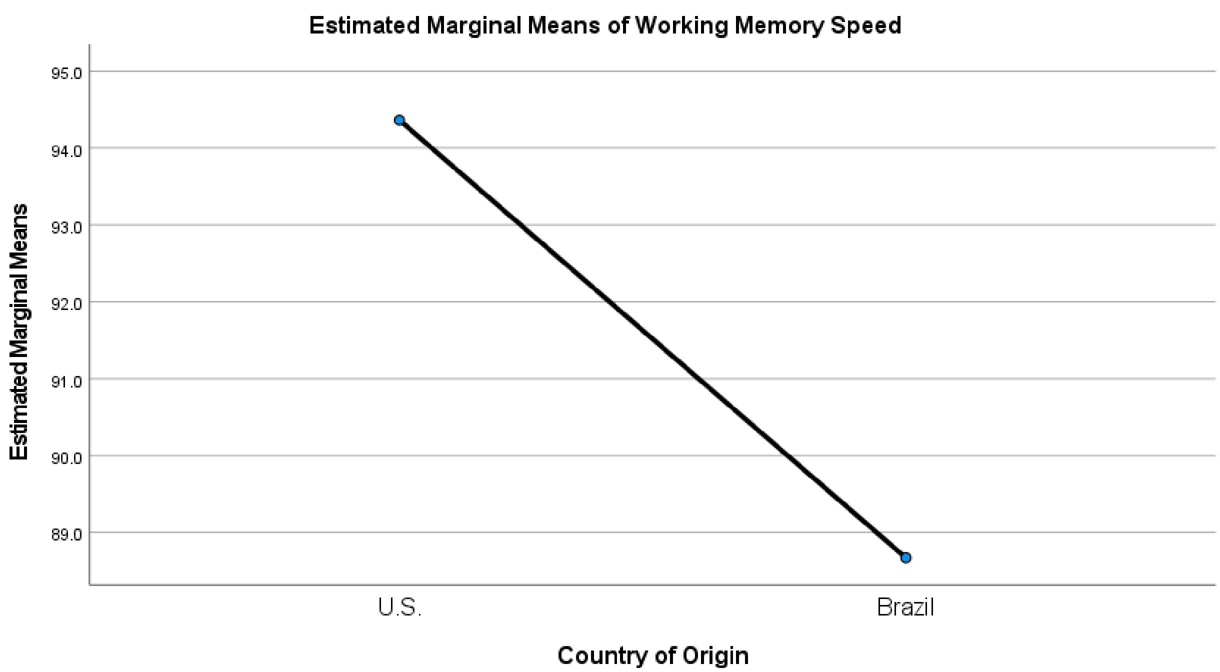


Covariates appearing in the model are evaluated at the following values: Age = 25.27

APPENDIX B

Results of Analysis 2

Between-Subjects Factors

		Value Label	N
Country of Origin	1	U.S. (group 1)	75
	2	U.S. (group 2)	75
	3	Brazil	60

Descriptive Statistics

	Country of Origin	Mean	Std. Deviation	N
Psychomotor Function	U.S. (group 1)	94.512	7.7367	75
	U.S. (group 2)	96.332	9.1341	75
	Brazil	85.773	11.8883	60
	Total	92.665	10.5031	210
Attention	U.S. (group 1)	95.704	8.5862	75
	U.S. (group 2)	97.916	8.4508	75
	Brazil	89.347	8.2861	60
	Total	94.678	9.1144	210
Learning	U.S. (group 1)	98.147	9.3083	75
	U.S. (group 2)	97.412	7.2920	75
	Brazil	100.077	10.7462	60
	Total	98.436	9.1260	210
Working Memory Speed	U.S. (group 1)	93.815	9.0696	75
	U.S. (group 2)	94.905	8.7354	75
	Brazil	88.680	9.5120	60
	Total	92.737	9.4081	210

Box's Test of Equality of Covariance Matrices[a]

Box's M	43.368
F	2.107
df1	20
df2	140380.981
Sig.	.003

Tests the null hypothesis that the observed covariance matrices of the dependent variables are equal across groups.

a. Design: Intercept + Age + Country

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Intercept	Pillai's Trace	.880	373.686[b]	4.000	203.000	<.001	.880
	Wilks' Lambda	.120	373.686[b]	4.000	203.000	<.001	.880
	Hotelling's Trace	7.363	373.686[b]	4.000	203.000	<.001	.880
	Roy's Largest Root	7.363	373.686[b]	4.000	203.000	<.001	.880
Age	Pillai's Trace	.016	.800[b]	4.000	203.000	.527	.016
	Wilks' Lambda	.984	.800[b]	4.000	203.000	.527	.016
	Hotelling's Trace	.016	.800[b]	4.000	203.000	.527	.016
	Roy's Largest Root	.016	.800[b]	4.000	203.000	.527	.016
Country	Pillai's Trace	.212	6.048	8.000	408.000	<.001	.106
	Wilks' Lambda	.788	6.407[b]	8.000	406.000	<.001	.112
	Hotelling's Trace	.268	6.765	8.000	404.000	<.001	.118
	Roy's Largest Root	.266	13.565[c]	4.000	204.000	<.001	.210

a. Design: Intercept + Age + Country

b. Exact statistic

c. The statistic is an upper bound on F that yields a lower bound on the significance level.

Levene's Test of Equality of Error Variances[a]

	F	df1	df2	Sig.
Psychomotor Function	3.738	2	207	.025
Attention	.141	2	207	.869
Learning	2.552	2	207	.080
Working Memory Speed	.005	2	207	.995

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Design: Intercept + Age + Country

Tests of Between-Subjects Effects

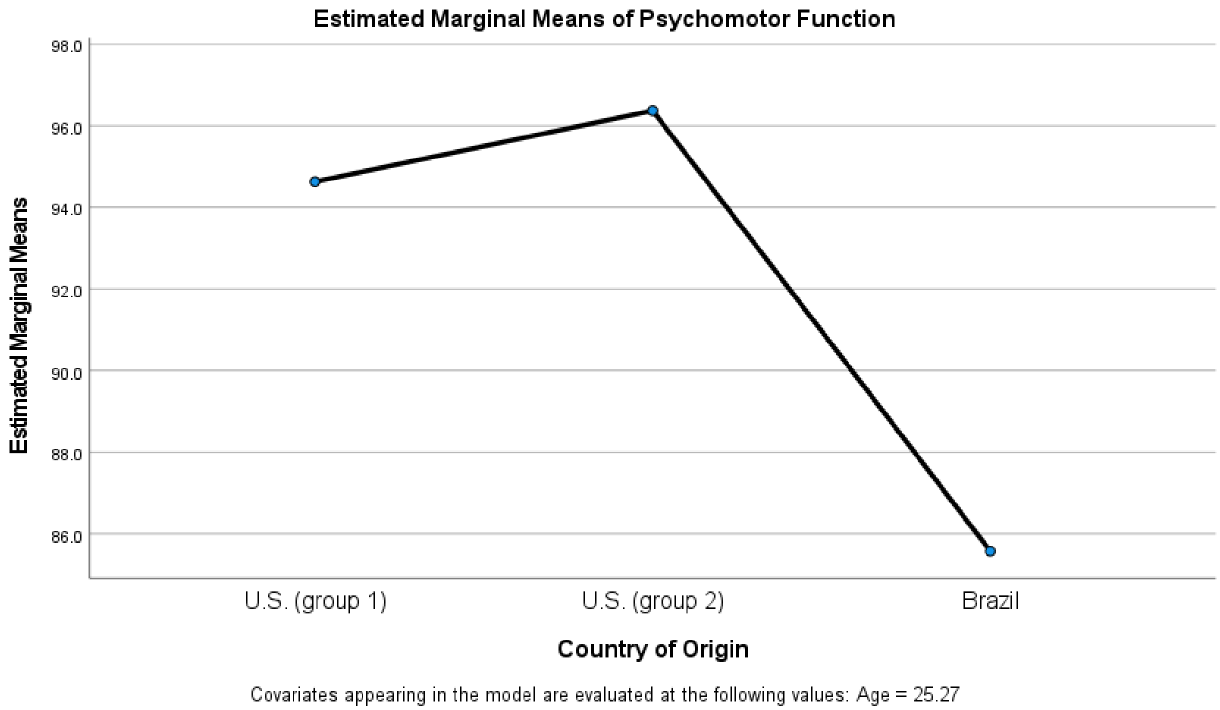
Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	Psychomotor Function	4140.157[a]	3	1380.052	15.029	<.001	.180
	Attention	2707.172[b]	3	902.391	12.685	<.001	.156
	Learning	264.380[c]	3	88.127	1.059	.368	.015
	Working Memory Speed	1427.460[d]	3	475.820	5.742	<.001	.077
Intercept	Psychomotor Function	49167.748	1	49167.748	535.457	<.001	.722
	Attention	48604.289	1	48604.289	683.224	<.001	.768
	Learning	56732.634	1	56732.634	681.774	<.001	.768
	Working Memory Speed	51905.206	1	51905.206	626.323	<.001	.753
Age	Psychomotor Function	26.080	1	26.080	.284	.595	.001
	Attention	136.486	1	136.486	1.919	.168	.009
	Learning	17.951	1	17.951	.216	.643	.001
	Working Memory Speed	.178	1	.178	.002	.963	.000
Country	Psychomotor Function	3902.673	2	1951.336	21.251	<.001	.171
	Attention	2689.286	2	1344.643	18.901	<.001	.155
	Learning	190.108	2	95.054	1.142	.321	.011
	Working Memory Speed	1276.756	2	638.378	7.703	<.001	.070
Error	Psychomotor Function	18915.740	206	91.824			
	Attention	14654.753	206	71.140			
	Learning	17141.922	206	83.213			
	Working Memory Speed	17071.810	206	82.873			
Total	Psychomotor Function	1826293.630	210				
	Attention	1899770.750	210				
	Learning	2052220.170	210				
	Working Memory Speed	1824536.580	210				
Corrected Total	Psychomotor Function	23055.896	209				
	Attention	17361.925	209				
	Learning	17406.302	209				
	Working Memory Speed	18499.270	209				

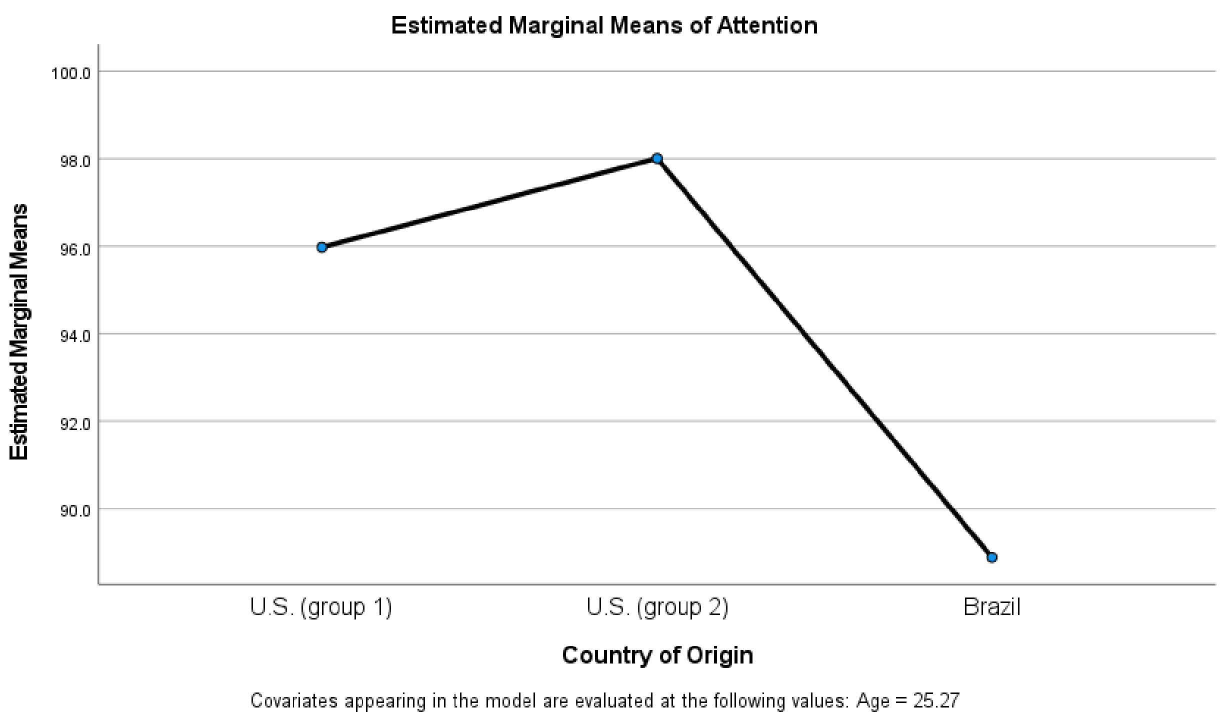
a. R Squared = .180 (Adjusted R Squared = .168)

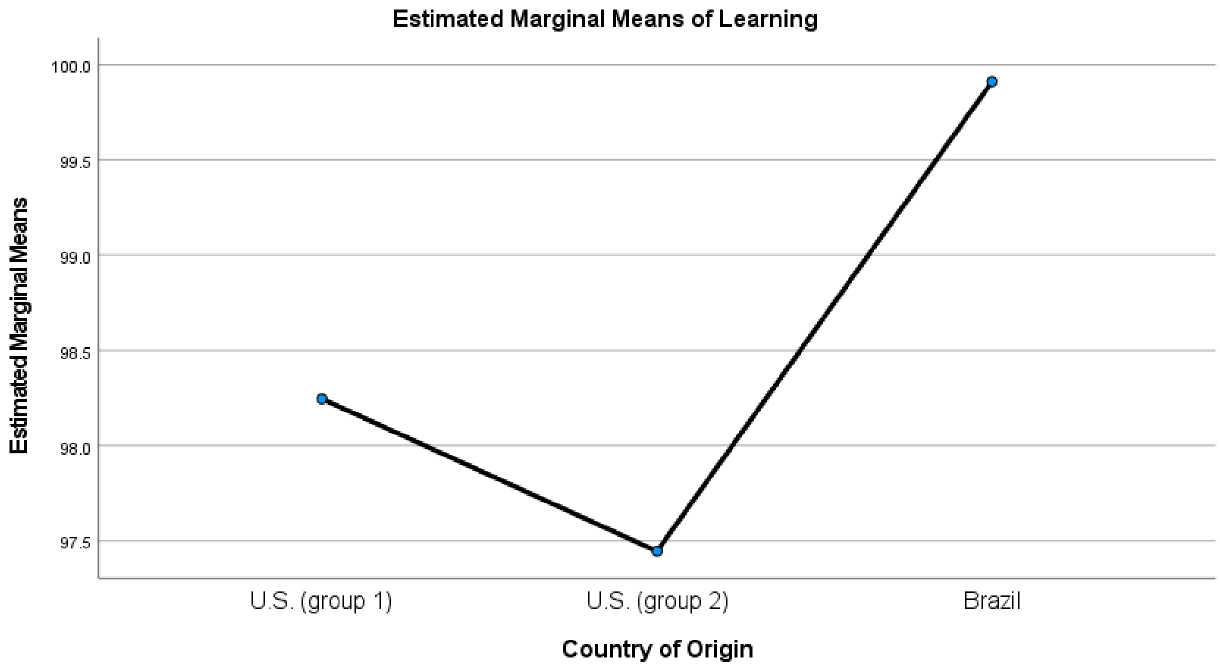
b. R Squared = .156 (Adjusted R Squared = .144)

c. R Squared = .015 (Adjusted R Squared = .001)

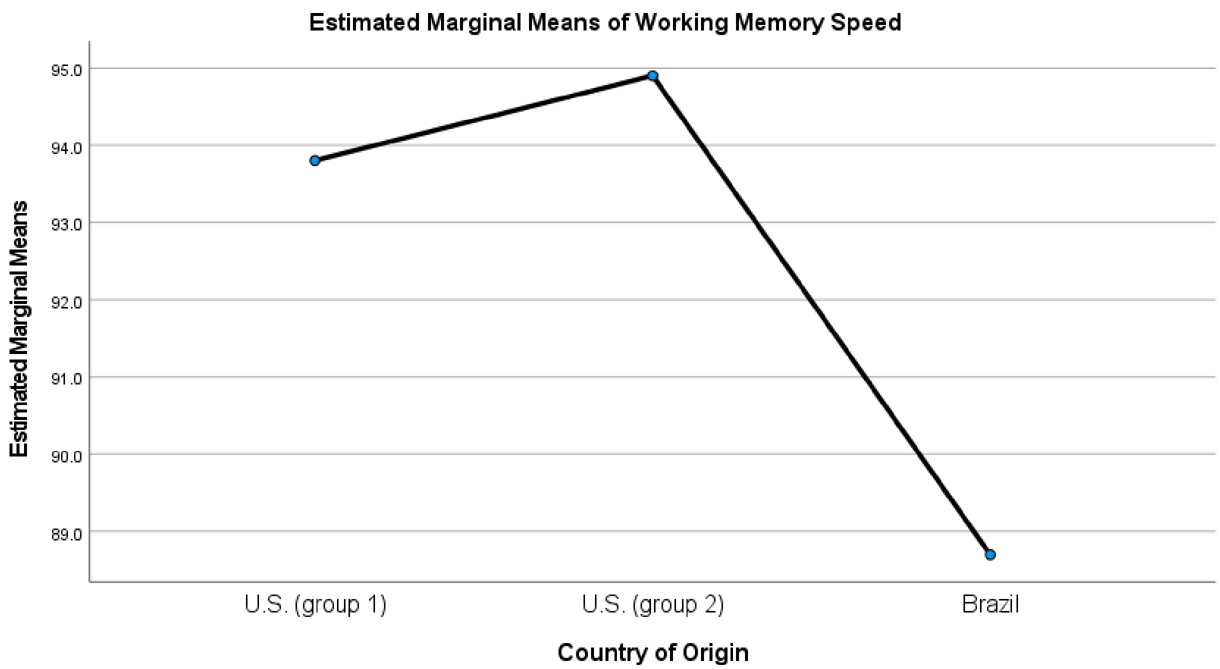
d. R Squared = .077 (Adjusted R Squared = .064)


Estimated Marginal Means of Psychomotor Function
Estimated Marginal Means
98.0
96.0
94.0
92.0
90.0
88.0
86.0
U.S. (group 1)
U.S. (group 2)
Brazil
Country of Origin
Covariates appearing in the model are evaluated at the following values: Age = 25.27


Estimated Marginal Means of Attention
Estimated Marginal Means
100.0
98.0
96.0
94.0
92.0
90.0
U.S. (group 1)
U.S. (group 2)
Brazil
Country of Origin
Covariates appearing in the model are evaluated at the following values: Age = 25.27



Covariates appearing in the model are evaluated at the following values: Age = 25.27



Covariates appearing in the model are evaluated at the following values: Age = 25.27