Investigating the Effects of Arousal State on Cognitive Performance in Individuals with and without Mild Head Injury

by

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Abstract

We examined the cognitive and emotional sequelae following mild head injury (MHI; e.g., concussion) in high-functioning individuals and whether persons with MHI present, both physiologically and via self-report, in a manner different from (i.e., underaroused) that of persons who have no history of head injury. We also investigated the effect arousal state has on the cognitive performance of this population. Using a quasi-experimental research design ($N = 91$), we examined changes in attention, working memory, and cognitive flexibility (subtests of the WAIS-III, 1997,WMS-III, 1997, & DKEFS, 2002) as a function of manipulated arousal (i.e., induced psychosocial stress/activation; reduced activation/relaxation). In addition to self-reported arousal and state anxiety (State-Trait Anxiety Inventory; Speilberger, 1983a) measures, physiological indices of arousal state (i.e., electrodermal responsivity, heart rate, and respiration activity) were recorded (via Polygraph Professional Suite, 2008) across a 2.5 hour interval while completing various cognitive tasks. Students also completed the Post-concussive Symptom Checklist (Gouvier et al., 1992). The results demonstrate that university students who report a history of MHI (i.e., "altered state of consciousness") experience significantly lower levels of anxiety, were physiologically underaroused, and were less responsive to stressors in their environment, compared to their non-MHI cohorts. As expected, cognitive flexibility (but not other neuropsychological measures of cognition) was advantaged with increased stress, and disadvantaged with reduced stress, in persons with reported MHI, but not for those without reported MHI which provided limited support for our hypothesis. Further, university students who had no complaints related to their previous MHI endorsed

a greater number of traditional post-concussive symptoms in terms of intensity, duration and frequency as compared to students who did not report a MHI.

The underarousal in traumatic brain injury has been associated with (ventromedial prefrontal cortex) VMPFC disruption and may be implicated in MHI generally. Students who report sustaining a previous MHI may be less able to physiologically respond and/or cognitively appraise stressful experiences as compared to their no-MHI cohort and experience persistent, long-lasting consequences despite the subtle nature of a history of head injury.

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Dedication

This thesis is dedicated to the following amazing people in my life.
To my husband—thank you for your love, support and painstaking patience with me. I am forever grateful for our life together.
To my parents—thank you for teaching me courage, passion, and strength; thank you for believing in me.
To my sister—thank you for listening.
To my friends and family—thank you for your daily encouragement.

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List of Acronyms and Abbreviations

ACC	Anterior Cingulate
ACTH	Adrenal Corticotrophin Hormone
ANOVA	Analysis of Variance
CD	Compact Disc
CDC	Center for Disease Control
CRH	Corticotrophin Releasing Hormone
CT	Computerized Tomography
CTONI	Comprehensive Test of Nonverbal Intelligence
DKEFS	Delis-Kaplin Executive Functioning System
DLPFC	Dorsolateral Prefrontal Cortex
DSM-IV-TR	Diagnostic and Statistical Manual of Mental Disorders 4th Edition—Text Revised
EDA	Electrodermal Activity
fMRI	Functional Magnetic Resonance Imaging
GCS	Glascow Coma Scale
GR	Glucocorticoid Receptor
HPA	Hypothalamic-Pituitary-Adrenal
ICD	International Classification of Diseases
LOC	Loss of Consciousness
MHI	Mild Head Injury
mOFC	Medial Orbitofrontal Cortex
mPFC	Medial Prefrontal Cortex

MR	Mineralocorticoid Receptors
MTBI	Mild Traumatic Brain Injury
NEPSY	Neuropsychological Evaluation 2nd Edition
No-MHI	No Mild Head Injury
NTS	Nucleus of the Solitary Tract
OFC	Orbitofrontal Cortex
PCD	Post-concussional Disorder
PCS	Post-concussion Syndrome
PET	Positron Emission Tomography
PFC	Prefrontal Cortex
PNS	Peripheral Nervous System
PTA	Post Traumatic Amnesia
PVN	Periventricular Nucleus
rCBF	Regional Cerebral Blood Flow
SNS	Sympathetic Nervous System
STAI	State-Trait Anxiety Inventory
STM	Short-Term Memory
TSST	Trier Social Stress Test
VMPFC	Ventromedial Prefrontal Cortex
WAIS-III	Wechsler Adult Intelligence Scale 3rd Edition
WHO	World Health Organization
WMS-III	Wechsler Memory Scale 3rd Edition

Introduction

Head injury, and in particular, mild head injury (MHI) is a very common phenomenon (Kraus & Chu, 2005) and may result in changes in cognition, emotion, and physical presentations (Mateer & D'Arcy, 2000) although the persistence of these changes has long been controversial, and at times is still poorly understood. In the past decade research has focused on milder, rather than moderate or severe traumatic brain injuries (TBI). However, to our knowledge, little research has been conducted to examine the cognitive sequelae and emotional responsivity following MHI, especially with high-functioning individuals such as university students. The general purpose of this thesis is to: examine the physiological and self-reported arousal status of university students with MHI as compared to students without MHI; examine stress responsivity as a function of MHI history; investigate the effects of modified arousal state on cognitive performance in university students with and without MHI; and, explore post-concussive symptom reports in this competent population as a function of MHI history. The following discussion regarding the epidemiology, classification, symptoms and decrements in function following MHI, as well as stress responsivity, stress-induced changes in cognitive performance, and the role of the orbitofrontal cortex (OFC) in emotional arousal will provide a framework for investigation of persons with MHI who are potentially underaroused.

Prevalence of Head Injury

Head injuries occur frequently and are primarily a result from accidental falls, motor vehicle collisions, and sports activities (Belanger & Vanderploeg, 2005; Canadian Institute for Health Information [CIHR], 2006; Cassidy et al., 2004) or occur in a myriad

of ways. In the United States the occurrence of mild traumatic brain injuries (MTBI) has been estimated to be 131 per 100, 000—or approximately 325, 000 occurrences per year (Kraus et al., 1984). A recent report by the Canadian Institute for Health Information (2006) on the incidence of head injuries stated that in 2003-2004 there were 16, 811 hospital admissions for traumatic head injuries, comprising 9% of all trauma admissions. The report did not present data for head injuries differing in severity. Other sources report that 75 to 80% of all head injuries are classified as mild (Bernstein, 1999; Iverson, in press [a]; Kraus & Nourjah, 1989; Kraus & Chu, 2005). Bazarian et al. (2005) reported that 56 per 100,000 persons are evaluated in US emergency departments each year for an MTBI. However, many mild head injuries do not result in hospital visits or admissions and will typically go unreported (e.g., Sosin, Sniezek, & Thurman, 1996) and therefore are not identified or included in statistical analyses. As such, the incidence of milder head injuries is greatly underestimated and incidence via self-report presents a different picture.

For example, a study based on a national household survey via the U.S. Census Bureau asked individuals to report about head trauma that resulted in a loss of consciousness without resulting in death or need for long-term care; with this self-report measure the incidence of mild injuries was found to be 519 per 100,000 persons (Sosin et al., 1996). Notably, 460 of the 519 reported no hospitalization. However, the criteria used for this survey most likely captured both mild and moderate head injuries as duration of loss of consciousness or other severity indicators were not specified. Furthermore, this study did not include incidents of mild head injury with an altered state of consciousness and no loss of consciousness—it is likely that studies with such criteria would have even higher estimates.

In another retrospective self-report epidemiological study in a sample of 1, 345 high school and 2, 321 university students, Segalowitz and Lawson (1995) found the prevalence of MHI to be 30% to 37% (when adjusted for gender ratio), with 12% to 15% reporting a loss of consciousness, and 11.8% to 12.6% reporting multiple head injury incidents. This high incidence rate is consistent with the finding that head injuries are more frequent in teenagers and young adults than other age groups (Cassidy et al., 2004; Kraus & Nourjah, 1988; Ryan, O'Jile, Gouvier, Parks-Levy, & Betz, 1996). Notably, 74% of the high school students and 81% of the university students in the study (Segalowitz & Lawson, 1995) reported that they were not admitted to the hospital for their head injury. In short, mild head injuries are common and incidence rates are much higher when obtained via self-report than hospital admissions records since many do not seek or receive medical care for their MHI.

Biomechanics of Head Injury

Mild head injuries occur in a biomechanical fashion similar to that of more moderate to severe traumatic brain injuries (TBI) (Mateer & D'Arcy, 2000). Head injury may be sustained via direct or indirect impact and/or acceleration-deceleration forces on the head and neck creating linear or rotational forces on the brain (Barth, Varney, Ruchinskas, & Francis, 1999; Liu, 1999). The skull contains the jelly-like brain which floats in cerebrospinal fluid (CSF). Damage via direct or indirect impact causes acceleration-deceleration via hyperextension-hyperflexion motion of the head and neck and causes the brain to jostle inside against the bony skull (Liu, 1999). Damage at the site of initial impact is referred to as a *coup* and in closed-head injuries the impact may be sufficient to cause it to come in contact with the opposite side of the skull resulting in a

countercoup (Gazzaniga, Ivry, & Mangun, 2002; Lui, 1999) during which angular acceleration occurs and these rotational forces may introduce shear strains, particularly diffuse axonal shearing, microscopic lesions (Alves, Macciocchi, & Barth, 1993; Bigler, 1999; Giza & Hovda, 2001; King, 1997) or metabolic deficiencies (Giza & Hovda, 2001; Lifshitz, Sullivan, Hovda, Wieloch, & McIntosh, 2004).

The frontal, especially the orbitofrontal cortex (OFC), and temporal lobes are vulnerable to damage due to their close proximity to the bony proturberances of the skull (Alves et al., 1993; Bigler, 1999; Gazzaniga et al., 2002; Morales, Diaz-Daza, Hlatky, & Hayman, 2007). The cribiform plate is a rough bony structure that supports the inferior regions of the frontal lobes (Varney, 1999), and thus damage to the OFC is particularly common (King, 1997; Mateer & D'Arcy, 2000). Axonal pathways throughout the brain are disrupted, especially in the frontal lobes, and particularly the orbitofrontal regions (Mateer & D'Arcy, 2000; Morales et al., 2007). Although less common, macroscopic lesions or contusions may be evident following MHI (Bigler, 1999; Iverson et al., 2000; Sekino et al., 1981); however, diffuse axonal injury is most likely the organic basis for the sequelae following MHI (Bigler, 1999; King, 1997).

Pathophysiology of Neurological Disruption

The underlying pathophysiologic processes following neurological disruption have been described by Giza and Hovda (2001; 2004) via animal studies including abrupt changes in neurochemical activity, glucose metabolism, cerebral blood flow, and axonal functioning (Giza & Hovda, 2001). In short, immediately after biomechanical injury to the brain all the neurons in the brain fire at once, essentially resulting in an overdepolarization of the central nervous system (CNS). There is an excess release of the excitatory

neurotransmitter glutamate which binds to N-methyl-D-aspartate (NMDA) receptors which causes a sudden efflux of potassium (K^+) and influx of calcium (Ca^{++}) to the affected neurons resulting in diffuse, and nonspecific neurofilament and microtubule disruption, impairing neurotransmission. To restore the ionic imbalance, the sodium-potassium (Na^+/K^+) pump becomes excessively active requiring the consumption of a considerable amount of energy (adenosine triphosphate [ATP]) and this, in turn, prompts an increase in glucose metabolism to generate more ATP. However, due to decreased vascular capacity, an abnormal uncoupling occurs in which cerebral blood flow (CBF) is decreased despite the increased glucose metabolism. Following this "energy crisis" there is increased lactate production and accumulation, followed by additional Ca^{++} influx, which further impairs mitochondrial functions essential to glucose metabolism resulting in decreased glucose metabolism thus resolving the energy mismatch.

The above description of pathophysiological changes that occur both acutely and over a period of several hours to days and longer (Giza & Hovda, 2001) do not require a loss of consciousness. The pathophysiology suggests that mild brain injuries should not be considered trivial and do result in neuropathological effects (also see Jane, Steward, & Gennarelli, 1985). All of these complex changes produce neuronal disruption, particularly, axonal dysfunction, each of which may constitute the underlying pathophysiology of cognitive impairments following neurological compromise (Giza & Hovda, 2001). As early as 1968, researchers (e.g., Oppenheimer) reported finding axonal disruption (called axonal retraction bulbs) and changes in glial cell distribution via autopsies of persons who had sustained mild injuries (e.g., one patient reported only an altered state of consciousness of "being stunned" and no loss of consciousness). Similarly, Taylor and

Bell (1966) documented the slowing of cerebral blood circulation in humans following milder brain injuries (via electronystagmography). Electronystagmography was an early technique used to estimate cerebral blood circulation time. The patient was injected with a gamma-ray emitter I-labelled 'Hippuran' and its flow through the vertebral and carotid arteries was monitored through the head by an external scanning technique consisting of a collinated sodium-iodide crystal placed on the inion and the field scanned was above the nasion. This signal was then amplified and passed to a graph recorder. This technique provided data from which total transit time across the head could be estimated (i.e., injection to appearance time; mean circulation time; appearance to clearance time; and, so forth).With the usage of newer neuroimaging techniques it has been noted that residual abnormal glucose metabolism and disrupted CBF have been correlated with complaints and impaired performance on neuropsychological tests in persons with MHI (e.g., Gross, Kling, Henry, Herndon, & Lavretsky, 1996; see Belanger, Vanderploeg, Curtiss, & Warden, 2007 for review).

Mild Head Injury Classification and Detection

Traumatic brain injuries occur on a wide continuum of severity ranging from very mild, potentially transient injuries, to more moderate, severe, or catastrophic injuries that may result in fatality or long-term changes in ability (Alexander, 1995; Iverson & Lange, in press[a]). The classification of severity of head injury is usually based on guidelines of assessment (Glascow Coma Scale (GCS); Teasdale & Jennett, 1974) of visual, verbal, and motor function; length of post-traumatic amnesia (PTA; Crovitz & Daniel, 1987), length of altered, or loss of, consciousness, and the presence or absence of brain abnormalities via neuroimaging techniques. The assessment is typically performed soon after the injury

(within the first 48 hours) and is classified as mild, moderate, or severe (Teasdale & Jennett, 1974). However, the classification of severity does not consider the etiology of the head trauma, location of the injury, nor the long-term sequelae of the injury.

Head injuries associated with a GCS score of 13 to 15 are typically classified as mild, 9 to 12 as moderate, and 3 to 8 as severe (Teasdale & Jennett, 1974). While GCS can aid in the prognosis of moderate to severe head injuries, particularly physical (as opposed to cognitive) recovery, it is not sensitive enough to determine outcome in milder cases (Gomez, Lobato, Ortega, & DeLa Cruz, 1996; Ruff, 1999). For example, many persons with a MHI would get a score of 15, but this is the same score persons with unaltered brain functioning also would obtain (Giza & Hovda, 2001). Similarly, post-traumatic amnesia, defined as the length of time between the head injury and when the person regains continuous memory function (Crovitz & Daniel, 1987; Russell & Smith, 1961) has also been used as an outcome indicator, but is most effective for predicting moderate to severe head injuries recovery, particularly cognitive, rather than mild injury (King, 1997).

Despite the high prevalence of MHI, there is no uniformly accepted definition or diagnostic criteria. To demonstrate the lack of precision in terminology the term mild head injury is often used interchangeably with mild brain injury, mild traumatic brain injury, mild traumatic head injury, minor head injury, minor brain injury, or concussion (King, 1997; Mateer & D'Arcy, 2000). Current research in sports-related injury adopts 'concussion' terminology with differing grades of severity (e.g., Cantu, 1986) whereas the clinical and research-based literature commonly uses the terms MTBI or MHI for milder head injuries (Iverson & Lange, in press[b]). MHI describes any injury to the head whereas MTBI refers specifically to cases in which brain damage is evident (Kay, Newman,

Cavallo, Ezrachi, & Resnick, 1992). This distinction does not discount injury to the brain, and brain function, in MHI. To this end, MTBI has also been classified as uncomplicated or complicated with the latter demonstrating indices of brain abnormality (e.g., hematoma, contusion, and may also include skull fractures) (Williams, Levin, & Eisenberg, 1990; Lange, Iverson, & Franzen, 2009). Severity of neural disruption is to be viewed on a continuum (McAllister & Flashman, 1999) ranging from mild to severe (MHI, concussion, post-concussive syndrome (PCS), MTBI, moderate, to severe brain injury).

Despite the lack of a universal definition there are three frequently used definitions for MTBI (Mild Traumatic Brain Injury Committee of the Head Injury Interdisciplinary Special Interest Group of the American Congress of Rehabilitation Medicine [Kay et al., 1993]; World Health Organization (WHO) Collaborating Task Force on Mild Traumatic Brain Injury [Carroll, Cassidy, Holm, Kraus, & Coronado, 2004]; and, the Center for Disease Control (CDC) Working Group [National Center for Injury Prevention and Control, 2003]) that include similar criteria. The term MHI is used throughout this thesis and the now familiar definition developed by the Mild Traumatic Brain Injury Committee of the Head Injury Interdisciplinary Special Interest Group of the American Congress of Rehabilitation Medicine (Kay et al., 1993) was adopted. Kay and colleagues (1993) defined MTBI as a "traumatically induced physiological disruption of brain function" and delineates the following four criteria of which "at least one must be present: (1) any period of loss of consciousness, (2) any loss of memory for events before or after the event, (3) any alteration in mental state at the time of the injury (e.g., feeling dazed, disoriented, or confused), (4) focal neurological deficits that may or may not be transient" (pp. 86-87). The exclusion criteria are "(1) a loss of consciousness exceeding 30 minutes, (2) a GCS

score below 13, and (3) PTA persisting longer than 24 hours" (p. 86-87) [each of which indicate a more severe injury]. Thus, an actual loss of consciousness is not the essential criterion as in other classifications, but rather a change or alteration of consciousness is sufficient. For the purpose of this thesis, a MHI was determined by self-reported injury to the head via biomechanical forces that was sufficient to produce an alteration in consciousness (and the MHI may (symptomatic) or may not (asymptomatic) be associated with post-concussive symptoms).

Lastly, in terms of classifying an MHI, traditional neuroimaging in MHI via computerized tomography (CT) typically does not demonstrate major abnormalities or structural deficits (Bigler, 1999). For example, a study by Iverson, Lovell, Smith, and Frazen (2000) of 624 patients with MHI only 144 (i.e., 23%) had abnormal CT scans. However, structural imaging techniques usually lack the sensitivity for detecting microscopic tissue damage or metabolic changes in MHI and may not be as useful as neuropsychological assessment in diagnosing a MHI (Jacobs, 1998; Ogden, 2005). In contrast, functional imaging techniques that assess more of the metabolic/neurochemical changes in the brain, such as positron emission tomography (PET) which detects changes in regional cerebral blood flow (rCBF), have shown greater sensitivity to detecting cerebral dysfunction following MHI (Chen, Kareken, Fastenau, Trexler, & Hutchins, 2007). Giza and Hovda (2001) state that significant changes in glucose metabolism can exist even in head injured persons with normal GCS scores. Other techniques such as functional magnetic resonance imaging (fMRI), diffusion-weighted magnetic resonance imaging, and more recently, diffusion tensor imaging may be useful for detecting abnormalities and cerebral dysfunction (e.g., see Belanger, Vanderploeg, Curtiss, &

Warden, 2007 for review), but due to their expense are not likely to be used universally for neuroimaging in MHI. As noted earlier, GCS scores or PTA are not overly useful in detecting MHI and are often unavailable if the individual did not seek medical treatment following injury. Thus, diagnostic criteria such as that defined by Kay et al. (1993) that includes an alteration in consciousness may capture the more subtle neurological disruption associated with MHI. Further, neuropsychological techniques are indispensable in detecting impairments from neural disruption. However, there is a body of literature (e.g., Iverson, 2007; Iverson, Lange, & Franzen, 2005) that suggests that neuropsychological tests are not sensitive enough to discriminate symptomatic persons with MTBI from those who are asymptomatic. Similarly, Iverson et al. (2005) also presented evidence that neuropsychological test performance of persons with uncomplicated MTBI could not be reliably differentiated from those with substance abuse issues. In contrast, and hence the controversy in the field, some literature (e.g., Raskin et al., 1998) has shown impaired performance on neuropsychological test measures for persons with MTBI.

Mild Head Injury Sequelae

A longstanding controversy exists regarding the prevalence, chronicity, and etiology of cognitive and emotional sequelae following MHI. A MHI is commonly accompanied by a constellation of symptoms such as headaches, dizziness, attentional difficulties, blurred vision, disrupted sleep, hypersensitivity to noise or light, memory difficulties, alterations in cognitive functioning and mood. This cluster of symptoms is referred to as Post-Concussion Syndrome (PCS) (Binder, 1986; Gouvier, Cubic, Jones, Brantley, & Cutlip, 1992; International Classification of Diseases (ICD)-10; World Health

Organization, 1992; 1993). PCS complaints are more common in the week following the MHI (Levin et al., 1987), and typically these symptoms subside after a 3 month period with functioning assumed to return to previous abilities (e.g., Dikmen, McLean, & Temkin, 1986; Levin et al., 1987).

However, since those early studies there has been accumulating evidence to suggest that complaints or impairments following MHI or MTBI are not transient for a subpopulation of persons with MHI (15% to 50%) having persistent psychological, behavioural, socioemotional, occupational, and cognitive difficulties attributed to an MHI that impair daily functioning (e.g., Alexander, 1995; Gouvier et al., 1992; Kay et al., 1992; Raskin, Mateer, & Tweeten, 1998). Although more recent literature (e.g., Iverson & Lange, 2003; in press [b]) suggest that this is an overestimate in that persistent difficulties are more likely experienced by only 5 to 10% of those with MTBI. In addition, the post-concussive symptoms have been suggested to be non-specific to MTBI or MHI as they have been reported in persons with no injury to the head (e.g., Gouvier, Uddo-Crane, & Brown, 1988; Iverson & Lange, 2003; Lees-Haley & Brown, 1993; Wong, Regennitter, Barrios, 1994). Oftentimes if the symptoms persist beyond the 3 to 6 month period it is termed persistent PCS (Alexander, 1995; ICD-10, World Health Organization, 1992; 1993), symptomatic MHI or Postconcussional Disorder (PCD; Diagnostic and Statistical Manual of Mental Disorders Fourth Edition-Text Revised [DSM-IV-TR], American Psychiatric Association, 1994), and is termed chronic PCS for symptoms that prevail past one year (Ruff & Grant, 1999).

There are polarized views regarding the persistence of PCS as to whether the symptomology is a result of psychological or organic factors. Initially the literature

focused on psychological factors such as neurotic or stress-related factors, rather than a neurological disorder (e.g., Mittenberg & Strauman, 2000). The lack of neurological evidence via CT scans as well as the fact that PCS complaints have been reported in non-head injured populations (e.g., Lees-Haley & Brown, 1993) has propelled this view. On the other hand, based on findings from animal (Giza & Hovda, 2001) and functional neuroimaging studies (e.g., Chen et al., 2007) it is *likely* that organic factors underlie PCS.

Furthermore, in the literature there is constant discussion regarding the role of pre-injury factors (i.e., premorbid differences) that may predispose individuals to being more vulnerable to sustaining a brain injury or may account for differences in performance on neuropsychological tests or other outcomes. For example, pre-existing personality types, pre-morbid emotional or psychiatric problems, pre-existing neurological factors such as learning disability or neurological illnesses, pre-morbid psychosocial issues, alcohol or drug use, sex, and age at time of injury have been identified as factors that may contribute to differential outcome following brain injury (see McCrea, 2008; Ruff & Grant, 1999 for discussion). It is difficult to ascertain if differences in post-injury presentation are related to the head injury or are related to pre-morbid differences. In the current study, it would be difficult to elucidate the causality of this argument.

The Frontal Lobes

As previously mentioned, the frontal, especially OFC, and temporal lobes are vulnerable to damage following MHI (Alves et al., 1993; Bigler, 1999; Gazzaniga et al., 2002; Morales et al., 2007). The following is a brief discussion of the connectivity and functional significance of the frontal lobes.

The prefrontal cortex (PFC) is comprised of three regions: the dorsolateral PFC (DLPFC), the orbitofrontal cortex (OFC), and the medial prefrontal cortex (mPFC) all of which receive unique combinations of sensory and contextual information from other parts of the brain to organize and guide behaviour (Gazzaniga et al., 2002; Kolb & Wishaw, 2003). These regions have differing connections to the other areas of the brain and thus, functional heterogeneity (Chow & Cummings, 2007; Fuster, 1987; Kolb & Wishaw, 2003), although these areas do interact in a complex fashion (Groenewegen & Uylings, 2000; Happaney, Zelazo, & Stuss, 2004; Urry et al., 2006).

In short, the DLPFC is involved in working memory for spatial information (Wilson, Scalaidhe, & Goldman-Rakic, 1993), attention, abstract reasoning and other executive functions (Chow & Cummings, 2007; Kaufer, 2007; Kolb & Wishaw, 2003; Stuss & Levine, 2002) and works with the anterior cingulate cortex (ACC) for guiding behaviours (Kaufer, 2007). DLPFC dysfunction may result in several disturbances in memory and planning strategies, possibly apathy and indifference symptoms, decreased interest or motivation and other manifestations (e.g., Stuss, Gow, & Hetherington, 1992).

The OFC comprises the most ventral portion of the PFC (Kolb & Wishaw, 2003). Oftentimes, the mPFC and OFC are collectively termed the ventromedial PFC (VMPFC) which has extensive connections to limbic, sensory, and other areas and appears to be more involved in affective, social decision making, and outcome-contingent behaviour than the DLPFC (Barbas, 2000; Bechara, Damasio, & Damasio, 2000; Chow & Cummings, 2007; Happaney et al., 2004; Rolls, 1998; Rosen & Dean, 2007). It is beyond the scope of this paper to discuss these functions at length. For the purpose of this thesis the discussion will focus on emotional and autonomic functions mediated by the OFC.

The OFC receives inputs from olfactory, gustatory, auditory, visual, somatosensory, and visceral systems primarily via the thalamus (Rolls, 2004). Further, the OFC is extensively interconnected with the hypothalamus and amygdala, particularly the central and medial nuclei, thus modulating visceral and emotional functioning (Barbas, Saha, Rempel-Clower, & Ghashghaei, 2003; Ogar & Gorno-Tempini, 2007). Barbas et al. (2003) demonstrated that in primates the OFC has intricate projections to the hypothalamus which then has connections with the autonomic regions of the brainstem (reticular formation, parabrachial nucleus, raphe nuclei, periaqueductal gray area), and the intermediolateral column of the spinal cord which innervates peripheral autonomic organs, as well as hormonal control of the autonomic nervous system. An early neurophysiological experiment with monkeys demonstrated that electrical stimulation of the OFC results in changes in heart rate, respiration, and vascular activity (Kadda, Pribram, & Epstein, 1949).

The medial OFC (mOFC) influences activity in the neuroendocrine and autonomic functions of the stress response and modulates stress-related behaviour via its connections with the brainstem, hypothalamus, and amygdala (Amaral, Price, Pitkanen, & Carmichael, 1992; Barbas et al., 2003; Jaferi & Bhatnagar, 2007). Due to the connections of the amygdala to the preganglionic sympathetic nervous system (which activates the eccrine glands in the skin) electrodermal activity in response to emotionally laden stimuli can indicate mOFC and amygdala activation (Andreassi, 2007; Tranel & Damasio, 1994; for review see Tranel, 2000).

Damage to the OFC could result in disrupted communication between the ventromedial PFC, amygdala, hypothalamus, and autonomic structures, thus interfering with emotional arousal, particularly decreasing emotional responsiveness (Barbas et al.,

2003) and poor decision making (Bechara et al., 2000). Barbas and colleagues (2003) suggest that such disrupted prefrontal-autonomic pathways may account for the abnormal (decreased) autonomic responsivity to meaningful stimuli, particularly that which is socially or emotionally salient found in persons with mOFC damage (Bechara et al., 2000; Damasio, Tranel, & Damasio, 1990; Hornak, Rolls, & Wade, 1996). The mOFC performs complex cognitive appraisals of emotional stimuli (Ochsner & Gross, 2005) and, as such, patients with mOFC damage have difficulties assigning emotional valence to stimuli or events (Chow & Cummings, 2007), as well as dysfunction in reward processing and disinhibited behaviour (Eslinger & Damasio, 1985). Similarly, persons with damage to the VMPFC produce smaller skin conductance responses (a measure of autonomic responsivity) to psychological (i.e., strong affective pictures), but not physical (i.e., a loud noise), stimuli as compared to controls (Tranel & Damasio, 1994). This speaks to the importance of the ventromedial frontal lobes in modulating visceral, neuroendocrine, and autonomic functioning in relation to emotional experience, particularly arousal and evaluation of emotional or social stimuli or events. This function will be further discussed in the context of MHI and stressful experience.

Cognitive Impairments Following MHI

Following MHI, cognitive functions such as working, verbal, and spatial memory (e.g., Raskin et al., 1998; Chuah, Maybery, & Fox, 2004), divided and selective attention, inhibition (e.g., Bohnen, Jolles, & Twijnstra, 1992), and other executive functions (e.g., Leininger, Gramling, Farrell, Kreutzer, & Peck, 1989) may be impaired, as well as processing speed (Evans & Wilberger, 1999; Raskin et al., 1998; Segalowitz, Bernstein, & Lawson, 2001). The following evidence demonstrates that subtle neuropsychological

deficits and head injury-related impairments persist in a subgroup of persons who have sustained trauma to the head.

A study by Raskin et al. (1998) was conducted to assess which neuropsychological measures are most sensitive or appropriate for detecting cognitive impairments following injury. MTBI criteria were adopted from Kay et al. (1993) (i.e., loss of consciousness less than 30 minutes, disorientation or confusion, and lasting neurologic or cognitive complaints). The sample was referred by emergency room staff for clinical assessment by a neuropsychologist. At the time of neuropsychological assessment, on average, two years had passed since acquiring the injury. Of the battery of neuropsychological tests used, Raskin et al. (1998) found impairment (defined as one standard deviation or greater below the normative mean for that neuropsychological test) mostly on measures of complex attention (Stroop Color Word Interference Test [Stroop, 1935]), working memory (California Verbal Learning Test [Delis, Kramer, Kaplan, & Ober, 1987], Wechsler Memory Scale Revised subtests [WMS-R; Word Lists, Wechsler, 1984]; Trail Making Test [Army Individual Test Battery, 1944]), verbal narrative memory (Logical Memory I and II; WMS-R), and time-dependent tasks. However, individuals were not impaired on measures of general intellectual functioning (Wechsler Adult Intelligence Scale Revised [Wechsler, 1981]).

The results of Raskin et al. (1998) demonstrate that a subset of persons exhibit persistent specific cognitive impairments at approximately 2 years post-MTBI while general intellectual functioning remains intact. Furthermore, Raskin et al. demonstrated that neuropsychological tests are sensitive to detecting impairments following MTBI. It is important to note that the participants in this study had received medical care for their head

injury, were referred to a neuropsychologist for assessment, and many were not employed following their injury at the time of testing compared to pre-injury employment status. These factors may indicate greater injury severity and more impaired functioning of the sample in this study as compared to other studies later discussed.

Leininger and colleagues (1989) also examined neuropsychological performance in head-injured persons. Persons who had a loss of consciousness (LOC) were classified as the concussion group, persons who had a minor head injury without LOC were classified as the mild concussion group, and both groups were compared to controls. Head-injured persons were tested 1 to 20 months post-injury. The groups did not differ on measures of verbal intelligence. Interestingly, the concussion and mild concussion groups' neuropsychological performance did not differ demonstrating that the occurrence or non-occurrence of LOC did not distinguish persons at an increased or decreased risk for presenting with neuropsychological consequences. Subsequent analyses showed neuropsychological impairments after minor head injury (compiled MHI group—i.e., concussion group plus mild concussion group) when compared to healthy controls particularly in tests of reasoning, verbal learning, delayed visuospatial memory, and information processing.

Similarly, a study by Bohnen, Jolles, and Twijnstra (1992) compared the neuropsychological performance of persons with asymptomatic MHI ($N = 9$), symptomatic MHI (i.e., PCS six months after injury) ($N = 9$), and individuals without neurological compromise ($N = 9$). MHI criteria consisted of PTA less than one hour, a LOC less than 15 minutes, a GCS score of 15 on admission to the emergency department of the medical treatment facility, and no other serious traumatic physical complications. PCS was

measured via a checklist and those with three or more symptoms six months after injury were classified as symptomatic MHI. The results demonstrate that the symptomatic MHI group performed significantly worse on the Stroop Colour Word Interference Task, particularly for the more demanding subtasks, than the asymptomatic MHI group and healthy controls. In addition, the symptomatic MHI group had a slower reaction time on a computerized divided attention task than the other two groups. Although the symptomatic MHI group made more errors than asymptomatic and healthy control groups this was not found to be significantly different. These findings indicate that symptomatic MHI persons exhibit residual impairment on tasks of selective and divided attention as compared to controls or asymptomatic MHI persons.

Many persons with milder head injuries are high-functioning individuals and may attend college or university, but this does not exclude the possibility of subtle, long-term cognitive changes. Academic problems possibly encountered by university and college students with MHI have often been overlooked in the existing literature. Perhaps it is because these persons are considered to be cognitively competent and intellectually capable. Regardless, there is some evidence that university students with MHI have shown subtle, but significant, differences in cognitive performance when compared to controls as illustrated by the following studies.

A study conducted by Beers, Goldstein, and Katz (1994) included a neuropsychological battery to assess cognitive deficits in students (mean age = 21 years) with a history of MHI ($N = 25$) or learning disabilities ($N = 35$) compared to controls ($N = 22$). History of previously sustaining MHI was obtained by self-report and was defined as LOC of at least one minute but not greater than 20 minutes and PTA less than one hour.

Overall, the MHI group was significantly impaired on neuropsychological measures of narrative explicit memory (WMS-R Logical Memory I), problem solving/abstract reasoning/executive functions (Picture Completion; Picture Arrangement; WAIS-R), and visuospatial ability (Object Assembly; WAIS-R) compared to the control group. In addition, the students with MHI did more poorly than students with learning disabilities on tasks of problem solving, attention, visuospatial ability, and abstract conceptual formation.

Another study by Chuah et al. (2004) investigated short-term visuospatial memory in high-functioning university students with and without previous MHI. MHI was defined as yes/no to the question of "have you ever suffered from a head injury that involved any loss of consciousness or period of disorientation?" (p. 306). Twenty-six percent of participants (n = 126 of a total N = 482) reported a history of a MHI (i.e., 356 students did not report a head injury). From these two groups, 16 students were randomly chosen as controls and 16 students comprised the MHI group. Eleven out of the 16 students in the MHI group reported a LOC (mean of 5 minutes in duration) and of these 11 participants 3 reported that the LOC lasted 5-30 seconds, 6 reported a period of LOC for 1 to 5 minutes, and one reported a LOC for 25 minutes. The rest of the MHI group (i.e., 5 of the 16) reported experiencing a head injury with no LOC (i.e., were disoriented). All head injuries were reported to have been incurred in the past 6 years (mean length of time since injury = 2.64 years). Only 19% of participants reported attending a hospital following their head injury. The mean age of participants was 19 years. The two groups did not differ on intellectual abilities assessed via the reading subtest of Wide Range Achievement Test-Revised (WRAT-R; Jastak & Wilkinson, 1984).

To assess potential changes in short-term memory (STM) between these groups, participants completed three computerized tasks requiring recall of abstract polygons in randomly arranged locations: participants had to recall the shape (visual STM), the location (spatial STM), or both location and shape (visuospatial STM) of the abstract polygons. Each stimulus display was presented for 5 seconds and then participants were given an immediate test. Chuah et al. (2004) found significantly impaired spatial, but not visual or visuospatial, memory for persons with MHI compared to controls.

Others have found similar subtle, but statistically different, impairments in university students with a history of MHI in terms of non-verbal reasoning ability (DeBono & Good, 2008; Osbourne, 2003), processing speed (Peltsch, 2004), verbal memory (St. Cyr, 2006; St. Cyr & Good, 2007), working memory (Dzyundzyak & Good, 2008), and selective attention (Jung & Good, 2007; Klerkx, 2008). Overall, high-functioning university students with MHI exhibit subtle, subclinical deficits in cognitive performance. Of interest to the current study is how cognitive performance may be influenced by modifying arousal state (induced psychosocial stress or relaxation) in high-functioning students with and without history of sustaining an MHI.

Stress

Numerous factors may contribute to cognitive performance and one such factor of particular interest to the current study is stress. Hans Selye (see Selye, 1953 for review) is credited with introducing the concept of stress in which a physiological cascade of neurochemical and hormonal responses are initiated in an adaptive response to stressful stimuli. Selye's General Adaptation Syndrome theory (see Selye, 1953) proposed that the stress response, which includes adrenergic and hypothalamic-pituitary-adrenal (HPA) axis

activity, was a non-specific phenomenon in that all types of stressors evoke the same stereotyped response. For example, running away from a hungry bear or giving a presentation would induce the same physiological response. However, these stressors may be classified as either physical stressors that pose a real, immediate threat (e.g., being chased by a bear, experiencing a hurricane) or psychological stressors that pose an implied threat (e.g., giving a presentation, having a job interview) and the stress response may be less pronounced to the latter (Johnson, Kamilaris, Chouros, & Gold, 1992; Lupien, Maheu, Tu, Fiocco, & Schramek, 2007). The stress response to psychological stressors is typically induced in a new and/or unpredictable situation, and/or during a loss of feeling of control (Mason, 1968), and/or concern of social evaluation by others (Dickerson & Kemeny, 2004) and involves cognitive appraisal of the situation (Folkman, Lazarus, Dunkel-Schetter, DeLongis, & Gruen, 1986). Greater inter-individual variation is seen in response to psychological stressors (Lupien et al., 2007) and is most likely due to individual differences in cognitive interpretation of what is, or is not, stressful (Folkman et al., 1984). Furthermore, stressors affect physiology by activating cognitive and affective processes and the central nervous system. The thalamus receives, and the PFC appraises information leading to emotional responses via connections to the limbic and prefrontal cortices and the hypothalamus (activating HPA axis) (Dickerson & Kemeny, 2004; Lupien et al., 2007).

In short, when a stressor (physical or psychological) is experienced two major systems of the stress response are activated (refer to McCormick, 2007; Lupien et al., 2007 for reviews). One is the activation of the sympathetic nervous system (SNS) with concurrent decreased activation of the parasympathetic nervous system (PNS) also known

as the fight-or-flight response (Cannon, 1929), and the other is the activation of the HPA axis. When a stressor is experienced, the sympathetic nervous system (SNS) secretes the catecholamine norepinephrine (Nelson, 2005). Stress also facilitates HPA axis activity resulting in eventual release of glucocorticoids and another catecholamine (epinephrine) from the adrenal cortex and adrenal medulla, respectively. Basically, the paraventricular nucleus (PVN) of the hypothalamus releases corticotrophin releasing hormone (CRH) via the hypophyseal portal system to activate the anterior pituitary. Then the anterior pituitary releases adrenal corticotrophin hormone (ACTH), and in turn, ACTH activates the release of glucocorticoids, nominally cortisol, into the bloodstream via the adrenal cortex (Stratakis & Chrousos, 1995; Miller & O'Callaghan, 2002). This HPA activity is managed by a negative feedback loop (Anisman & Merali, 1999) involving the hippocampus which regulates and inhibits HPA activity (Jacobson & Sapolsky, 1991; Sapolsky, Zola-Morgan, & Squire, 1991) by signaling the PVN of the hypothalamus to cease CRH secretion (Anisman & Merali, 1999); and initiates HPA activity by involving the amygdala (Vyas, Mitra, Shankaranarayana Rao, & Chattarji, 2002) in emotionally arousing situations (Kalat, 2004).

Cortisol release plays a critical role in helping prepare the body to respond to stress by activating the SNS (Drolet et al., 2001) to decrease digestive function, reproductive behaviour, and other functions to conserve energy (Johnson, Kamilaris, Chouros, & Gold, 1992; Nelson, 2005). As well, activation of both systems in response to stressors results in changes such as increases in respiration, glucose metabolism, sweat response, heart function, and blood pressure to prepare the body for action (Andreassi, 2007; Cannon, 1915; 1929; Nelson, 2005; Sauro, Jorgensen, & Pedlow, 2003). These changes in

physiological activity serve as indicators of reactivity to stressful stimuli (Poole, Hunt-Matheson, & Cox, 2005).

Of interest to the current study is the impact of the stress response on cognitive performance. The highly complex physiological response and/or exogenous stress-related hormonal changes have been shown to impact cognitive performance (see Lupien et al., 2007 for review) with many studies reporting a dose-dependant (inverted U-shape) manner akin to the theory proposed by Yerkes and Dodson (1908) of the arousal-performance relationship. Too little or too much arousal/stress is associated with poor performance, whereas optimal performance is related to an optimal level of arousal known as the *Yerkes-Dodson Law* (Anderson, 1990; Hebb, 1955).

Catecholamine Effects on Cognitive Function

As previously mentioned, the norepinephrine-locus coeruleus system is involved in arousal (Johnson et al., 1992; Chamberlain, Muller, Blackwell, Robbins, & Sahakian, 2006) and has been shown to effect learning, memory and attention via noradrenergic activation in the basolateral amygdala (Ferry, Roozendaal, & McGaugh, 1999; Hatfield & McGaugh, 1999), medial temporal areas (Chamberlain et al., 2006), and areas of the PFC attributed to working memory (Arnsten & Li, 2005). In line with the Yerkes-Dodson Law, it has been suggested that moderate levels of norepinephrine during stress may improve short-term memory performance; whereas, heightened levels of norepinephrine during stress may impair short-term memory and cognitive functioning (Arsten & Li, 2005; Ferry et al., 1999). Epinephrine, a neuromodulator associated with heightened stress, does not readily access the brain but it has an impact via vagal adrenal receptors which project to the nucleus of the solitary tract (NTS) (Clark et al., 1998; Lupien et al., 2007). The NTS

projects to many structures involved in cognitive processes and arousal such as the locus coeruleus (van Bockstaele, Colago, & Aicher, 1998) and the amygdala (McGaugh & Roozendaal, 2002). Therefore, norepinephrine and epinephrine influence cognitive performance during stress and distress.

Glucocorticoid Effects on Cognitive Function

Glucorticoids are liposoluble and therefore can cross the blood-brain barrier having direct effects on cognitive function (Lupien et al., 2007). Research with animals has shown there are two types of glucocorticoid receptors: mineralocorticoid receptors (MR) and glucocorticoid receptors (GR) with differential affinity and distribution in the brain (Reul & de Kloet, 1985; McEwen, Weiss, & Schwartz, 1968). GRs, in particular, are found in prefrontal regions (Sanchez, Young, Plotsky, & Insel, 2000) and even though both types of receptors are activated during periods of stress (Lupien et al., 2007) it is heightened GR activation, not MR, which is implicated in cognitive impairments associated with high cortisol levels (Reul & de Kloet, 1985; de Kloet, 1991; de Kloet, Oitzl, & Joels, 1999). It is also important to note that cortisol follows a circadian rhythm. During the afternoon or evening cortisol levels are low and activate mostly MRs; whereas, cortisol levels are highest in the morning just prior to wakening in which both MR and GR receptors are activated (Lupien et al., 2007).

In humans, pharmacologically modulated or experimentally-induced heightened levels of cortisol has been shown to impair declarative and spatial memory functions (Kirschbaum, Wolf, May, Wippich, & Hellhammer, 1996; Newcomer et al., 1999), working memory (Lupien, Gillin, & Hauger, 1999; Young, Sahakian, Robbins, & Cowen, 1999), and attention (Hsu, Garside, Massey, & McAllister-Williams, 2003). Low levels of

cortisol have been shown to impair declarative memory performance in healthy young adults (Lupien et al., 2002). Altogether these studies indicate that too low or too high cortisol levels impair cognitive performance similar to that of the Yerkes-Dodson Law and glucocorticoid ratio hypothesis of de Kloet and colleagues (1999).

Stress responsivity has been commonly reported via laboratory stress induction. A frequently used laboratory technique to induce psychosocial or psychological stress is the Trier Social Stress Test (TSST; Kirschbaum, Pirke, & Hellhammer, 1993) and typically consists of having the subject prepare and perform a speech followed by doing a mental arithmetic task. The TSST has been shown to be sufficient to induce physiological changes in humans of all age groups and in both genders (Kudielka, Buske-Kirshbaum, Hellhammer, & Kirshbaum, 2004). Various studies have demonstrated elevated heart rate and blood pressure (e.g., Kudielka et al., 2004; Hoffman & al'Absi, 2004), increased catecholamine levels (e.g., Ward et al., 1983), heightened HPA activity via cortisol measures (e.g., Kirschbaum et al., 1996), increased anxiety (e.g., Childs, Vicini, & De Wit, 2007; Hoffman & al'Absi, 2004) and cognitive impairments (refer to Kudielka, Hellhammer, & Kirschbaum, 2007 for review).

Stress, Mild Head Injury and Cognitive Performance

Much research has been conducted to examine cognitive deficits following stress (either pharmacological manipulation or psychologically- induced stress) in persons without neurological compromise. In addition, a good deal of research has been conducted on cognitive and emotional sequelae in persons with MHI. However, little research has examined how stress and MHI may interact to effect cognitive performance in high-functioning persons with MHI which is a purpose of the current study.

Following moderate-to-severe TBI there are typically increased reports of stress and/or anxiety disorders. A meta-analysis of 12 studies totaling 1,199 persons with head injuries of differing severity found the prevalence of anxiety to be approximately 29% following TBI (Epstein & Ursano, 1994). Research has been reviewed (see Moore, Terryberry-Spohr, & Hope, 2006) that indicated when studies using patients with moderate and severe brain injuries were excluded from the meta-analysis, the prevalence of anxiety disorders in the MTBI-only population was lower, at approximately 23%. Further, the lifetime prevalence of anxiety disorders in the general population is approximately 12% (Health Canada, Report on Mental Illnesses in Canada, 2002).Yet, of the few studies conducted on MHI and stress/anxiety (e.g., Gouvier et al., 1992; Bryant & Harvey, 1998; Harvey & Bryant, 1998) the findings have been inconsistent (see Moore et al., 2006), but appear to mirror that of persons with more severe TBI (i.e., increased reports of stress and/or anxiety), and the research has been otherwise silent with respect to arousal levels of persons with MHI. However, previous undergraduate thesis research from our lab (Brock University Neuropsychology Cognitive Research Lab; Jung, 2006; Jung & Good, 2007; St. Cyr, 2006; St. Cyr & Good, 2007) has shown that individuals with MHI are relatively underaroused and less responsive to stressors in their environment as compared to no-MHI students and indeed, in contrast what is typically found, benefit from being activated to a higher level of arousal.

In one study (Jung, 2006; Jung & Good, 2007), the effects of induced psychological stress on cognitive performance (attention, working memory) were examined in university students with ($N = 22$) and without MHI ($N = 38$). History of MHI was obtained via self-report with criteria similar to that of Kay et al. (1993). Psychological

stress was induced by having subjects prepare and present a speech while being videotaped. Recordings of heart rate and blood pressure were obtained as indices of physiological stress responsivity at baseline, during psychological stressor, and afterwards. The results indicated that persons with MHI are underaroused and have a decreased physiological response to environmental stressors. Persons with MHI reported lower levels of anxiety (standardized self-report; State-Trait Anxiety Inventory [STAI], Speilberger, 1983a) and also showed lower heart rate and blood pressure than persons without MHI. As expected, increased stress led to impaired attentional performance (Colour Word Naming Interference Task; Delis-Kaplan Executive Functions System [DKEFS], 2002) for students without MHI; however, increased stress/arousal improved attentional performance for students who reported a MHI.

In another study (St. Cyr & Good, 2007), we examined the effects of self-reported anxiety (STAI, Speilberger, 1983a) on memory performance in university students with (N = 15) and without MHI (N = 35). Overall, students with MHI reported significantly lower levels of state anxiety than students without MHI. Immediate and delayed narrative memory performance (Logical Memory I and II; Wechsler Memory Scale-III, Psychological Corporation, 1997), as well as processing speed for a visuospatial memory task (Rey Complex Figure test; Osterreith, 1944), differed as a function of state anxiety and MHI history. As expected, students without MHI performed more poorly on memory tasks with higher levels of self-reported anxiety and performance improved when anxiety was reported to be lower. In contrast, for students who had sustained a MHI, memory performance was improved with higher self-reported anxiety and was impaired when less anxious. Therefore, increased arousal (i.e., self-reported anxiety) enhances performance

and processing speed on memory tasks for persons with a history of MHI, however, increased arousal negatively impacts performance for persons without MHI.

We suggest these findings reflect the potential limitations of underarousal that has been associated with orbitofrontal disruption (e.g., Tranel & Damasio, 1994; Tranel, 2000) and may be implicated in MHI generally. As previously mentioned, the VMPFC is vulnerable to damage and, in particular, axonal disruption (Mateer & D'Arcy, 2000; Morales et al., 2007) can result in altered communication with the brainstem, hypothalamus, and amygdala (Amaral et al., 1992; Barbas et al., 2003; Jaferi & Bhatnagar, 2007). Persons with MHI may be less able to physiologically respond to, and cognitively appraise, stressful stimulation via decreased autonomic and endocrine responsivity due to VMPFC disrupted connections and, overall, are underaroused. The Yerkes-Dodson Law can provide an explanation for the findings from our lab (Jung, 2006; Jung & Good, 2007; St. Cyr, 2006; St. Cyr & Good, 2007). When persons without MHI experience too much arousal (i.e., beyond optimal/moderate levels of stress), performance on cognitive tasks is impaired; whereas, persons with MHI are typically underaroused and increases in arousal (self-report of anxiety or induced-stress) permit them to experience increased activation/more optimal arousal and subsequent improved cognitive performance.

In summary, the premise of the current study[1] originated from findings of underarousal of intellectually-competent persons who reported a history of MHI relative to their no-MHI counterparts (i.e., Jung, 2006; Jung & Good, 2007; St. Cyr, 2006; St. Cyr & Good, 2007) and investigates whether persons with MHI present, both physiologically and

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via self-report, in a manner similar to that of persons who have experienced more extensive disruption to the VMPFC (i.e., reduced emotional and physiological [EDA] responses; Tranel & Damasio, 1994; Tranel, 2000); and to examine the effects of modified arousal state on cognitive performance. It is expected that persons who have no MHI would elicit greater physiological indices of arousal and have heightened ratings on self-report measures of arousal as compared to those who report history of a MHI because the latter group may be less able to physiologically respond and/or cognitively appraise stressful experiences. We also further examine the cognitive limitations or benefits that occur despite subtle head injury in this intellectually competent sample of students as a function of arousal state (induced-stress or induced-relaxation). Specifically, we used a quasi-experimental research design (group variable: history of head injury—MHI or no-MHI; manipulated variable: arousal manipulation—induced-stress/heightened arousal or induced-relaxation/lowered arousal) to examine the resulting cognitive limitations or benefits for memory processing, attention, planning/abstract reasoning skills i.e., we expect that persons with no history of head injury will demonstrate impaired cognitive performance on neuropsychological measures when stress is induced through a psychosocial stressor as compared to induced relaxation. In contrast, persons with MHI are expected to cognitively benefit from induced-psychosocial stress, particularly with respect to abilities associated with OFC function such as attention, working memory, and cognitive flexibility as compared to induced-relaxation. Despite these differing response patterns, persons with MHI are expected to present with general intelligence capacities similar to that of their no-MHI counterparts and demonstrate competence on some cognitive tasks, given their university student status. Finally, we will investigate PCS

status since there is little research investigating PCS-type complaints in a competent university population as a function of self-reported MHI history. We expect self-reports of post-concussion symptoms, especially those commonly reported following head trauma, to be qualitatively different (i.e., experienced more often, more intensely, and for longer durations) as a function of sustaining a previous MHI (i.e., greater experience of symptoms for students who acknowledge a previous MHI compared to those who do not endorse such history) despite not being actively treated for these symptoms or of current concern. Implications of this research will provide a greater understanding of the overall functioning of persons who have experienced mild/subtle neurological compromise and contribute to research on brain-behaviour relationships.

Hypotheses

Hypothesis 1

Persons who report a history of MHI will be underaroused, overall, compared to those without head injury (similar to that of persons with moderate-to-severe VMPFC injury) and will present, in general, a decreased physiological arousal response (as indicated by lower responsivity on physiological measures of electrodermal activity) and decreased perceived stress (as indicated by lower ratings of stress on self-reported measures) due to their expected reduced emotional and functional reactivity.

Hypothesis 2

Due to the above mentioned expected overall reduced responsivity (i.e., underarousal) in persons with MHI, it is expected that the effect of the arousal manipulations (psychosocial stress or relaxation) will be relatively greater for persons with

no-MHI as compared to persons with MHI with respect to both self-reported measures of arousal and physiological indices.

Hypothesis 3

Consistent with the Yerkes-Dodson Law, induced-psychosocial stress (i.e., heightened arousal) and/or perceived stress will impair cognitive performance in persons without head injury. In contrast, induced-psychosocial stress should improve cognitive abilities associated with OFC function, namely attention, working memory, and cognitive flexibility, but not those associated with other cognitive skills (planning, reasoning) and intelligence, for persons with MHI who are expected to initially, and typically, be underaroused relative to their cohorts. Conversely, cognitive skills (attention, working memory, cognitive flexibility) will benefit from induced and/or perceived relaxation for individuals without head injury and impair performance for persons with head injury (as this should further lower their arousal state which is expected to be already reduced prior to any manipulation).

Hypothesis 4

Self-reports of post-concussion symptoms, especially those that are predominant complaints for those who have experienced head trauma, namely, concentration and judgment difficulties, headaches, and irritability, are expected to be experienced more often, be of greater intensity and longer duration for students with history of MHI compared to students without MHI.

Method

Participants

Ninety-four university students[2] were recruited for this study via the local Psychology Department Research Website and through poster advertisements around Brock University (see Appendix A1 and A2). The participants in this study were post-secondary students ($N = 91$; 90 Brock University students; 1 student from a local Community College) that were, on average, 21 years of age ($SD = 3.20$) ranging from 16 years to 32 years (median = 20; mode = 19). Of the 91 participants whose data were included (28 male, 63 female), the majority (68.10%) were upper year university students (i.e., second year and above) currently enrolled as full-time students. Chi-square analysis revealed that participants did not differ in years of education for sex in the two arousal manipulation conditions, χ^2 $(1, N = 46) = .01, p = .950$[3]; χ^2 $(1, N = 45) = .38, p = .737$[3]. The majority (93.49%) of the sample was right-handed (refer to Appendix C Tables C1 through C4 for details).

The students who participated in this study were randomly assigned to one of two arousal manipulation conditions—either psychosocial stress ($n = 45$) or relaxation ($n = 46$) induction. After evaluation of the demographic questionnaire, it was noted that 51 students (56%) self-identified as having previously experienced a head injury sufficient to alter their state of consciousness (e.g., dizzy). The four groups consisted of a) psychosocial stress MHI ($n = 27$, 10 male, 17 female); b) relaxation MHI ($n = 24$, 10 male, 14 female);

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[2] *Note.* Originally 94 students participated in this study. However, one participant withdrew from the study due to an intense response to our psychosocial stress manipulation and as such these data were destroyed and not included in the analyses. Also, two participants were excluded from all analyses, one due to technical difficulties with physiological data and the other because of extremely limited performance on cognitive tasks (could not complete most neuropsychological tasks).

[3] Fisher's Exact Test values used.

c) psychosocial stress no-MHI (n = 18, 3 male, 15 female); and, d) relaxation no-MHI (n = 22, 5 male, 17 female). Note that history of head injury represents a categorical variable to which participants belonged, but was not randomly assigned.

It is important to note that we did not recruit participants based on history of head injury to avoid the impact of diagnosis threat on cognitive performance (see Suhr & Gunstad, 2002; 2005). Suhr and Gunstad have found that when attention is directed to head injury history as a reason for invitation to participate in a study, the participants with head injury performed more poorly on cognitive tasks. Therefore, participants in our study were recruited to participate in a 'Cognitive Abilities and Arousal State' study with no mention of investigation of head injury until after testing during debriefing. As well, questions pertaining to head injury were embedded with 11 other health-related questions in the demographic questionnaire. The majority of participants with reported head injury (86.30%, n = 44) were beyond the acute post-injury phase (i.e., greater than 3 months); 13.70% (n = 7) reported that their head injury occurred within the past 3 months (i.e., acute post-injury phase); and 4.00% (n = 2) reported having one in the past 3 to 6 months; 11.80% (n = 6) had one in the past 6 to 12 months); while 70.50% (n = 36) experienced their head injury more than a year previous to participating in this study (refer to Table 1).

Table 1

Recency of Mild Head Injury

	Most recent MHI (n = 51, 56.00%)	
Recency of Injury	*n*	*Percentage*
Acute Injury Phase	7	13.70
(i.e., occurred within the past 3 months)		
Post-acute Injury Phase	44	86.30
Injury occurred in the past 3 to 6 months	2	4.00
Injury occurred in the past 6 to 12 months	6	11.80
Injury occurred more than a year previous	36	70.50

Participants were tested individually in a private lab setting in the Jack and Nora Walker Lifespan Development Centre testing facilities at Brock University. Participants were offered the opportunity to receive credit for research participation hours towards applicable courses at the university. Data collection commenced upon receiving ethics clearance by the local university's Research Ethics Board (see Appendix B) and committee approval of the proposed research.

Intelligence capacity did not differ as a function of MHI History. Measures of intelligence capacity were conducted prior to other cognitive tasks and/or arousal manipulations. Separate 2 (MHI History: MHI, No-MHI) X 2 (Condition: Stress,

Relaxation) ANOVAs were conducted to examine potential differences in performance between students with and without MHI for intelligence capacity measures (Vocabulary, Block Design; WAIS-III, 1997). Visuospatial performance (as measured by Block Design Test), $F(1, 87) = .09$, $p = .768$, and vocabulary competence, $F(1, 87) = 1.85$, $p = .177$, did not differ for students with and without MHI. Students in the relaxation condition demonstrated more competent vocabulary skills than students in the stress condition, $F(1, 87) = 4.32$, $p = .041$, but not as a function of MHI history, $F(1, 87) = 1.13$, $p = .291$. Similarly, there was no significant interaction of MHI history and arousal manipulation condition for visuospatial skills, $F(1, 87) = .30$, $p = .583$, (refer to Appendix C Tables C5 to C8).

Materials

Everyday Living demographic questionnaire. Participants completed the Everyday Living questionnaire (Brock University Neuropsychology Research Lab, 2008; see Appendix A3) to collect information on history of mild head injury (i.e., "*Have you ever hit your head with a force sufficient to alter your consciousness (e.g., loss of consciousness, vomiting, dizziness?"*), concussion, and time elapsed since injury. Other information such as sex, age, level of education, and exercise and sleep habits was also collected.

Life Stressors Scale (adapted from the *Social Readjustment Rating Scale* of Holmes & Rahe, 1967). This measure was originally developed to examine the impact of significant life stressors on overall health. The original, and our modified version, contains a list of major stressful life events (the modified version has 18 events) such experiencing as a loss of a relationship or entering the first year of university. Each life event stressor is

differentially weighted based on psychometrically derived life impact units. For the current research, the participants were asked to endorse any of the 18 listed major life stressors that had occurred in the past 6 months. A total score is derived by summing each weighted score to reflect the relative amount of readjustment required following the life stressor. Frequency of endorsing stressful life events was also tallied.

Post-Concussive Syndrome Checklist (PCSC; Gouvier et al., 1992). The PCSC (see Appendix A4) was used to provide an index of the self-reported frequency, intensity, and duration of the ten symptoms typically associated with persistent concussions in students with and without MHI. Participants rated each symptom with respect to frequency (1 *not at all* to 5 *all the time*), intensity (1 *not at all* to 5 *crippling*) and duration (1 *not at all* to 5 *constant*). An overall total score was calculated for all symptom reports (minimum total score 30; maximum 150) as well as for each qualitative aspect (minimum score 10; maximum score 50).

Arousal State Measures

Electrophysiological measures. Polygraph Professional equipment (Limestone Technologies, 2008), specifically the Datapac USB™ 16-bit Data Acquisition Instrument, was used in concert with Polygraph Professional Suite Software and a 16"Acer Laptop computer to record heart rate (HR), blood pressure (BP), respiration and electrodermal activity (EDA) as indices of physiological arousal state.

Heart rate was recorded via a pulse oximeter on the middle finger of the non-dominant hand. The pulse oximeter detected blood perfusion of the digit and pulse pressure changes for each cardiac cycle via a light emitting diode (by measuring changes in light absorption). Heart rate was sampled in 2 second windows and averaged over a 60

second interval and was measured in *beats per minute.* Blood pressure data were collected via a pneumatic blood pressure finger cuff with a sphygmomanometer that measures changes in blood volume with minimal discomfort to the participant. Due to technical difficulties, the blood pressure channel was not analyzed for the current research. Respiration was recorded via pneumatic chest bands with the upper band placed at the level of the sternum and the lower band across the abdomen. Respiration was measured in *cycles per minute* and only the upper band recording was utilized in data analyses due to better sensitivity in detecting inhaling and exhaling than the lower band. EDA was recorded via silver-silver chloride plated pads placed on the distal phalynx of the index and fourth fingers of the non-dominant hand. A latency window of 5 seconds at onset of the recording period was specified and EDA data were sampled after this period and averaged over a 60 second interval. Electrodermal responses were measured in terms of frequency (*cycles per minute*) and *amplitude* (i.e., the height of the electrodermal response measured in microsiemens [μS]). All data were carefully screened for artifact prior to analysis.

Verbal self-report of perceived arousal state. Participants were asked to provide a self-report of current perceived arousal state (1 *very relaxed* to 10 *very stressed*) prior to and after arousal manipulation induction and at various times (a total of 6) throughout the testing session.

State-Trait Anxiety Inventory (STAI, Speilberger, 1983a). The State scale provided an index of current state anxiety (20 item self-report questionnaire with a 4-point intensity scale ranging from *not at all* to *very much so*). An index of long-standing quality of trait anxiety was provided by another 20 item self-report questionnaire (4-point frequency scale ranging from *almost never* to *almost always*). Total scores for each construct range from a

minimum of 20 to a maximum of 80 and higher scores reflect more anxiety. Internal consistency reliability analysis was conducted (refer to Barnes, Harp, & Jung, 2002) in order to replicate previously reported Cronbach's alpha coefficients (α) of .90 and .93 for trait and state anxiety, respectively (Spielberger, 1983b) and was found to be .91 for trait anxiety and .89 for state anxiety on the STAI Form-Y of this sample. Pearson product moment correlation indicated that state and trait anxiety were also moderately positively correlated, $r\,(89) = .45, p < .001$ (refer to Appendix C Figure C1 for visual depiction).

Neuropsychological Measures

Participants completed protected, standardized tests from three main neuropsychological domains, specifically, memory, attention, and planning/abstract reasoning to assess arousal influences on cognitive performance. Additionally, they completed two brief tests of intelligence to estimate their verbal and non-verbal intelligence. While accuracy is the primary measure for each, reaction time (RT) is indicated when applicable for timed measures.

Narrative explicit memory. Logical memory I and II (subscale of Weschler Memory Scale Revised-III (WMS ®-III, 1997) was used to provide a measure of immediate (Logical Memory I) and delayed (Logical Memory II) narrative memory skills. Logical Memory I consists of a short story that is read to the participant. Participants freely recall what they heard immediately after verbal presentation of the story as a measure of explicit memory. After a 30-minute delay, participants freely recall, without prompts, as much information as possible from the short story previously administered. Accuracy for the number of units recalled (out of a maximum of 25), as well as the total number of generic themes recalled (out of a maximum of 7), are recorded.

Spatial memory. The *Memory for Design* (subtest of the NEPSY-II, 2007, Harcourt Assessment) was used to provide a measure of non-verbal spatial memory. Participants were presented with a display of 10 geometric designs arranged in a complex spatial pattern and were to replicate the pattern choosing 10 cards with designs from a deck of 20 cards and placing them in a grid, both immediately (after the design display was removed) and after a 25 minute delay. Accuracy was recorded for the designs recalled (out of a maximum of 50).

Working memory. Working memory abilities were measured via three subtests: *Mental Control* (WMS®-III, 1997), *Trail Making Test* (Delis Kaplan Executive Function System [DKEFS], 2002), and *Digit Symbol-Coding* (WAIS-III, 1997). For the *Mental Control* subtest participants were given a series of speeded accuracy tests by being asked to say the days of the week forwards and backwards, the months of the year forwards and backwards, the alphabet forwards, and lastly to alternate saying the days of the week while adding by sixes—all as quickly and as accurately as possible. The latter task is a measure of cognitive flexibility. There are three parts to the *Trail Making Test.* In Part Ia, participants were asked to use a pencil to connect dots that were randomly and spatially arranged on a 14" x 17" sheet of paper by following numbers in sequence as quickly and accurately as possible, and in Part Ib participants were to connect the dots in alphabetical order; and in Part II, participants connected the dots alternating between numbers and letters in sequential order. Mental Control and the Trail Making Test produced both an accuracy and RT measure. For the *Digit Symbol-Coding* subtest participants were asked to replicate geometric symbols that were paired with a number (1 through 9) presented in a random order and participants were to fill in the correct symbol associated with that

number on a sheet of paper and to do so as quickly and as accurately as possible in a two minute time period. Accuracy (number of correct symbols produced out of a maximum of 120 symbols) was the primary measure for the Digit Symbol-Coding task.

Planning/abstract reasoning. Planning and abstract reasoning skills were tested via subscales from the DKEFS (2002), the Comprehensive Test of Nonverbal Intelligence (CTONI; Hammill, Pearson, & Wiederholt, 1996) and the Wechsler Adult Intelligence Scale (WAIS-III, 1997). The *Picture Arrangement* (WAIS-III) task assesses reasoning and sequencing abilities. Participants are to arrange a set of pictures on cards to create a storyline with both accuracy (out of a maximum score of 22) and response time being measured. *Pictorial Analogies* (CTONI) provides a measure of abstract semantic reasoning as participants are required to select one of five choices to complete an analogy depicted by pictures (e.g., "shoe" is to "foot", as "glove" is to "hand"). They progressively increase in difficulty across subsequent trials. Only accuracy is measured (out of a maximum of 25) as time to respond was restricted to 30 seconds. The *Tower of Hanoi* (DKEFS) task provides a measure of planning abilities in which participants are asked to reproduce a picture of a sequence of wooden rings (a "tower") using a physical wooden device and up to five coloured rings of different sizes in as few moves as possible and abiding by certain sequencing rules of procedure. The number of moves made, the number of times a sequencing rule was violated, and the time to complete each of the nine trials is recorded.

Selective attention. Participants completed the *Colour-Word Naming Interference Test* (DKEFS, 2002) which measures selective attention, cognitive flexibility, and impulse control/inhibition via four sub-tasks. This task required participants to: 1) name colours, 2) read words, 3) name the colour of the ink the word is printed in, with interference from the

fact that the words are the names of other colours (i.e., the Stroop effect, 1935), and 4) switch between reading the word and naming the colour of the ink the word is printed in dictated by a visual cue (a rectangle around the target word), and to do so as quickly and as accurately as possible. Reaction time is the primary measure for this subtest. This attentional measure was also examined as part of an undergraduate student thesis project from the pilot data.

Brief estimate of intelligence. To verify the students' capacity, an abbreviated measure of ability was given using the *Vocabulary* and *Block Design subtests* of the WAIS-III. Participants were asked to provide definitions to words that increased in difficulty across trials to assess "verbal" intelligence. They received a score of 0, 1, or 2 per definition according to a standardized scoring procedure and a total accuracy score was recorded. For the "nonverbal" measure of intelligence, participants were asked to reproduce visually presented designs using specially designed blocks (2 sides red, 2 sides white, 2 sides red and white on the diagonal) to assess visuospatial ability. Accuracy and response times were recorded and using a standardized scoring procedure provided a total score.

Procedures

The informed consent form was read aloud to the participant by the researcher and the participant could ask any questions at that time. For participants in the "stress-induction" experimental condition (half of the students), participants were told that their performance during one of their tasks would be observed and evaluated by another researcher through the one-way mirror in the testing room (in reality, however, no one was observing their performance, they were debriefed at the end of the experiment as to this misinformation). Participants in the "relaxation-induction" condition were informed

regarding participation in a relaxation task (i.e., listening to a guided imagery recording, experiencing aromatherapy, and dimmed lighting). All students were advised that physiological recordings via electrodes and other instruments would be taken to measure heart rate, blood pressure and electrodermal responses. The participant and researcher completed two copies of the written informed consent form (one copy was given to the participant for his or her records and the other copy was retained by the researcher—see Appendix A5 and A6). Participants were informed that their participation in the study was voluntary, and that he or she was free to leave at any time without penalty.[4]

After informed consent was obtained, participants were connected to physiological recording equipment (Polygraph Professional; Limestone Technologies, 2008) to record heart rate (via pulse oximeter), respiration (via pneumatic chest bands), blood pressure (via a pneumatic blood pressure finger cuff) and EDA (via silver-silver chloride plated pads). Participants received initial instructions to remain relatively still, specifically not to intentionally move or tense their hands (i.e., given example of not pressing hand against table and were instructed that movement interferes with collecting a clear signal), and to breathe normally during physiological recordings. A three-minute baseline physiological recording was then obtained. All physiological activity recorded was coded numerically without personal identifiers. The physiological activity was recorded across the 2.5 hour testing session at seven different intervals: initial (baseline) recording, a pre-manipulation recording, during induction (as a manipulation check), after experimental induction (either stress-induction or relaxation depending on experimental condition), after cognitive testing

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[4] *Note.* One participant withdrew from the study early due to an exaggerated response to the psychosocial stressor and was provided with a debriefing form, debriefing from the faculty supervisor. The subject's data were not included in the analysis.

had commenced, after testing had completed, and at end of testing session. Note that the baseline physiological recording period lasted 3 minutes and all subsequent recordings were for a period of 2 minutes except during the arousal manipulation induction for which data was recorded throughout as a manipulation check. After initial baseline recording was taken, participants were asked to report their current level of arousal on a 10-point scale (1 *very relaxed* to 10 *very stressed*).

All participants were administered the Everyday Living (demographic) Questionnaire followed by the same battery of protected and standardized neuropsychological measures. Intelligence capacity measures (Vocabulary Test, Block Design Test, WAIS-III, 1997) as well as three cognitive tests to assess pre- and –post-manipulation differences were conducted: Colour-Word Naming Interference Test, Digit Symbol-Coding, and Trail Making Test; after which the arousal manipulation was introduced.

For the stress condition, the participant was asked to perform a verbal mathematical task (i.e., psychosocial stress-induction adapted from Shostak and Peterson (1990); Wymer (1996)—refer to Appendix A7 for verbal script[5]) consisting of 5 trials counting backwards from varied starting numbers by subtracting a constant digit and being asked to do so as quickly and as accurately as possible while being evaluated by a male spectator through the one-way mirror window in the testing room. Further, every time the participant made an error he/she was asked to start the sequence again from the last correct number. The purpose of this task was to induce psychological stress and increased arousal that mirrored,

[5] Similar to the Trier Social Stress Test (TSST; Kirschbaum, Pirke, & Hellhammer, 1993) procedure.

and is consistent with, the type of stress (and presumably less) students would typically experience in their university life (e.g., assignments, examinations, etc.).

The relaxation induction (refer to Appendix A8 for verbal script) consisted of listening to a compact disc (CD) recording (McMaster University, 2004; Guided Relaxation CD: Guided Imagery) of guided visual imagery and deep breathing exercises overlaid with calming ocean sounds. Participants listened to the recording via a Sony Discman. In addition, the lights were dimmed and aromatic scent (lavender) was diffused in the testing room to aid in inducing relaxation. All participants received the olfactory experience as none indicated sensitivity to scents. The experimenter left the testing room after giving instructions for the relaxation induction.

Physiological recordings were taken throughout both inductions as a manipulation check and participants were asked to provide a self-report of arousal state pre-and-post-manipulation induction. Both the stress and relaxation inductions took approximately nine minutes to complete, after which participants proceeded with the cognitive testing.

Manipulation Check

To verify that relaxation and psychosocial stressor manipulations were effective in inducing changes in arousal status separate 2 (MHI History: MHI, No-MHI) x 2 (Condition: Stress, Relaxation) X 4 (Time: Baseline, Before Manipulation, During Manipulation, After Manipulation) Repeated Measures Analysis of Variance (ANOVA) were conducted for physiological measures (EDA amplitude, EDA frequency, heart rate, and respiration frequency) of arousal and a 2 (MHI History: MHI, No-MHI) x 2 (Condition: Stress, Relaxation) X 3 (Time: Baseline, Before Manipulation, After Manipulation) Repeated Measures ANOVA was conducted for self-reported perceived

arousal state (refer to Tables C9 to C18 for details). Greenhouse-Geisser correction (denoted by $^{G\text{-}G}$) was used for electrodermal activity amplitude and frequency, as well as for self-reported arousal state.

Notably, the manipulations were effective. The two-way interactions of arousal manipulation condition as a function of time for each of the arousal measures was significant such that students both reported or produced heightened physiological arousal following the psychosocial stress manipulation compared to baseline measures; similarly, students' self-reported and physiological measures of arousal were lower following the relaxation manipulation as compared to baseline measures. As is evident from Figures 1 through 5, a pronounced effect occurred during the manipulations, but remained significantly changed: post-manipulation.

More specifically, self-reported arousal varied significantly as a function of time (baseline, before and after manipulation), $F^{G\text{-}G}(2, 174) = 7.50, p = .001$, and arousal manipulation (stress versus relaxation) conditions, $F(1, 87) = 36.19, p < .001$. There was also a significant interaction. Self-reported arousal varied significantly across time as a function of arousal manipulation condition, $F^{G\text{-}G}(2, 174) = 113.40, p < .001$, such that self-reported arousal scores were higher after the psychosocial stress induction and lower after the relaxation induction. As well, there was a significant main effect for MHI history in that students with MHI indicated lower self-reported arousal as compared to students without MHI, $F(1, 87) = 4.16, p = .044$. There was no significant interaction of MHI history and arousal manipulation condition, nor was there a 3-way interaction of time, arousal manipulation condition, and MHI history. Refer to Figure 1 and Tables C9 to C10.

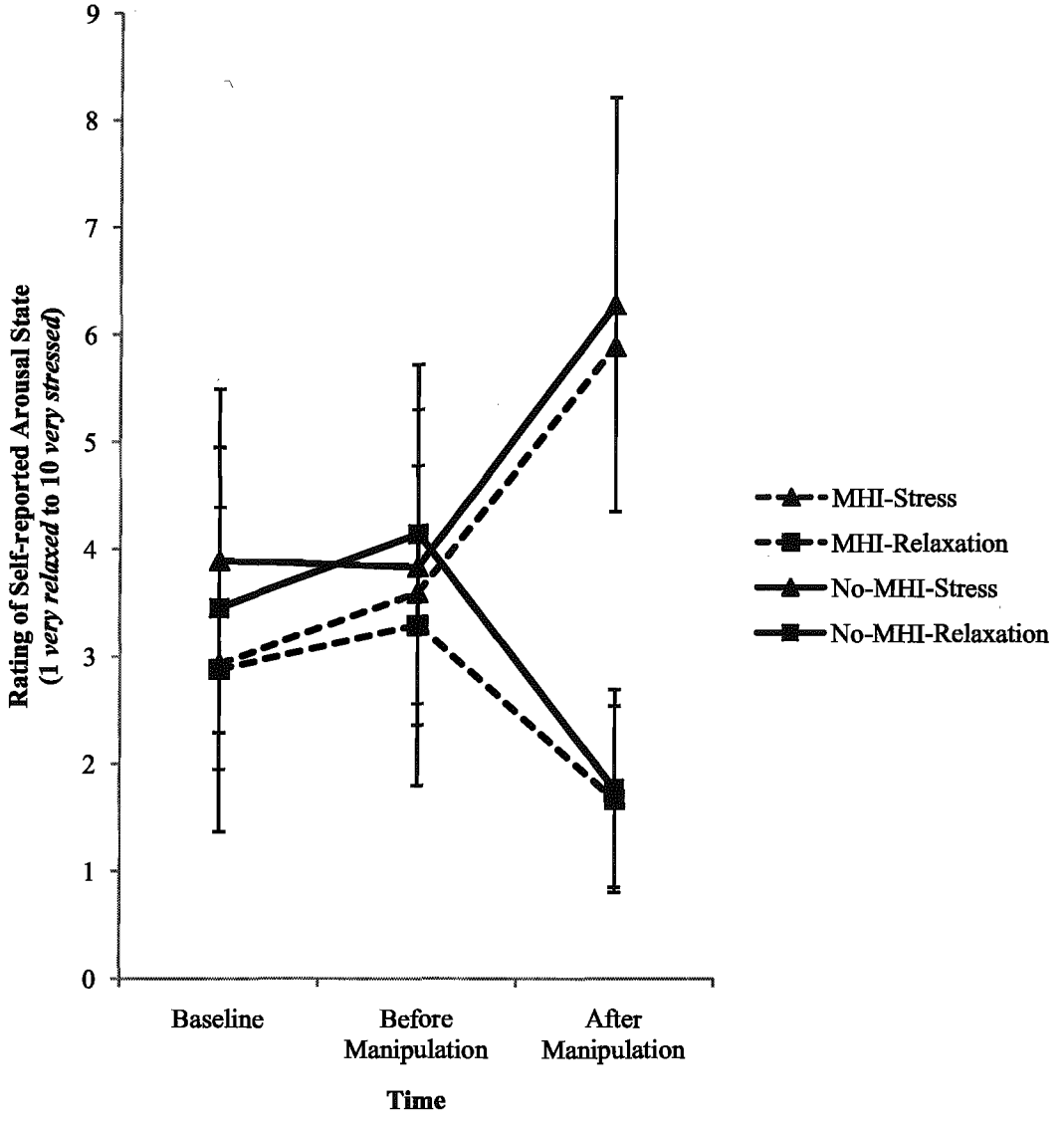

Figure 1. Self-reported arousal state across time (baseline, before manipulation, during manipulation, after manipulation) as a function of arousal manipulation condition and MHI history.

Electrodermal activity frequency (cycles per minute) increased significantly across time (baseline, before, during, and after arousal manipulation), $F^{G\text{-}G}(3, 261) = 30.36, p < .001$, but was not significantly different between arousal manipulation conditions, $F(1, 87) = 1.87, p = .173$. However, there was a significant interaction of arousal manipulation condition across time such that EDA frequency changed more for the stress group than the

relaxation group across time, $F^{G\text{-}G}(3, 261) = 3.27$, $p = .022$. Again, students with MHI were significantly less aroused (as indicated by slower EDA cycles) than their no-MHI counterparts, $F(1, 87) = 26.38$, $p < .001$, although MHI history did not produce any significant interactions. Refer to Figure 2 and Tables C11 to C12.

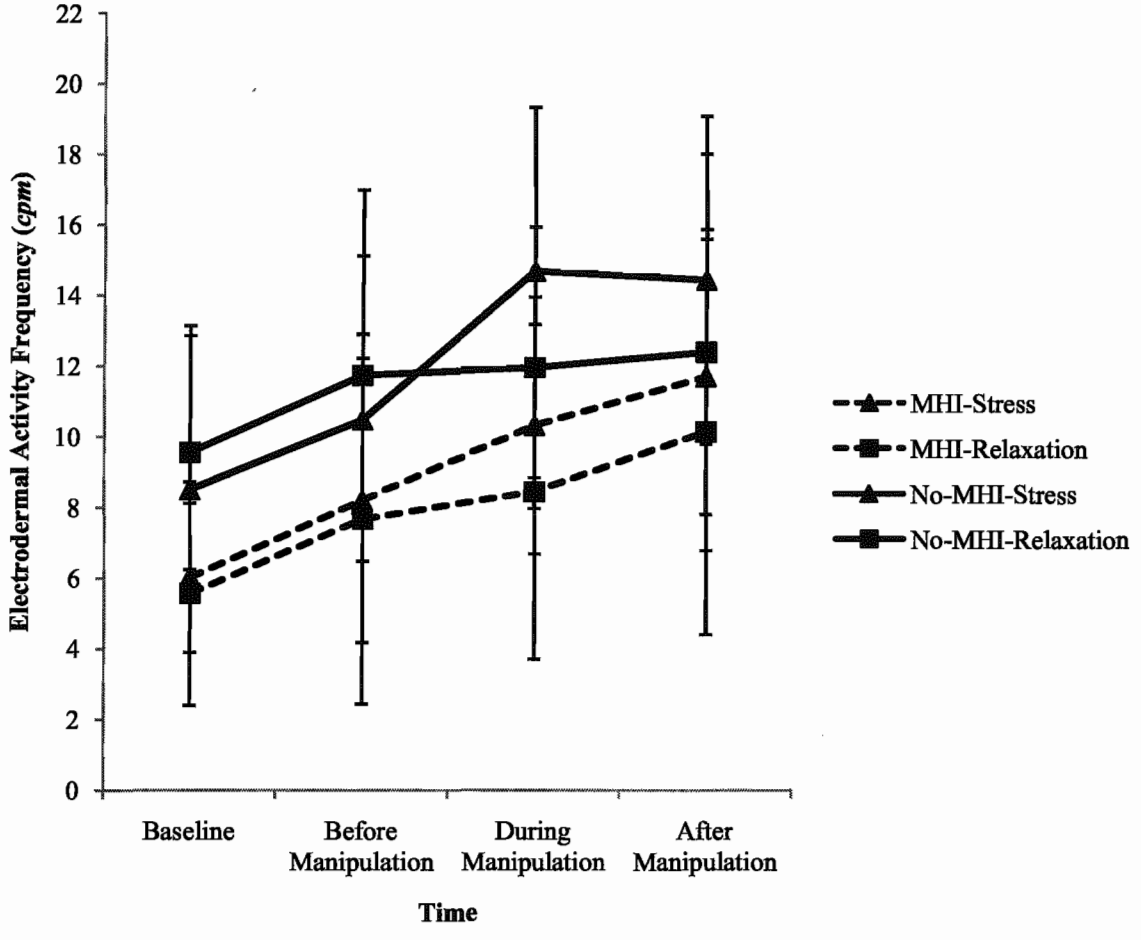

Figure 2. Electrodermal activity frequency across time (baseline, before manipulation, during manipulation, after manipulation) as a function of arousal manipulation condition and MHI history.

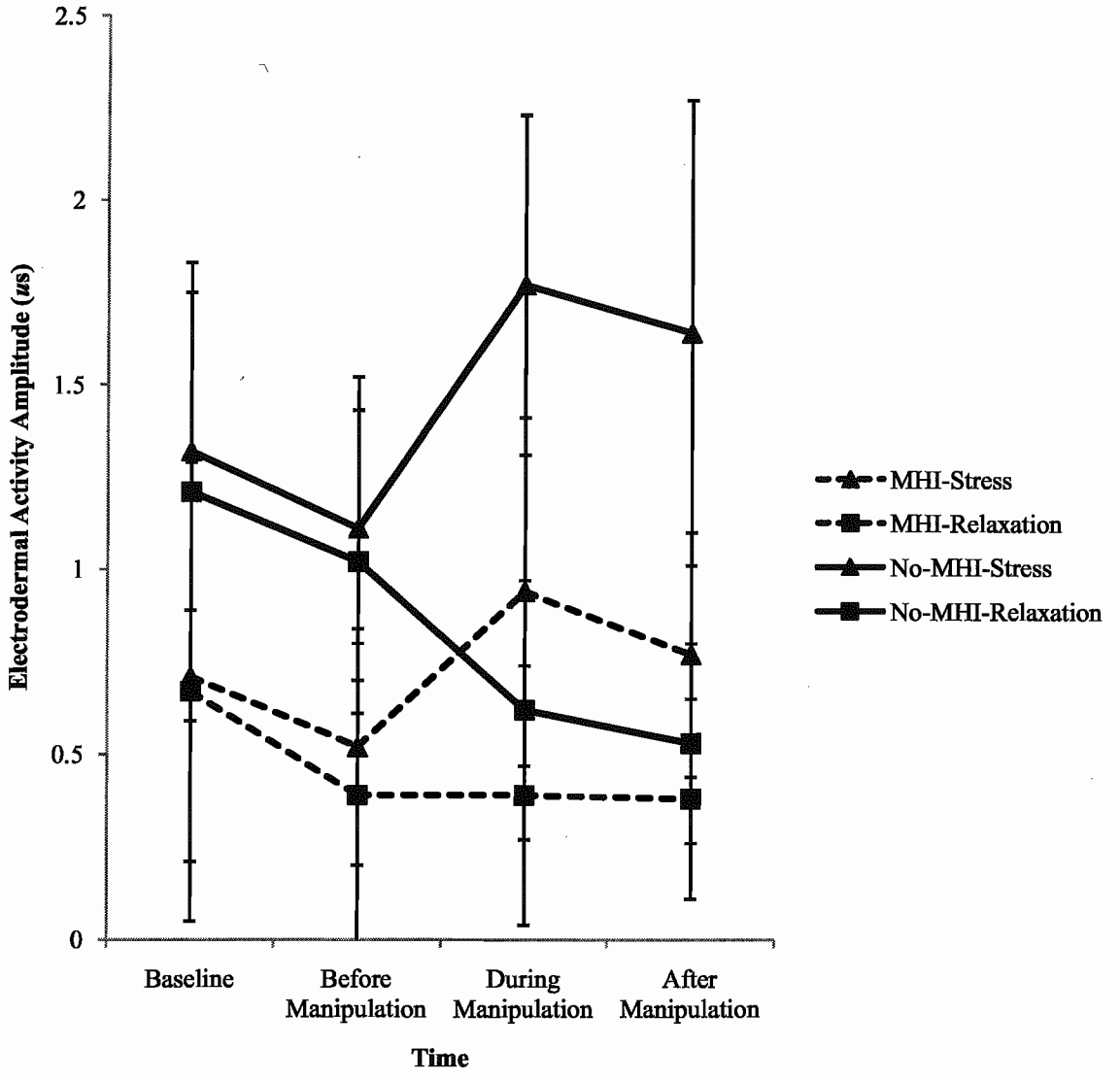

Figure 3. Electrodermal activity amplitude across time (baseline, before manipulation, during manipulation, after manipulation) as a function of arousal manipulation condition and MHI history.

EDA amplitude differed significantly across time, $F^{G\text{-}G}(3, 261) = 6.98$, $p = .001$, was found to be higher for the stress group as compared to the relaxation group, $F(1, 87) = 52.93$, $p < .001$, and was lower for students who reported a MHI as compared to students with no MHI, $F(1, 87) = 82.49$, $p < .001$. There was a significant interaction of time and arousal manipulation condition such that the difference between the arousal manipulation

conditions for EDA amplitude was greater after the manipulation than pre-manipulation measures, $F^{G\text{-}G}(3, 261) = 30.51, p < .001$. There was a significant interaction of MHI history and arousal manipulation condition, $F(1, 87) = 7.68, p = .007$, and a significant 3-way interaction of time, MHI history, and arousal manipulation condition, $F^{G\text{-}G}(3, 261) = 6.73, p < .001$. Refer to Figure 3 and Tables C13 to C14.

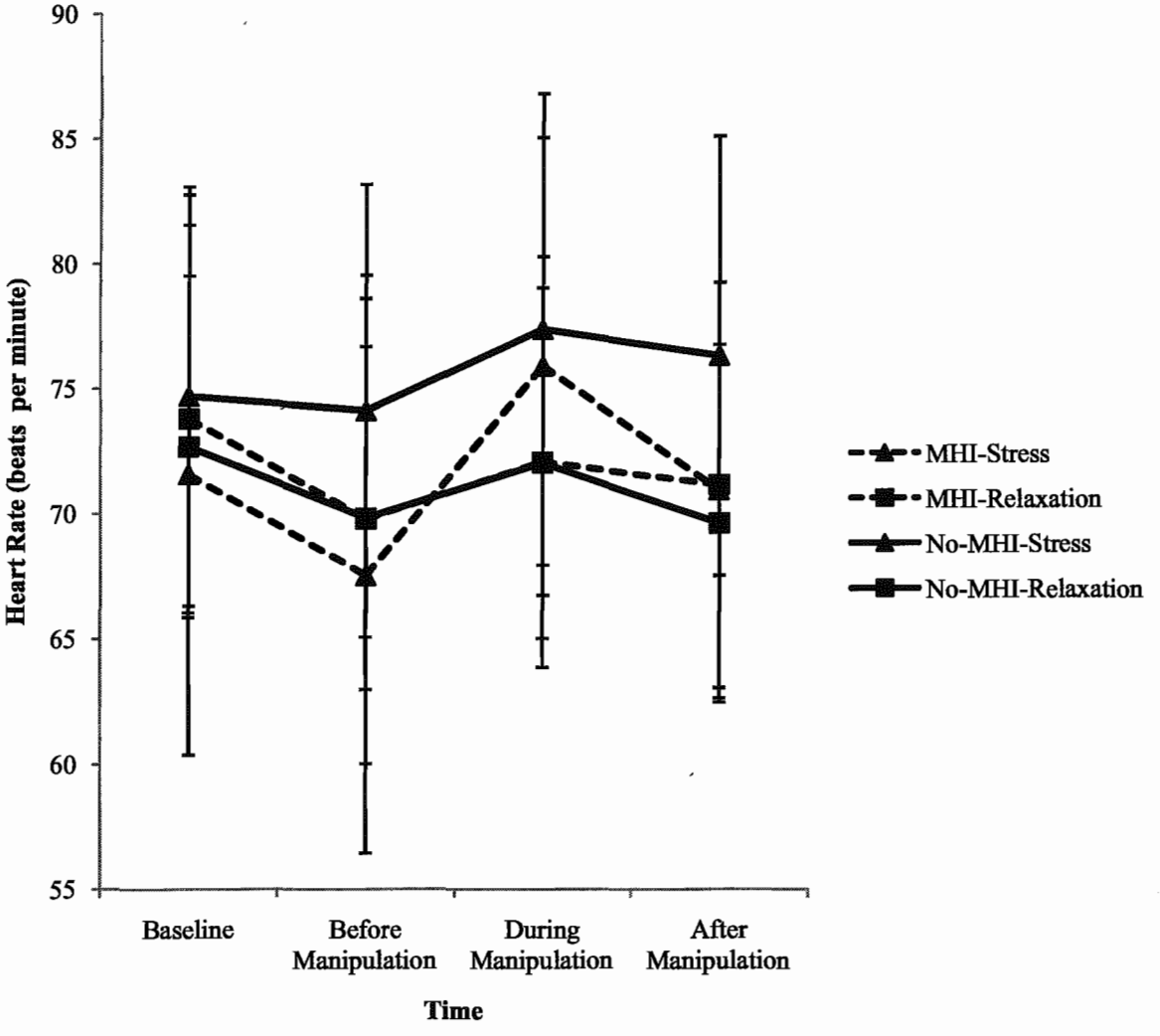

Figure 4. Heart rate frequency across time (baseline, before manipulation, during manipulation, after manipulation) as a function of arousal manipulation condition and MHI history.

Heart rate significantly varied across time, $F(3, 261) = 13.02$, $p < .001$, but was not found to differ significantly between MHI groups, $F(1, 87) = 1.11$, $p = .296$, nor between arousal manipulation conditions, $F(1, 87) = 1.74$, $p = .191$. A 2-way interaction of time and arousal manipulation condition was observed, $F(3, 261) = 4.95$, $p = .002$, such that heart rate increased in beats per minute during both stress and relaxation inductions as compared to pre-manipulation measures and post-induction heart rate remained high for the psychosocial stress group and was lower for the relaxation group. No other interactions were observed. Refer to Figure 4 and Tables C15 to C16.

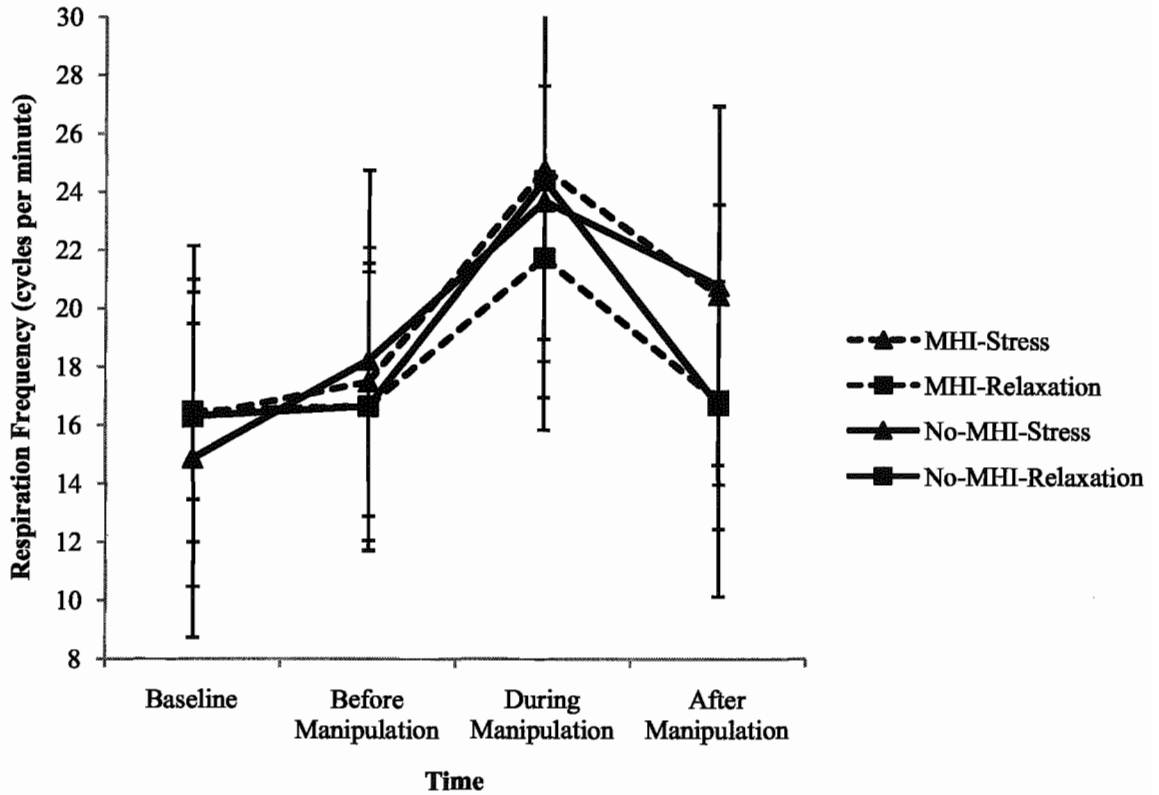

Figure 5. Respiration frequency across time (baseline, before manipulation, during manipulation, after manipulation) as a function of arousal manipulation condition and MHI history.

Respiration frequency (cycles per minute) increased significantly across time with faster cycles during the manipulation, $F(3, 261) = 42.88, p < .001$. There was a tendency for more rapid breathing to occur in the stress group as compared to the relaxation group, $F(1, 87) = 3.06, p = .084$. There was a 2-way interaction of time by arousal manipulation condition, $F(3, 261) = 3.47, p = .017$, in that faster frequencies were observed during the arousal induction and post-manipulation respiration remained elevated for the stress group and was lower (notably very similar to baseline) for the relaxation group. No other significant main effects or interactions were observed. Refer to Figure 5 and Tables C17 to C18.

Following the arousal manipulation and self-report of current level of arousal, participants were then given several cognitive tests. The tests included measures of narrative explicit memory (Logical Memory I and II [WMS-III, 1997]); non-verbal spatial memory (Memory for Design [NEPSY-II, 2007]); working memory capacity, cognitive flexibility, concentration, sequencing, and RT (Digit Symbol-Coding and Mental Control [WAIS-III, 1997]); Trail Making Test Parts Ib and II [DKEFS, 2002]); abstract reasoning and planning (Picture Arrangement [WAIS-III,1997]; Pictorial Analogies [CTONI, 1996]; Tower of Hanoi [DKEFS, 2002]); and, selective attention, cognitive flexibility, impulse control and RT (Colour-Word Naming Interference Test [DKEFS, 2002]; Mental Control [WAIS-III, 1997]). Participants also completed the State-Trait Anxiety Inventory Form-Y (STAI, Spielberger, 1983a) questionnaire, and the PCS Checklist (Gouvier et al., 1992). Participants also provided self-reports of current perceived level of arousal during and after neuropsychological testing; physiological recordings were also taken. Refer to Figure 6 for a summary of the procedures and the order of administration of tasks and data collection.

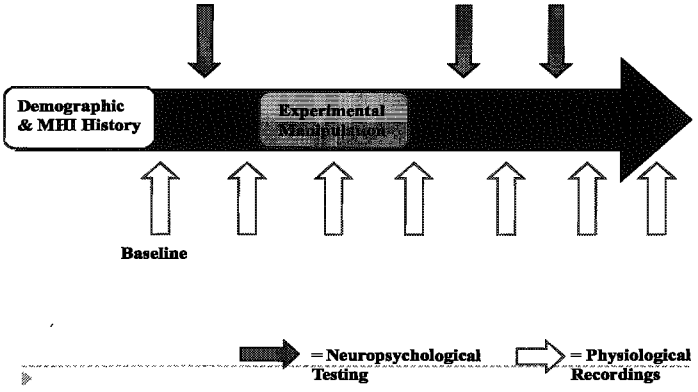

Figure 6. Summary of procedures.

Summary

1. Consent procedures and physiological recording check
2. Initial (Baseline) Physiological Recording (1) and Self-Report of Arousal State (1)
3. Brock University Neuropsychology Cognitive Research Lab Everyday Living Questionnaire
4. Pre-manipulation Neuropsychological testing
    a. Vocabulary Test—(WAIS-III, 1997)
    b. Block Design—(WAIS-III)
    c. Colour-Word Naming Interference Test—(DKEFS, 2002)
    d. Digit Symbol-Coding—(WAIS-III)
    e. Trail Making Test (Part Ia-DKEFS)
5. Pre-manipulation Physiological Recording (2) and Self-Report of Arousal State (2)
6. Experimental Arousal Manipulation and Manipulation Check Physiological Recording (3)
7. After manipulation Physiological Recording (4) and Self-Report of Arousal State (3)
8. After manipulation Neuropsychological Testing Block I
    a. Logical Memory I—Story A Immediate Recall (WMS-III, 1997)
    b. Picture Arrangement—(WAIS-III)
    c. Memory for Design—(NEPSY, 2007)
    d. Pictorial Analogies—(CTONI, 1996)
    e. Trail Making Test (Part Ib and Part II-letter-number-letter switching)
    f. Mental Control—(WAIS-III)
9. Physiological Recording (5) and Self-Report of Arousal State (4)
10. After manipulation Neuropsychological Testing Block II
    a. Logical Memory II—Story A Delayed Recall (WMS-III)
    b. Tower of Hanoi—(DKEFS)
    c. Colour-Word Naming Interference Test (2nd time; DKEFS)
    d. Digit Symbol-Coding (2nd time; DKEFS)
    e. Memory for Design—Delayed Recall (NEPSY)
11. Physiological Recording (6) and Self-Report of Arousal State (5)
12. STAI (Spielberger, 1983a) and PCS Checklist (Gouvier et al., 1992) Questionnaires
13. Final Physiological Recording (7) and Self-Report of Arousal State (6)
14. Debriefing Session

Overall, participation in this study (including time for acquisition of informed consent and debriefing procedures) did not exceed two and a half hours. After tests and questionnaires were completed, participants were verbally debriefed as to the purpose of the study and given a written debriefing form (see Appendix A9 and A10). Finally, participants were thanked for their time and participation in the study, and were invited to view the results of the study at its completion (by August 31, 2009).

Data Analyses

Analyses of the data were conducted via Statistical Package for the Social Sciences (SPSS Version 16.0, 2007). Note physiological data averages were computed via Polygraph Professional software (Polygraph Professional Suite, 2008, Limestone Technologies Inc.). With the exception of tabular or illustrated data presented in this section, the statistical results for all analyses are in Appendix C which is provided on the appended compact disc. Assumptions for all statistical analyses have been examined and are commented on with respect to any violation, otherwise assumptions may be assumed to be met. Again, Greenhouse-Geisser correction is denoted $^{G\text{-}G}$. Analyses are considered to be significant if $p \leq .05$, however, trends approaching statistical significance are also discussed.

For the descriptions of group differences on categorical variables, the Pearson Chi Square statistic was used; for the cell counts that were less than five, Fisher's Exact Test was used (as noted in Howell, 2007). To examine group differences for continuous measures, t-tests, one-way ANOVAs and factorial ANOVAs were used. Mixed model ANOVAs were conducted for physiological and self-reported measures of arousal as well as for certain cognitive measures to examine differences between MHI groups and

conditions. Partial eta-squared was manually calculated to ensure accuracy in reporting effect size (Levine & Hullett, 2002) and effect sizes are reported in Appendix C ANOVA summary tables. Because of the exploratory nature of some analyses, adjustments were not always made for multiple analyses. Nonparametric statistics were used for more conservative post-hoc analysis for measures where noted. Note that for all main hypothesized analyses sex was entered as a covariate and this was not found to impact the results as such the results presented here are not adjusted for sex.

Results

Demographic information by MHI History

Students reporting MHI. Fifty-six percent of students self-reported a history of MHI[6] occurring, most commonly, 2 years ago (median = 2 years; mode = 2 years); however, with a mean of 5 years (range 2 weeks to 23 years) at approximately16 years of age (median = 17 years; mode = 17 years). Of those who reported a history of MHI, one-third reported experiencing a loss of consciousness (LOC) with 93% reported experiencing a LOC for less than 5 minutes, and one participant reported a LOC greater than 5 minutes but less than 30 minutes. Based on the Cantu (1986) concussion severity grading scale, 70.59 % of students who reported an MHI reported experiencing only an altered state of consciousness and no LOC (i.e., Grade I concussion); the remaining were Grade II; none were in the highest concussion group—and all are considered mild head injuries. Approximately half of students described the MHI they most recently experienced had

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[6] *Note.* Although the prevalence of MHI makes up more than half of this sample, previous research in our lab (e.g, Chiappetta & Good, 2009 [40% MHI]; DeBono & Good, 2008 [52% MHI]; Dzyundzyak & Good, 2008 [51% MHI]; St.Cyr & Good, 2007 [30% MHI]; van Noordt & Good, 2009 [41% MHI] has shown similar proportions when using this liberal criterion of 'altered state of consciousness' in a university student population.

resulted in a concussion. Only 40% of students who reported a MHI also reported receiving medical treatment for their injury (such as receiving stitches) and approximately 10% stayed overnight in a medical facility for their injury (refer to Table 2). With respect to etiology (refer to Table 3), head injuries were most commonly reported to have been incurred via sport-related incidents (54.90%) followed by falls (25.50%). Notably, no participants had been in a motor vehicle collision. Note that reference to MHI group throughout this thesis refers to students who reported at least one mild head injury.

More than one MHI. Of those students who self-reported a MHI, 60.78 % ($n = 31$) reported more than one (ranging of 2 to 20 head injuries, mode = 2; median = 4; mean = 5.13, $SD = 4.94$). Students described the second, less recent MHI occurring at approximately 15 years of age ($SD = 3.80$; mode = 16, median = 16; ranging from 6 to 21 years) with an average of 6 years since the incident. Of those who reported more than one MHI, approximately two-thirds described the injury as consisting of an altered state of consciousness with no LOC (i.e., Grade I concussion severity). Of the remaining third, 72.70% reported an LOC less than 5 minutes duration and three reported an LOC of less than 30 minutes (i.e., all had Grade II Concussion or less). Similar to the descriptions of the most recent injury, approximately half ($n = 15$) reported that the second injury had resulted in a concussion with only a third seeking medical treatment (16% receiving stitches and two students staying overnight in a medical facility) (refer to Table 2). Students most commonly reported sports-related injuries and falling (83.90%) as the cause, while one participant (3.20%) reported the head injury resulted from a motor vehicle collision (refer to Table 3).

Table 2

Indicators of Severity for Self-reported Mild Head Injuries

N = 51	*Most recent MHI* *n* = 51; 56.00%		*Previous MHI* *n* = 31; 60.78%	
Mean age at Injury	16.01	(5.43)	14.97 (3.80)	
Years Since Injury	5.01	(5.72)	5.79 (4.93)	
	n	*Percentage*	*n*	*Percentage*
Loss of Consciousness (LOC)	15[a]	29.40	11[b]	34.40
Less than 5 minutes	14	93.33	8	72.70
More than 5 minutes but less than 30 minutes	1	6.67	3	27.30
Altered State of Consciousness (and no LOC)	36	70.59	20	64.51
Concussion	24	47.10	15	48.00
Received Medical Treatment	20	39.20	10	32.30
Stitches	7	13.70	5	16.10
Overnight stay at Medical Facility	5	9.80	2	6.50

Note. Numbers in parentheses are standard deviation.
Note[a]. Missing 5.9% of responses (*n* = 3) for loss of consciousness for most recent MHI.
Note[b]. Missing data for one participant (3.22%) for loss of consciousness for previous MHI.

Table 3

Self-reported Etiology of Mild Head Injuries

	Most recent MHI ($n = 51$, 56.00%)		*Previous MHI* ($n = 31$, 60.78%)	
Etiology of MHI	*n*	*Percentage*	*n*	*Percentage*
Sport-related injury	28	54.90	20	64.50
Falling	13	25.50	6	19.40
Other (e.g., fights)	10	19.60	4	12.90
Motor Vehicle Collision	0	0.00	1[a]	3.20

Note[a]. Participant was a 19 year old female who reported incurring an MHI via a motor vehicle collision 6 years prior to participation in our study; she reported experiencing a LOC for less than 5 minutes and she indicated that it had resulted in a concussion; she also reported that she did not receive medical treatment for this injury.

Thus, the most recent and immediately previous mild head injuries are all within the criteria for MTBI (i.e., refer to Kay et al., 1993) and Grade II Concussion or less (Cantu, 1986) with respect to the more subtle nature of the severity of injury.

Representation across MHI groups and arousal manipulation. As illustrated in Table 4, the participants were not differentially represented across arousal manipulations

and MHI history, χ^2 (1, N = 91) = .57, p = .452. Also, as expected[7], there was significantly more representation of males in the MHI group, χ^2 (1, N = 91) = 3.89, p = .049 (refer to Table C19). Although male and females with MHI appear to be differentially represented across arousal manipulation conditions with especially poor representation of males who reported no history of head injury, the Chi-square analysis was not significant, for stress, χ^2 (1, N = 45) = .36, p = .686[8], and relaxation, χ^2 (1, N = 46) = .40, p = .617[8], conditions, respectively (refer to Table C19). Further, students reporting MHI were equally represented in the stress and relaxation manipulation conditions, χ^2 (1, N = 91) = .57, p = .452, (refer to Table C20). Sex was not differentially represented in relaxation and stress conditions, χ^2 (1, N = 91) = .15, p = .701, (refer to Table C20). As well, students were not differentially represented by MHI history for years of education, for lower year students, χ^2 (1, 29) = .12, p = .728, and upper year students, χ^2 (1, 62) = .32, p = .575, respectively (refer to Table C21). For distribution of time since MHI occurred across arousal manipulation conditions see Tables C22 and C23.

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[7] E.g., Rutland-Brown, Langlois, Thomas, and Xi (2006) reported that males are 1.5 times as likely to incur a head injury than females; further, males are twice as likely as females to incur a mild head injury especially from 15-24 years of age (Kraus & Nourjah, 1988).

[8] *Note.* Fisher's Exact Test values as cell counts are less than 5.

Table 4

Representation across MHI History and Arousal Manipulation Condition

MHI History	Arousal Manipulation Condition		
	Stress	Relaxation	Total
MHI	52.90% (27)	47.10 % (24)	(51)
No-MHI	45.00% (18)	55.00% (22)	(40)
Total	(45)	(46)	

Note. Values in parentheses are *n*.

Other Health-related Information

Overall health. Students' reports of hospitalizations (i.e., for illness, fractures, surgery, or other medical complications), stimulant usage (caffeine, cigarettes), use of relaxation techniques and exercise history did not vary as a function of MHI history and arousal manipulation condition (refer to Tables C24 to C28). Similarly, arousal indicators such as level of alertness, reports of typical sleep and their ratings of sleep quality the night prior to participating in the testing session were not found to be differentially represented for MHI history and arousal manipulation condition (refer to Tables C29 to C33); nor did MHI differentially predict sleep quality ratings or alertness. However, no-MHI subjects, in general, did not exercise as regularly ($p = .071$, refer to Table C28); this was not found to affect further analyses.

Mental health and neurological conditions. Although five students in the MHI group and six students in the no-MHI group reported previous diagnoses of either a

psychiatric or neurological condition, such history was not differentially represented for students with MHI, χ^2 (1, N = 51) = 1.63, p = .354[9], or students without MHI, χ^2 (1, N = 40) = 4.19, p = .073[9], across manipulation conditions; however, there was a tendency for more no-MHI students in the stress condition to report a history of neurological or psychiatric history (refer to Table C34). Note the percentage of students' reports of such history in the total sample is 12.10% (n = 11) which is similar to, and less than, reports of prevalence of psychiatric disorders in other university samples (e.g., see Gallagher, Gill & Sysko, 2000; Kitzrow, 2003). Furthermore, only 6 of the 11 students (a total of 6.60% of the entire sample) who reported positive psychiatric or neurological history also reported current prescribed medication use for these conditions which is similar to other reports in university students (see Soet & Sevig, 2006). Medication use was not differentially represented across MHI groups and arousal manipulation, χ^2 (1, N = 91) = .10, p = .999; χ^2 (1, N = 91) = 2.95, p = .111, (refer to Table C35). Students were not requested to disclose the type of medication they were prescribed for treatment.

Other Psychosocial Information

Students with and without MHI reported similar living situations (e.g., with roommates, parents/guardians, partner, on his/her own) (refer to Table C36). As well, reports of history of receiving educational assistance (i.e., speech and language pathologist, occupational therapist, learning resource teacher, educational assistant, physical therapist, or tutor), or current student status (i.e., full-time), was not differentially represented for students with and without MHI (refer to Tables C37 and C38). Similarly, reports of the number of academic assignments completed in past month and reported

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[9] *Note.* Due to small cell counts Fisher's Exact Test values were used.

overall enjoyment of academics was not different between MHI groups (refer to Table C39).

Semester and Time of Day for Testing

These data were collected over an academic year (winter, spring, summer, and fall semesters[10]) in both morning and afternoon sessions. Students were equally represented in morning and afternoon testing sessions across arousal manipulation conditions for those with, χ^2 (1, 51) = 2.41, p = .121, and without MHI, χ^2 (1, N = 40) = .04, p = .842, (refer to Table C40). There was no differential representation across arousal manipulation conditions with respect to semester of testing for students with MHI, χ^2 (3, N = 51) = 3.02, p = .558, and those without MHI, χ^2 (3, N = 40) = 1.53 = .795, (refer to Table C41—Fisher's Exact Test values used).

The data were also examined for possible differences in baseline self-reported and physiological arousal measures via separate 2 (MHI group: MHI, no-MHI) X 2 (Condition: Stress, Relaxation) X 2 (Time of day of data collection: morning, afternoon) ANOVAs. Refer to Tables C42 to C56. Other than the predicted significant main effects demonstrating lowered initial baseline arousal for students reporting MHI (to be discussed later), no significant differences were observed for the interactions of MHI groups or arousal manipulation conditions as a function of time of day for data collection for baseline self-reported and physiological arousal (EDA amplitude, heart rate, or respiration), except one. A significant interaction of MHI history and time of day, F (1, 83) = 4.82, p = .031, was shown for EDA frequency (refer to Tables C45 and C46). Follow up investigation indicated that baseline EDA responses in the afternoon produced faster

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[10] *Note.* Data were not collected during the month of December.

frequencies than in the morning for no-MHI students but was not found to change for the MHI group (refer to Tables C47 to C50).

Hypotheses

Hypothesis 1: Decreased Arousal at Baseline for Students with MHI

Persons who report a history of MHI will be underaroused, overall, compared to those without head injury (similar to that of persons with moderate-to-severe VMPFC injury) and will present with a general decreased physiological stress response and decreased perceived stress (as indicated by lower ratings of stress on self-reported measures and lower responsivity on physiological measures of electrodermal activity) due to their expected reduced emotional and functional reactivity.

Self-report of Arousal and Perceived Stress at Baseline

Self-report of arousal. As hypothesized, students who had sustained MHI rated themselves (1 *very relaxed* to 10 *very stressed*) as having a significantly lower arousal state, $M = 2.90$, $SD = 1.51$, at baseline than students without MHI, $M = 3.65$, $SD = 1.54$, $F(1, 87) = 5.60$, $p = .020$, refer to Figure 7. Note that self-reported arousal state did not differ between assigned relaxation and stress conditions at baseline measurement, $F(1, 87) = .55$, $p = .459$, nor was there a significant interaction, $F(1, 87) = .35$, $p = .558$, (refer to Tables C57 to C58).

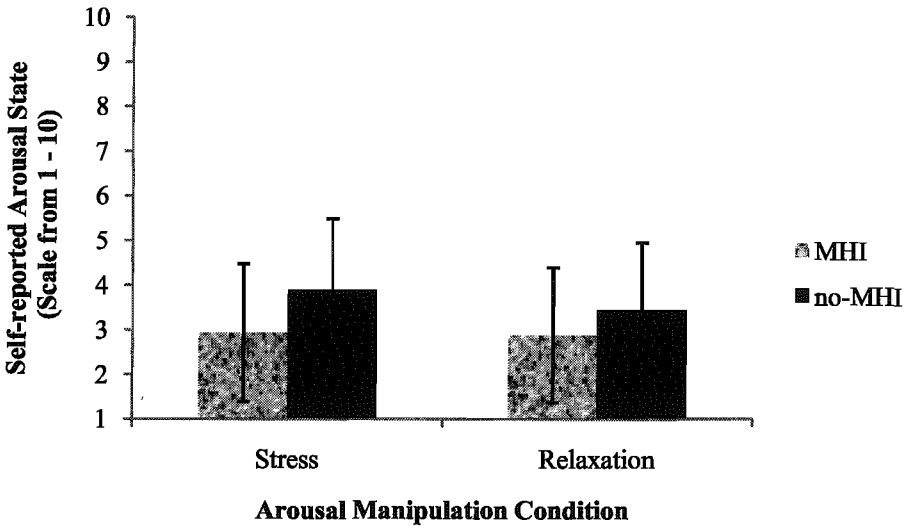

Figure 7. Self-reported arousal state as a function of MHI History at baseline.

Self-report of life stressors. Despite reporting lower levels of arousal, students with MHI acknowledged a significantly higher number of life stressors such as financial difficulties, moving, or difficulties in personal relationships than students without MHI, t (84) = 2.26, p = .027[11]. Similarly, students with MHI had higher total scores[12] on the Life Stressors Scale (modified from Holmes-Rahe, 1967) as compared to students without MHI, t (89) = 2.51, p = .014 (refer to Figure 8 and Table C59). However, on another measure of stress from the Everyday Living (demographic) Questionnaire that asked students to rate their perceived day-to-day life stress students with MHI did not differ from those without, t (89) = 1.35, p = .181. Interestingly, despite the greater reporting of stressful experiences, students with MHI tended to report greater life satisfaction than their cohorts, t (82) = 1.67, p = .099, (refer to Table C60).

[11] *Note.* Equal variances not assumed.
[12] *Note.* This is a weighted score as a function of stress impact.

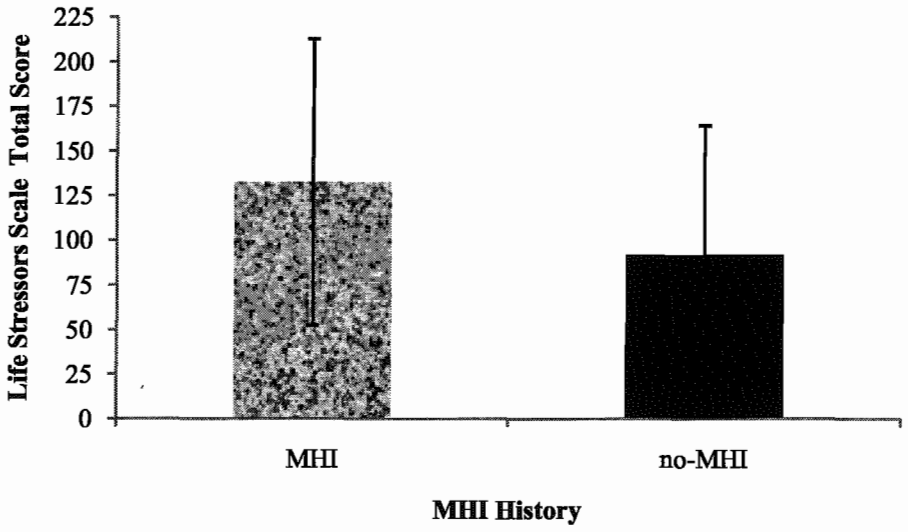

Figure 8. Life Stressors Scale Total Score for students with and without MHI.

Current day factors. Students' ratings of how stressful their current day had been prior to arriving for the testing session (1 *not stressful* to 10 *very stressful*) did not differ between MHI groups, t (89) = .62, p = .538. Similarly, students' ratings of how busy their day was (1 *calm* to 10 *busy*) did not differ by MHI group, t (89) = .09, p = .925, nor did their ratings of overall pleasantness (1 *more pleasant* to 10 *less pleasant*), t (89) = .94, p = .350, (refer to Tables C61 and C62). Furthermore, students were asked to report if anything out-of-the-ordinary had occurred in the past day or so and, again, there were no differences between MHI groups[13], χ^2 (1, N = 91) = 1.80, p = .180, (refer to Table C63). As such, these indices do not appear to account for the significantly lower self-reported arousal state observed for students who reported MHI as compared to students without such history prior to experimental manipulation.

[13] *Note.* Ratings of day prior to participating in testing session and occurrence of out-of-the-ordinary events did not differ between manipulation conditions either.

Baseline Physiological Arousal

Physiological arousal at baseline. To test the hypothesis of lowered resting physiological arousal (prior to any experimental manipulation) for students with MHI compared to students without MHI, separate one-way ANOVAs were conducted for each of the physiological measures (EDA, HR, Respiration) as a function of MHI history, with particular focus on EDA (amplitude and frequency measures) and HR (beats per minute) as indices of sympathetic arousal. As hypothesized, students with MHI produced significantly slower EDA responses (cycles per minute), $M = 5.80$, $SD = 2.64$, $F(1, 89) = 29.15$, $p < .001$, and attenuated average amplitude, $M = .69$, $SD = .49$, $F(1, 89) = 28.06$, $p < .001$, as compared to their no-MHI counterparts, $M = 9.08$, $SD = 3.15$, $M = 1.26$, $SD = .54$, (refer to Figures 9 and 10; Tables C64 to C67). However, differences in HR (beats per minute), $F(1, 89) = .28$, $p = .600$, or respiration (cycles per minute), $F(1, 89) = .48$, $p = .488$, were not significant (refer to Tables C68 to C71).

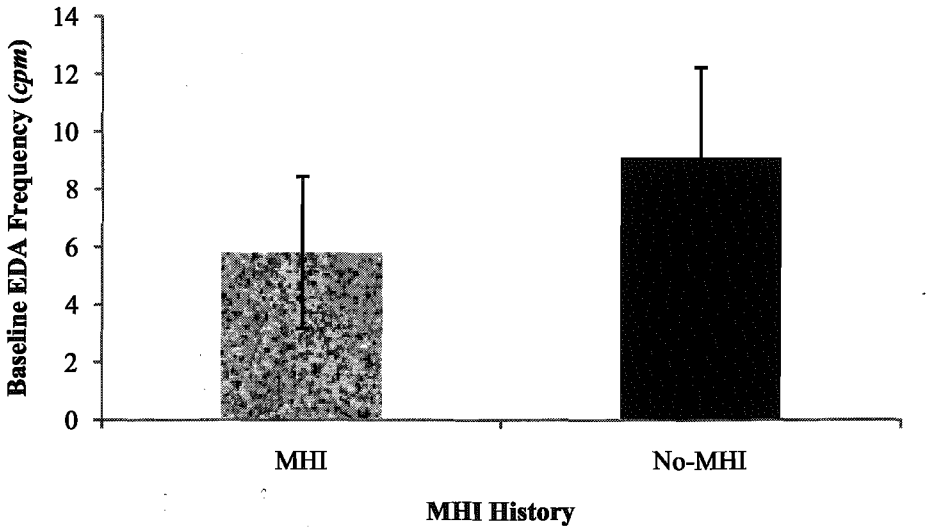

Figure 9. Baseline average EDA frequency as a function of MHI history.

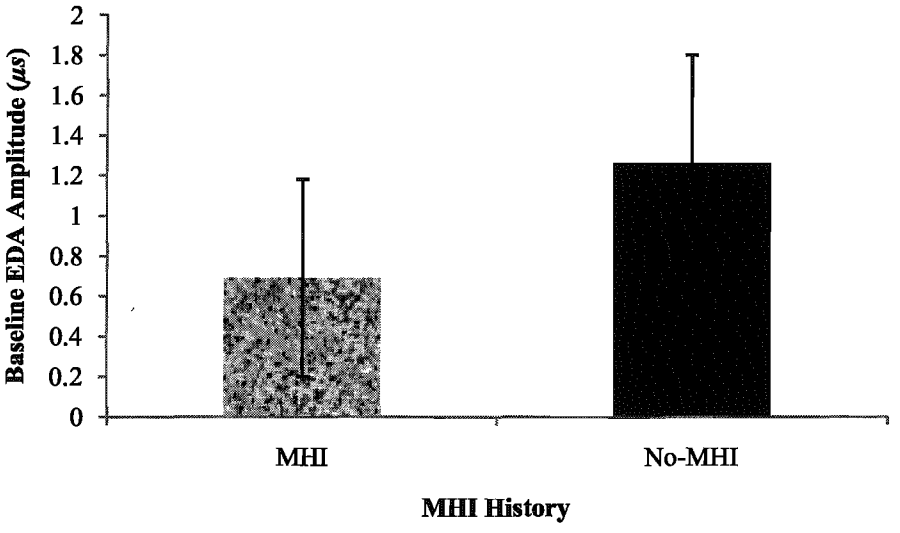

Figure 10. Baseline average EDA amplitude as a function of MHI history.

Intercorrelations of arousal measures at baseline. Note that before introducing the experimental manipulation of arousal, the self-reported arousal measure was positively correlated with the physiological arousal measures of EDA frequency and amplitude at baseline, but was not significantly correlated with resting respiration or heart rate (refer to Table C72).

Hypothesis 2: Responsivity to Arousal Manipulation between MHI Groups

Due to the expected overall reduced responsivity (i.e., underarousal) of persons with MHI it is expected that responsivity to the arousal manipulations (psychosocial stress or relaxation) will be relatively greater for persons with no-MHI as compared to persons with MHI with respect to both self-reported measures of arousal and physiological indices.

Responsivity to arousal manipulation as a function of MHI history. Separate 2 (MHI History: MHI, no-MHI) X 2 (Arousal Manipulation Condition: Stress, Relaxation) X 2 (Time: Pre-manipulation, Post-manipulation) ANOVAs were conducted for self-report

of arousal, EDA amplitude and heart rate to illustrate the dampened responsivity of students with MHI to the arousal manipulations. As portrayed in Figure 11 (refer to Tables C73 and C74), the psychosocial stress manipulation was effective for both students with or without MHI as they rated their arousal state as heightened following the psychosocial stressor as compared to the relaxation, $F(1, 87) = 80.50, p < .001$, and as a function of time, $F^{G\text{-}G}(1, 87) = 124.58, p = < .001$. There was a significant main effect for MHI history, $F(1, 87) = 3.94, p = .050$, in that students' ratings of arousal were lower for the MHI group; however, there was no significant interaction for self-reported arousal as a function of MHI history across time, $F^{G\text{-}G}(1, 87) = 2.01, p = .160$, nor was there a 3-way interaction observed, $F^{G\text{-}G}(1, 87) = .02, p = .892$. Note Greenhouse-Geisser correction used.

Despite reports of increased perceived stress, the physiological response (as indicated by EDA amplitude and heart rate measures—refer to Figures 12 and 13) for students who have sustained an MHI does not mirror this pattern, whereas the response for the no-MHI group does (see Tables C75 through C82). More specifically, students with MHI produced significantly smaller EDA responses as compared to their no-MHI cohort, $F(1, 87) = 55.53, p < .001$; EDA amplitude was also significantly smaller in the relaxation condition compared to the stress condition, $F(1, 87) = 31.86, p < .001$, and varied across time, $F^{G\text{-}G}(1, 87) = 29.57, p < .001$. A significant interaction was evident in that students with MHI demonstrated significantly less change in EDA amplitude when comparing stress and relaxation conditions than students without MHI, $F(1, 87) = 7.57, p = .007$, and as a function of time, $F^{G\text{-}G}(1, 87) = 6.94, p = .010$ (refer to Figure 12 and Tables C75 to C76).

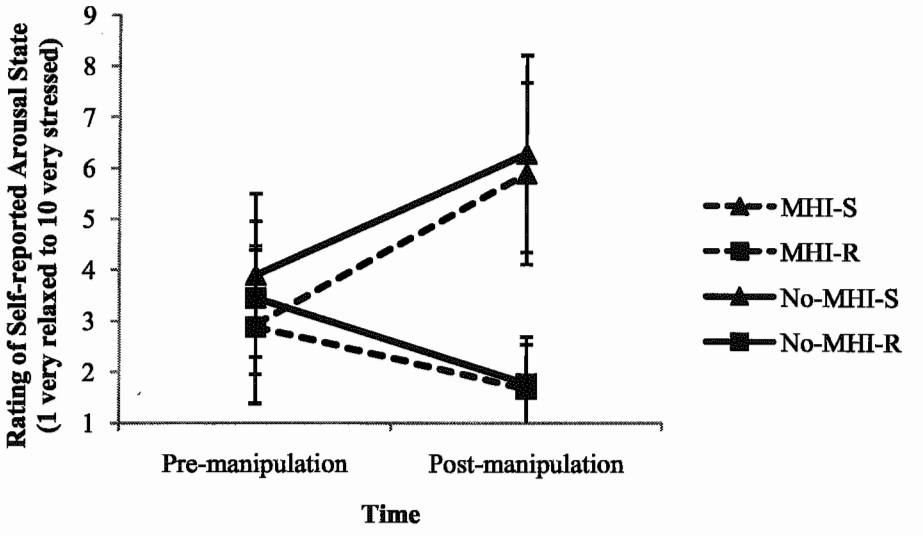

Figure 11. Self-reported arousal state as a function of MHI history and arousal manipulation condition across time.

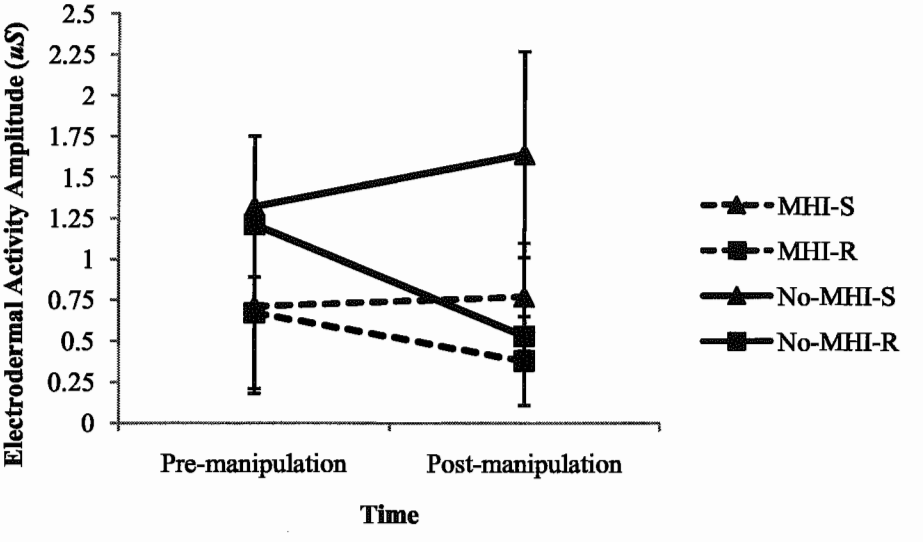

Figure 12. Electrodermal activity amplitude as a function of MHI history by arousal manipulation condition across time.

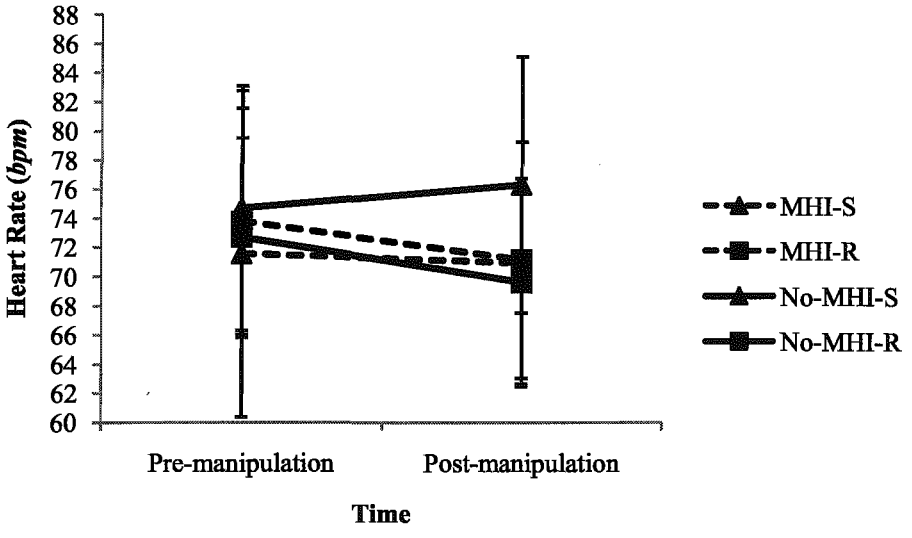

Figure 13. Heart rate as a function of MHI history and arousal manipulation condition across time.

Similarly, there was a significant interaction of arousal manipulation condition and time in that there was a greater change in heart rate following the stress condition as compared to the relaxation condition post-manipulation, F (1, 87) = 4.89, p = .030. Heart rate did not differ between MHI groups, F (1, 87) = .81, p = .371, or between conditions, F (1, 87) = .93, p = .339, despite showing the expected pattern of means. However, similar to that evidenced for EDA amplitude response, a trend for a interaction was observed, F (1, 87) = 2.93, p = .091, in that students with MHI demonstrated little change in heart rate for the two arousal conditions whereas students without MHI had significantly higher heart rate in the stress condition as compared to the relaxation condition, but this was not found to vary as a function of time, F (1, 87) = .76, p = .386. Refer to Figure 13 and Tables C77 and C78.

Intercorrelations between arousal measures. Note that self-reported arousal state remained positively correlated with most physiological measures across time, especially directly after the arousal manipulation was applied (refer to Tables C83 through C86).

Therefore, self-reported arousal mirrors the physiological measures as a description or reflection of how much stress the student is experiencing.

Self-report of anxiety (STAI; Spielberger, 1983a). After neuropsychological testing was complete, an additional, this time standardized, measure of arousal/stress (i.e., STAI), was administered and was found to vary also as a function of MHI history and arousal manipulation condition. Consistent with the self-reported measures, students with MHI tended to have lower state anxiety scores as compared to students without MHI, F (1, 87) = 2.87, p = .094. The arousal manipulation remained effective over the course of the experiment such that students reported higher state anxiety in the stress condition than in the relaxation condition, F (1, 87) = 3.90, p = .052; however, there was no significant interaction with history of MHI, F (1, 87) = .01, p = .934. Refer to Figure 14 and Tables C87 to C88. No significant differences between groups or arousal manipulation conditions were obtained for trait anxiety measures (refer to Tables C89 to C90).

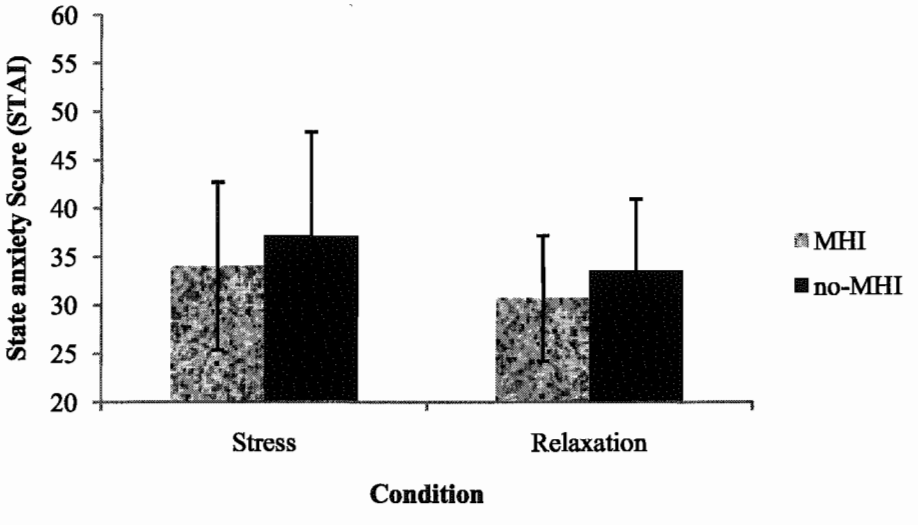

Figure 14. State anxiety as a function of MHI history and arousal manipulation condition.

Response to arousal manipulation across time as a function of MHI history. To test the hypothesis of observing a decreased physiological stress response in students with MHI compared to students without MHI history, separate 2 (MHI history: MHI, no-MHI) X 2 (Arousal Manipulation Condition: stress, relaxation) X 4 (after experimental manipulation, in-between neuropsychological testing, after neuropsychological testing, and final recording) Mixed Model ANOVAs were conducted for each of the self-reported (self-report of arousal state scale) and physiological measures (EDA, HR, Respiration) of arousal.

Self-reported arousal. Overall the arousal manipulation was effective, F (1, 87) = 47.88, p = .0001, but varied across time, $F^{G\text{-}G}$ (3, 261) = 17.08, p < .001, such that ratings of self-reported arousal significantly decreased across time (i.e., from the time of the induced arousal manipulation to the end of the session). For between-subjects factors, as hypothesized, self-reported arousal was significantly lower for students with MHI, F (1, 87) = 4.22, p = .043, than for those without MHI. There was no differential response to the arousal manipulation as a function of history of head injury, F (1, 87) = .60, p = .442, nor as a function of head injury across time, $F^{G\text{-}G}$ (3, 261) = 1.69, p = .179. However, there was a significant 2-way interaction of arousal manipulation condition across time, $F^{G\text{-}G}$ (3, 261) = 93.43, p < .001, such that simple effects analyses revealed the most prominent effects on self-reported arousal occurred immediately post-manipulation (i.e., arousal was highest after the psychosocial stressor and decreased to baseline levels by the end of the testing session, $F^{G\text{-}G}$ (3, 132) = 69.91, p < .001, and was lowest after the relaxation manipulation and increased to baseline levels by the end of the session $F^{G\text{-}G}$ (3, 135) =

31.31, $p < .001$). Refer to Figure 15 and Tables C91 to C100 for details. Note Greenhouse-Geisser correction used.

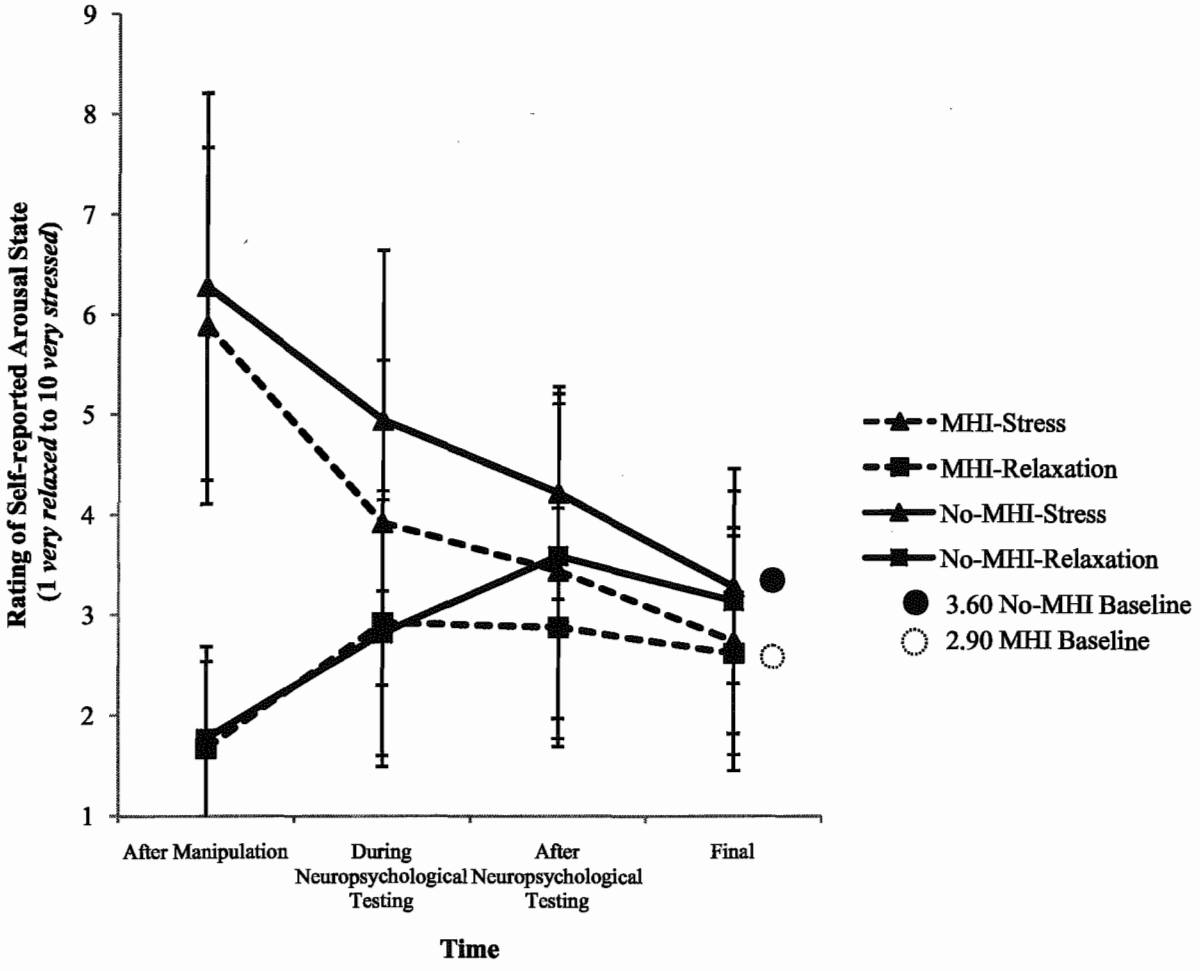

Figure 15. Self-reported arousal across time as a function of MHI history and arousal manipulation condition[14].

Electrodermal activity—frequency. Overall, EDA frequency significantly decreased across time, $F^{G\text{-}G}(3, 261) = 12.29, p < .001$. As for between subjects factors, students with MHI had a significantly slower EDA signal than students without MHI, $F(1, 87) = 20.39, p < .001$. EDA frequency was found to differ between arousal manipulation

[14] *Note.* 'Baseline' in the legend for Figures 15 through 19 is the average of the measure (self-reported or physiological) at initial baseline report or recording and is depicted in order to illustrate deviation from, or return to, baseline.

conditions, F (1, 87) = 3.93, p = .051, such that there were slower EDA signals for the relaxation condition and heightened activity for the stress condition. Refer to Table C104 for pairwise comparisons. There were no significant interactions between MHI group and arousal condition, F (1, 87) = 1.24, p = .268, or as a function of time, F (2.63, 229.17) = 1.67, p = .174 (see Figure 16 and Tables C101 to C104). Note Greenhouse-Geisser correction used.

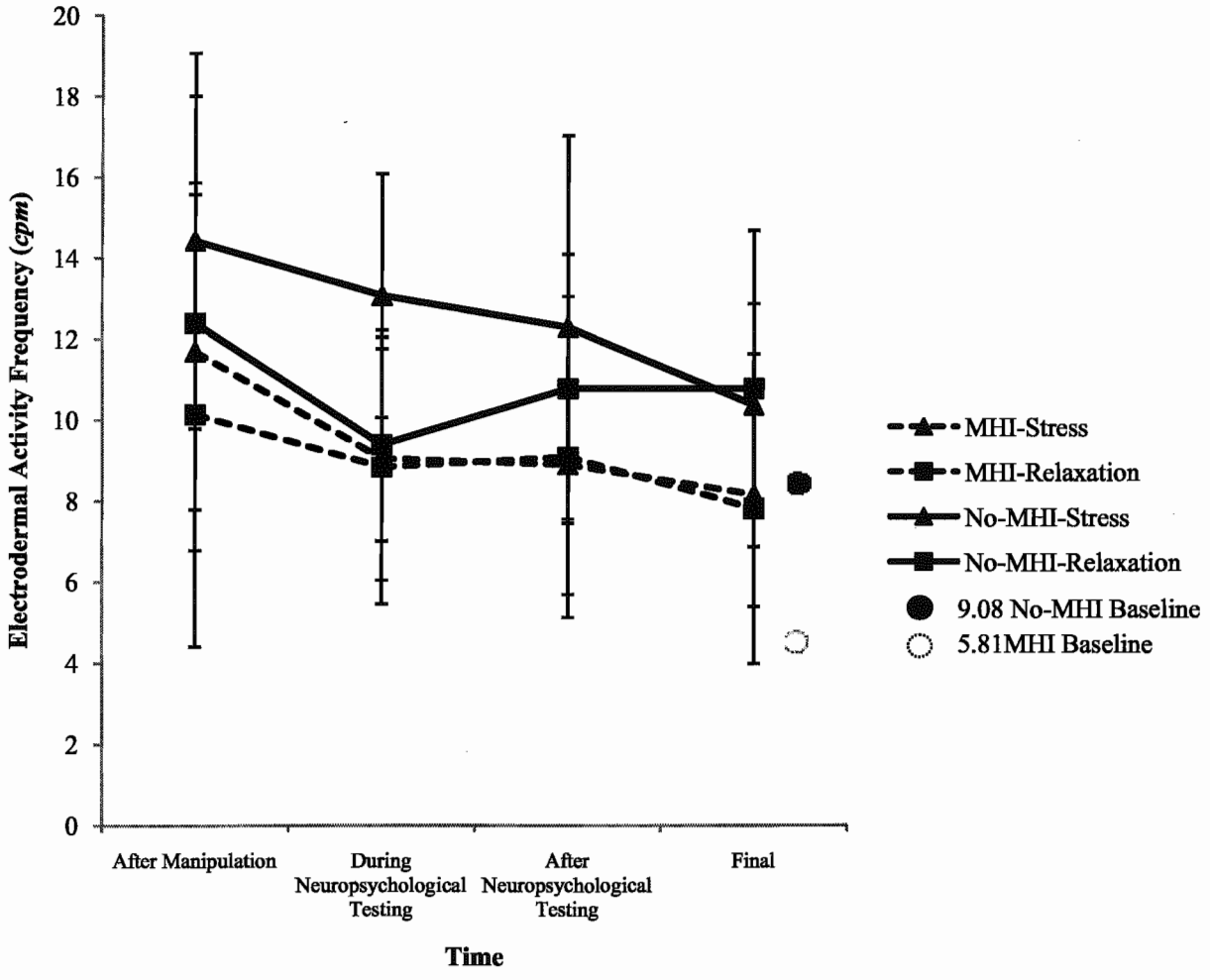

Figure 16. Electrodermal activity frequency across time by MHI history and arousal manipulation condition.

Electrodermal activity—amplitude. Similarly, EDA amplitude significantly decreased across time, $F^{G\text{-}G}$ (3, 261) = 9.95, p < .001. For between groups, as expected,

students with MHI exhibited smaller EDA amplitude signals than students without MHI, $F(1, 87) = 62.59, p < .001$. As well, EDA amplitude was significantly smaller in the relaxation condition than the stress condition, $F(1, 87) = 34.02, p < .001$. The EDA amplitude signal decreased across time as a function of arousal manipulation condition, $F^{G\text{-}G}(3, 261) = 41.15, p < .001$. For the significant 2-way interaction of time by arousal manipulation condition, repeated measures were conducted separately for each condition and were found to be significant for both the stress, $F^{G\text{-}G}(3, 132) = 35.59, p < .001$, and relaxation conditions, $F^{G\text{-}G}(3, 135) = 5.70, p = .002$. As well, a 3-way interaction was observed, such that students without MHI had more extreme and larger range of responses to the manipulations than those with reported MHI , $F^{G\text{-}G}(3, 261) = 5.06, p = .004$, (refer to Tables C105 to C108).

Separate Mixed Model ANOVAs were conducted for each arousal manipulation condition with MHI history to investigate these interactions (refer to Tables C109 to C126). For the relaxation condition, EDA amplitude significantly increased across time, $F^{G\text{-}G}(3, 132) = 5.82, p = .002$, but overall was significantly less for students who reported MHI as compared to students without MHI, $F(1, 44) = 14.76, p < .001$. For the stress condition, EDA amplitude decreased significantly across time, $F^{G\text{-}G}(3, 129) = 43.15, p < .001$, but varied differentially as a function of MHI history, $F^{G\text{-}G}(3, 129) = 5.26, p = .005$. Simple repeated measures of EDA amplitude found that students with no MHI tended to have a greater response across time, $F^{G\text{-}G}(3, 117) = 2.53, p = .087$; $F^{G\text{-}G}(3, 150) = 3.05, p = .052$. Relative to their no-MHI cohorts, students with MHI had a diminished EDA response overall, and may be experiencing a floor effect, particularly with respect to the

relaxation manipulation. Refer to Figure 17. Note Greenhouse-Geisser correction was used.

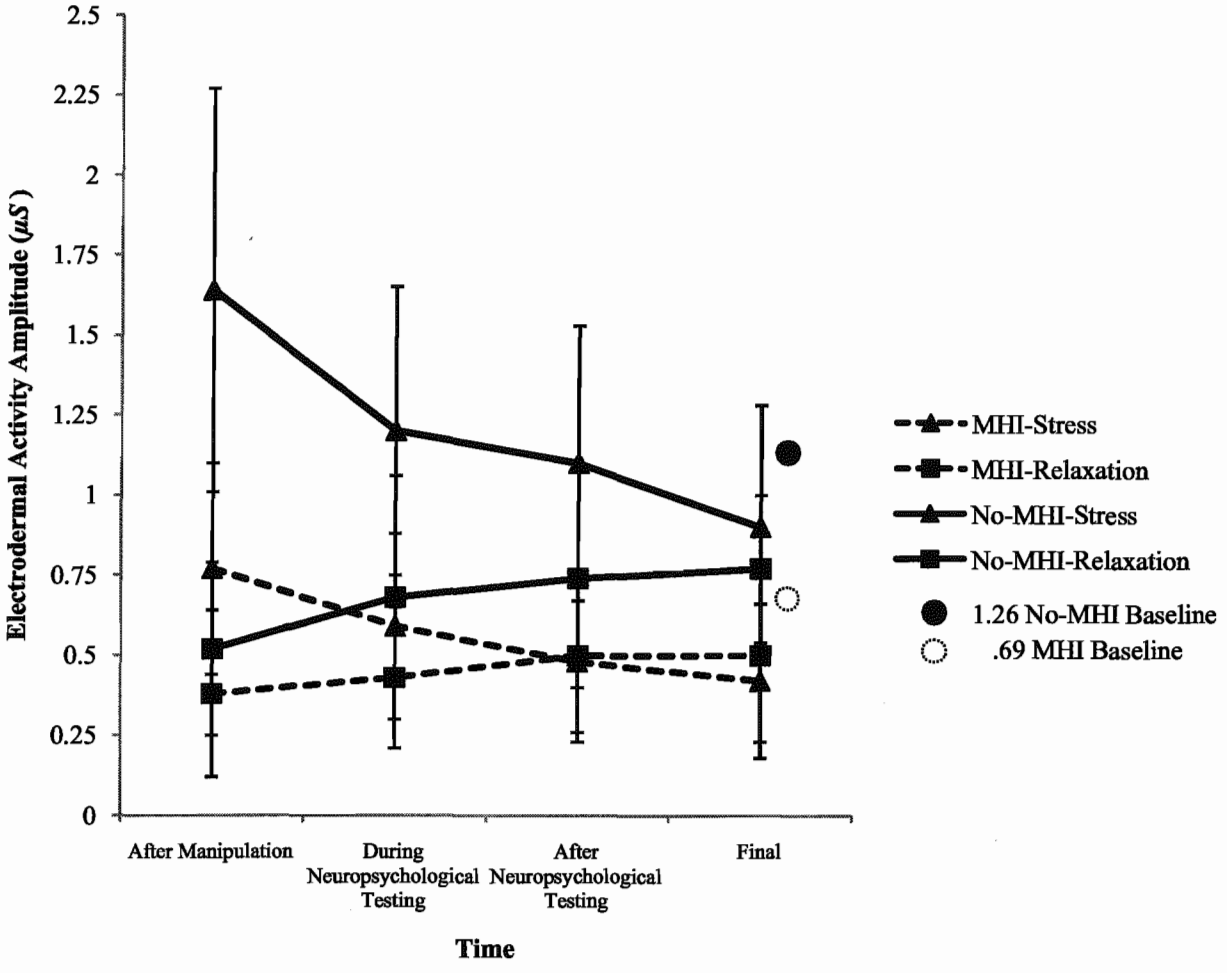

Figure 17. Electrodermal Activity amplitude across time as a function of MHI history and arousal manipulation condition.

Heart rate—beats per minute. No significant differences were found for MHI group, F (1, 87) = 1.56, p = .216, or arousal manipulation condition, F (1, 87) = 1.73, p = .192. Overall, heart rate was significantly greater as a function of stress as compared to the relaxation condition, F (3, 261) = 3.75, p = .012, and decreased across time, F (3, 261) = 4.12, p = .007, particularly as a function of the stress condition, F (3, 132) = 5.84, p = .001, (i.e., higher after manipulation and slowly decreased across time), as it did not

change for the relaxation condition, F (3, 135) = .68, p = .566. The HR measure may reflect a floor effect similar to that described above—and notably the mean heart rate, nominally remained around 69 bpm for 3 out of the 4 conditions (MHI-relaxation; no-MHI-relaxation; and MHI-stress) across time. Refer to Figure 18 and Tables C127 to C135.

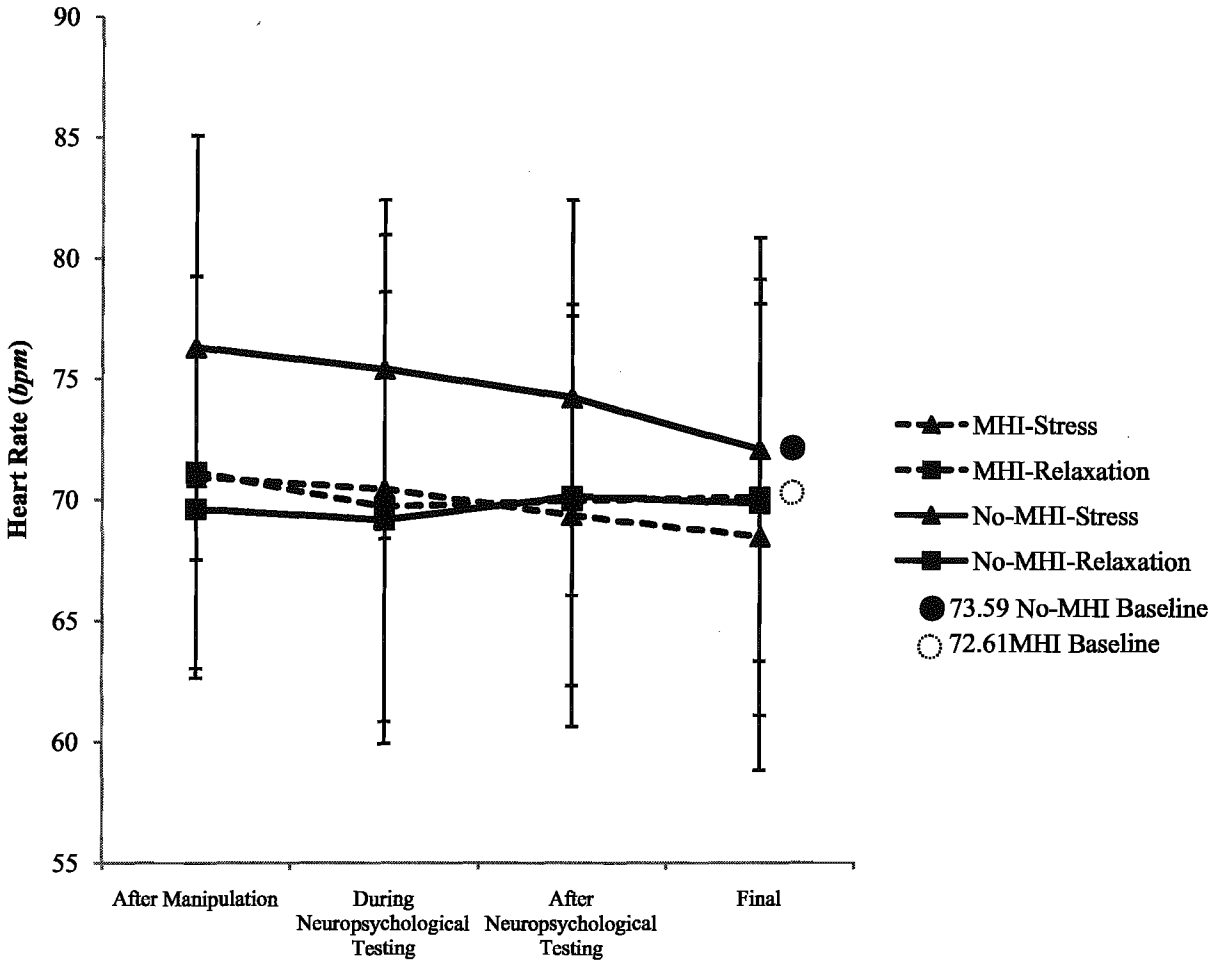

Figure 18. Heart rate across time by MHI History and arousal manipulation condition.

Respiration—frequency. Surprisingly, frequency of respiration (cycles per minute) was not significantly different across time, $F^{G\text{-}G}$ (3, 261) = .13, p = .923. Respiration did not differ as a function of MHI history, F (1, 87) = 1.68, p = .198, however, respiration

frequency was higher in the stress condition than the relaxation condition, F (1, 87) = 5.46, p = .022. There were no significant interactions, although a trend for respiration frequency across time as a function of condition was observed, $F^{G\text{-}G}$ (3, 261) = 2.40, p = .078. Visual inspection revealed a pattern similar to that mentioned previous such that respiration appeared to decrease across time for the stress condition (was highest directly after manipulation), and respiration appeared to increase across time for the relaxation condition (was lowest immediately after manipulation). Refer to Figure 19 and Tables C136 to C138. Note Greenhouse-Geisser correction used.

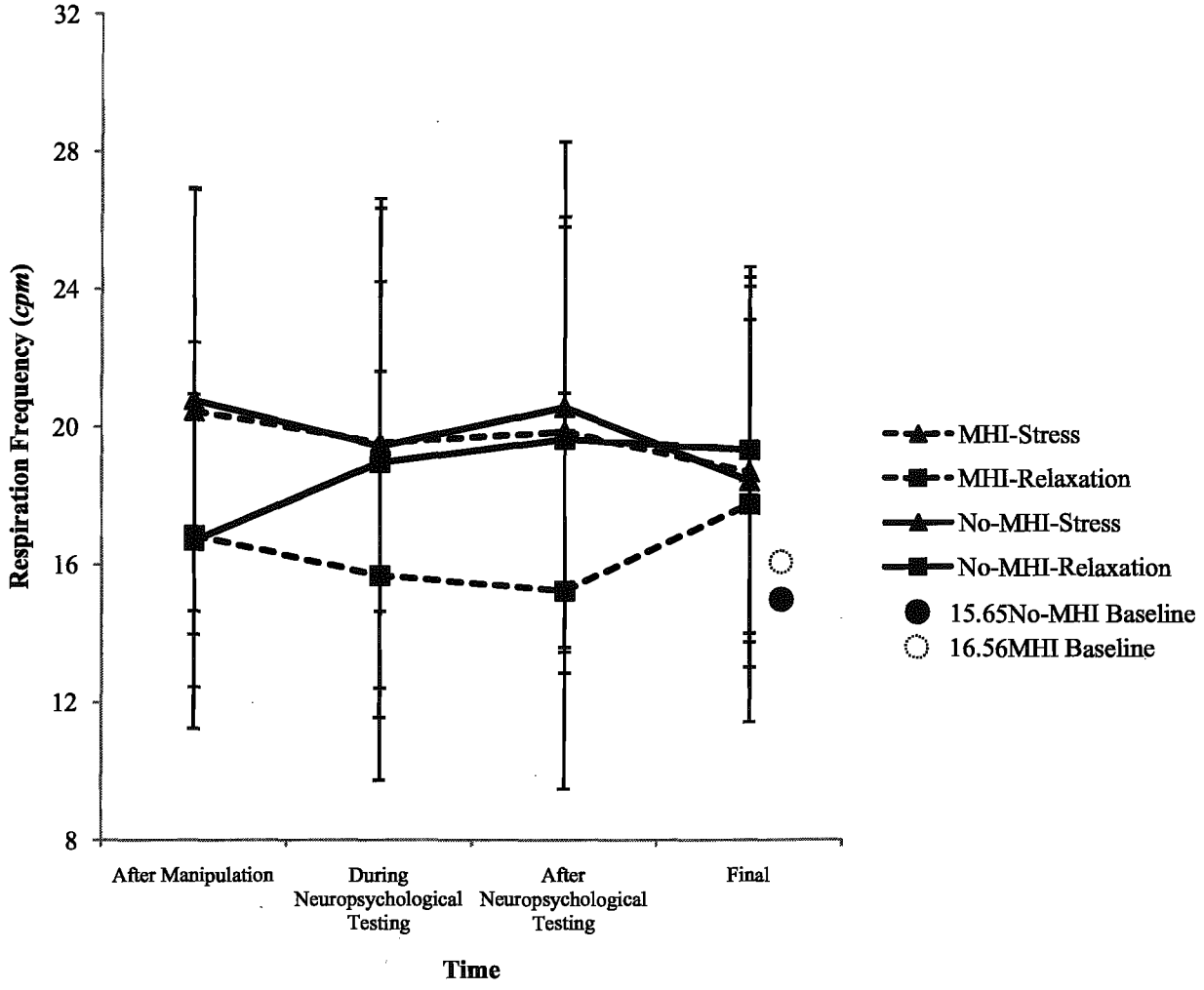

Figure 19. Frequency of respiration across time by MHI History and arousal manipulation condition.

Hypothesis 3: Arousal State, MHI, and Cognitive Performance

Consistent with the Yerkes-Dodson Law, induced-psychosocial stress (i.e., heightened arousal) and/or perceived stress will impair cognitive performance in persons without head injury. In contrast, induced-psychosocial stress should improve cognitive abilities associated with OFC function, namely attention, working memory, and cognitive flexibility, but not those associated with other cognitive skills (i.e., planning, abstract reasoning) and intelligence, for persons with MHI who are expected to initially, and typically, be underaroused relative to their cohorts. Conversely, cognitive skills (i.e., attention, working memory, cognitive flexibility) will benefit from induced and/or perceived relaxation for individuals without head injury and impair performance for persons with head injury (as this should further lower their arousal state which is expected to be already reduced prior to any manipulation).

Baseline Cognitive Performance Prior to Presenting Arousal Manipulation

Prior to arousal manipulation, baseline cognitive testing was conducted to examine cognitive capabilities in two domains: working memory and attention. Baseline cognitive performance was examined via 2 (MHI History: MHI, No-MHI) X 2 (Arousal Manipulation Condition: Stress, Relaxation) ANOVAs with a main focus on the comparison between MHI groups. As previously mentioned, students did not differ on intelligence capacity measures as a function of MHI history nor was there a difference in educational level. As expected, prior to the arousal manipulation, students with MHI tended to perform more poorly than students without MHI for most working memory and attentional tasks as discussed below.

Working memory. As expected, prior to arousal manipulation, students with a self-reported history of MHI tended to perform worse on working memory tasks than their no-MHI counterparts. More specifically, students with MHI tended to make more errors on the Trail Making Test Ia (DKEFS, 2002) than students without MHI, F (1, 87) = 3.38, p =.069, (refer to Figure 20 and Tables C139 to C140). However, processing speed for the Trail Making Test did not differ between MHI groups, F (1, 87) = 2.43, p = .123 (refer to Tables C141 to C142). Likewise, prior to the arousal manipulation, students with MHI tended to do worse on the Digit Symbol-Copy task (WAIS-III, 1997) compared to students without MHI, F (1, 87) = 3.50, p = .065 (refer to Figure 21 and Tables C143 to C144). No significant main effects were obtained for "assigned"[15] arousal manipulation condition nor were there any interactions.

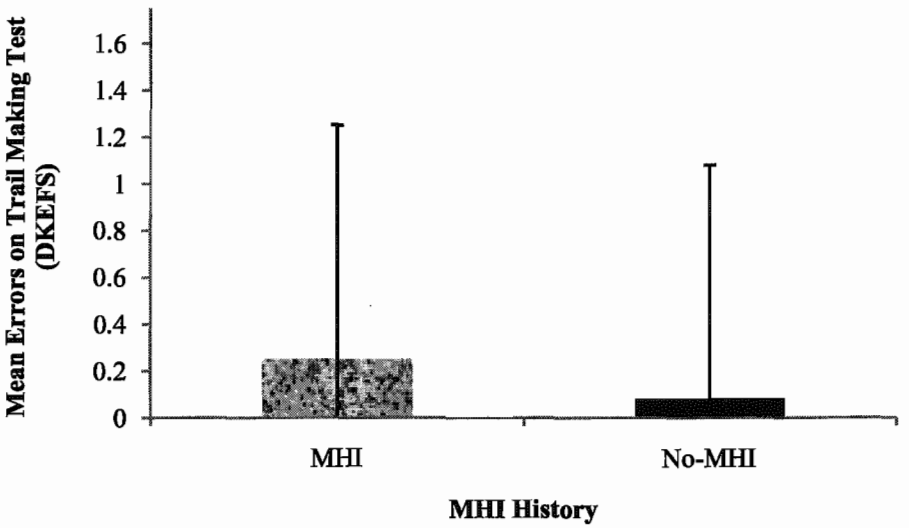

Figure 20. Errors on Trail Making Test (DKEFS, 2002) as a function of MHI history prior to arousal manipulation.

[15] *Note.* "Assigned" arousal manipulation condition refers to the fact that students were randomly assigned to conditions but had not yet experienced the psychosocial stress or relaxation induction.

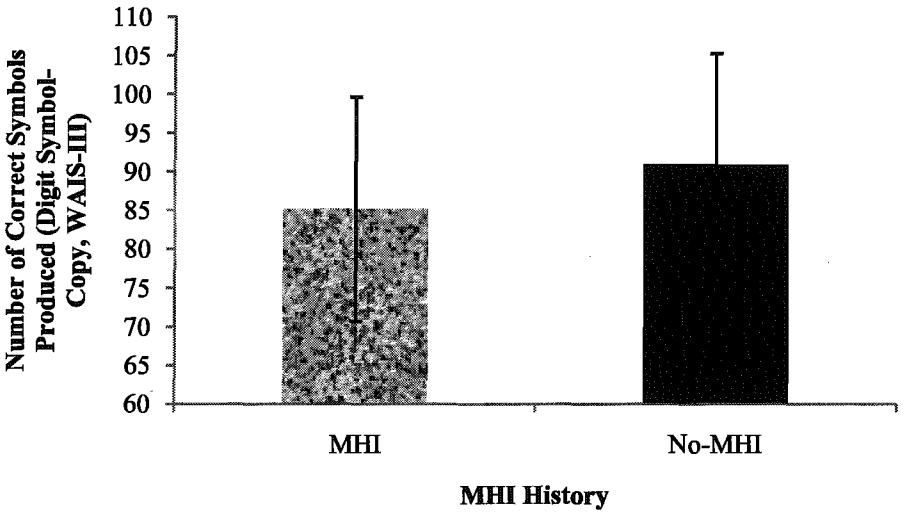

Figure 21. Number of correct symbols produced on the Digit Symbol-Copy task (WAIS-III, 1997) as a function of MHI history prior to arousal manipulation.

Attention. Similarly, the two groups differed in terms of attention as a function of MHI history. Students with MHI were significantly less efficient in completing the complex attentional switching task (Colour-Word Interference Task; DKEFS, 2002), F (1, 87) = 4.67, p = .033 (refer to Figure 22 and Tables C145 to C146). Students with MHI also tended to perform the colour naming task less efficiently as compared to their no-MHI counterparts, F (1, 87) = 3.06, p = .084. Again, performance did not vary as a function of "assigned" arousal manipulation condition, nor were there any significant interactions (refer to Tables C147 and C148). Similarly, students with MHI were significantly slower than students without MHI for the word reading task, F (1, 87) = 4.94, p = .029. Students "assigned" to the stress condition read the words significantly more slowly than students "assigned" to the relaxation condition, F (1, 87) = 4.26, p = .042, however, there was no significant interaction, F (1, 87) = .01, p = .933, as a function of MHI history (refer to Tables C149 and C150). Interestingly, for the inhibition task there were no significant differences observed for MHI history, F (1, 87) = 1.55, p = .217, arousal manipulation

condition, F (1, 87) = .39, p = .534, nor was there an interaction, F (1, 87) = .02, p = .892 (refer to Tables C151 and C152).

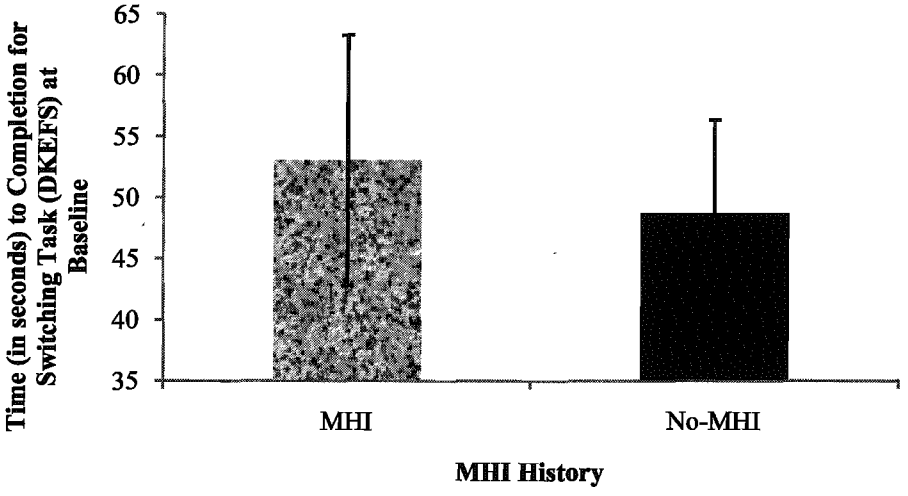

Figure 22. Time to complete an attentional switching task (DKEFS, 2002) as a function of MHI history prior to arousal manipulation.

Cognitive Performance as a Function of Arousal Manipulation Condition and MHI History

Cognitive capabilities were examined in three main domains: memory (working, visuospatial, and narrative), attention, and planning/abstract reasoning abilities. Cognitive performance was examined via 2 (MHI History: MHI, No-MHI) X 2 (Arousal Manipulation Condition: Stress, Relaxation) ANOVAs. Mixed Model ANOVAs were conducted for repeated cognitive measures to compare pre- and post-manipulation performance as a function of MHI history and arousal manipulation condition. Due to the nature of neuropsychological tests certain tests were not repeated and performance was investigated in a between-subjects design via 2 (MHI History: MHI, No-MHI) X 2 (Arousal Manipulation Condition: Stress, Relaxation) ANOVAs to examine hypothesized interactions.

Pre-and-Post-Manipulation Comparisons of Cognitive Performance

Working memory. While students produced significantly more symbols (Digit Symbol-Copy; WAIS-III, 1997) with repeated testing, F (1, 87) = 94.52, $p < .001$; there remains a main effect of MHI history such that students with MHI perform more poorly on the Digit Symbol-Copy test (WAIS-III, 1997), F (1, 87) = 4.81, $p = .031$ (refer to Figure 23). There was no main effect for arousal manipulation condition, F (1, 87) = .13, $p = .717$, nor a significant interaction, F (1, 87) = .61, $p = .437$ (refer to Tables C153 to C155).

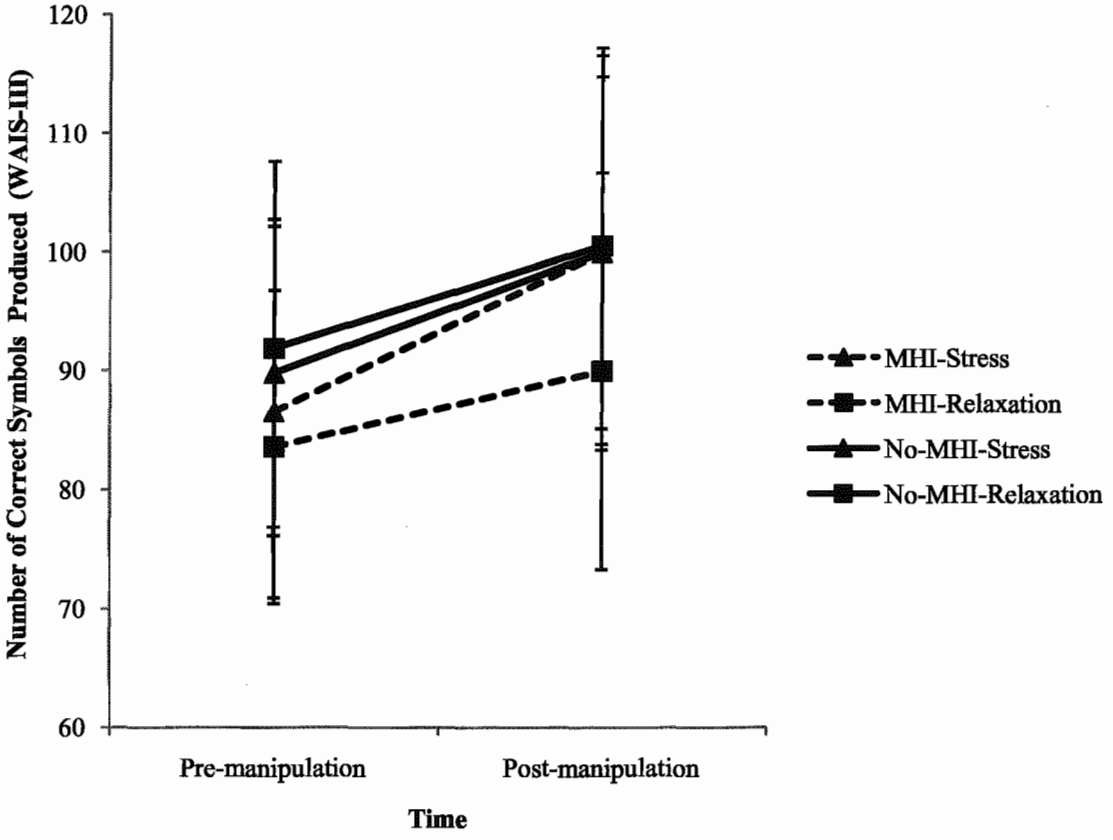

Figure 23. Number of correct symbols produced on the Digit Symbol-Copy task (WAIS-III, 1997) across time as a function of MHI history and arousal manipulation condition.

Working memory performance as measured via Trail Making Test (DKEFS, 2002) did not differ across time (pre-to-post manipulation), F (1, 87) = .48, $p = .492$; however, overall students with MHI were significantly faster on this task as compared to students

without MHI, F (1, 87) = 4.02, p = .048. There was no main effect for arousal manipulation condition, F (1, 87) = .36, p = .552, nor were any interactions significant, F (1, 87) = .01, p = .978 (refer to Tables C156 and C157). Similarly, no significant effects of MHI history, F (1, 87) = 2.10, p = .151, arousal manipulation condition, F (1, 87) = .06, p = .815, or time, F (1, 87) = 1.14, p = .289, nor interactions, F (1, 87) = .12, p = .729, were observed for the number of errors produced (refer to Table C158 through C160).

Attention. Participants were significantly faster at completing the more complex attentional switching task (Colour-Word Naming Interference Task; DKEFS, 2002) when it was given for a second time, F (1, 87) = 63.85, p = .0001. However, again, those with MHI were significantly slower than their no-MHI counterparts, F (1, 87) = 4.98, p = .028. No effect was observed between arousal manipulation conditions, F (1, 87) = .03, p = .864, and it did not result in a significant interaction, F (1, 87) = .37, p = .556 (refer to Figure 24; Tables C161 to C162).

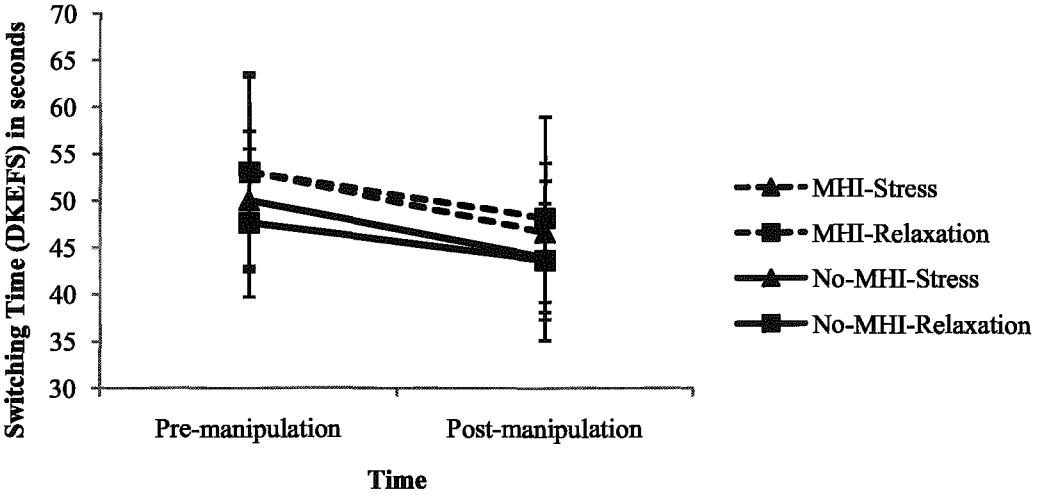

Figure 24. Time to complete switching Colour-Word Interference Task (DKEFS, 2002) across time as a function of MHI history and arousal manipulation condition.

Similarly, students were faster at naming the colour of the ink when repeating this attentional task (DKEFS, 2002), $F(1, 87) = 33.10, p < .001$; and again, those with MHI took longer to name the colour patches than students without MHI, $F(1, 87) = 3.90, p = .052$. No effects were found for arousal manipulation condition, $F(1, 87) = .81, p = .371$, and there was no interaction of the between subjects factors, $F(1, 87) = .08, p = .774$ (refer to Tables C163 and C164).

There was no main effect for time to read the words (DKEFS, 2002) at repeated testing, $F(1, 87) = 1.15, p = .287$, not surprisingly, since this measure often approaches a ceiling due to the ease of the task. Nonetheless students with MHI took significantly longer than students without MHI, $F(1, 87) = 4.36, p = .040$. Interestingly, students read faster in the stress condition than in the relaxation condition, $F(1, 87) = 4.47, p = .037$, but there was no significant interaction, $F(1, 87) = .26, p = .610$ (refer to Tables C165 and C166).

Students demonstrated significantly increased proficiency across time for the inhibition task (i.e., naming the colour of the ink the word is printed in while inhibiting the prepotent response of reading the word), $F(1, 87) = 51.33, p < .001$. However, performance on this task did not vary as a function of MHI history, $F(1, 87) = 2.57, p = .113$, despite a similar pattern of slower response times. There was no main effect for arousal manipulation condition, $F(1, 87) = .27, p = .606$, nor a significant interaction, $F(1, 87) = .01, p = .941$, (refer to Tables C167 and C168).

Post-manipulation Cognitive Performance

Cognitive flexibility. Student performance on the Mental Control tasks (WAIS-III, 1997) did not differ as a function of MHI group or arousal manipulation (saying information forwards, backwards refer to Tables C169 to C172) except when the task was

more complex and involved switching cognitive sets. In this case, a trend for an interaction was observed, $F(1, 87) = 3.17, p = .079$, such that, as expected, students with MHI tended to perform better in the stress condition than in the relaxation condition, whereas, persons without MHI performed better in the relaxation condition than in the stress condition for a task requiring cognitive flexibility. Refer to Figure 25 and Tables C173 to C174.

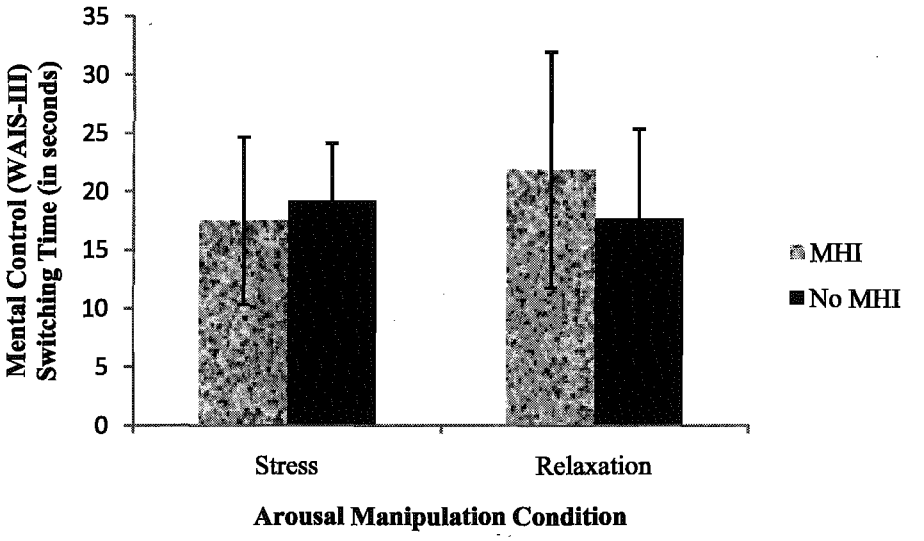

Figure 25. Switching time for Mental Control Task (WAIS-III, 1997) as a function of arousal manipulation condition and MHI history.

Working memory. The switching task of the Trail Making Test Part II (DKEFS, 2002) was assessed post-manipulation only and produced no significant main effects or interaction as evidenced in 2 (MHI History: MHI, No-MHI) X 2 (Arousal Manipulation Condition: Stress, Relaxation) ANOVAs for both time to complete the task or for the number of errors made (refer to Tables C175 to C178).

Narrative long-term memory. As expected, despite demonstrating poorer working memory capacity on a few measures, students with MHI did not perform worse on narrative or visuospatial memory tasks. 2 (MHI History: MHI, No-MHI) X 2 (Arousal Manipulation Condition: Stress, Relaxation) X 2 (Time: Immediate recall, Delayed recall)

ANOVAs were conducted for both narrative and thematic memory (Logical Memory I and II; WMS-III, 1997) performance. Overall, and as expected, recall was poorer for the delayed recall test for both specific facts from the story, $F(1, 87) = 32.59, p < .001$, and the overall gist, $F(1, 87) = 6.23, p = .014$. Students with MHI recalled more facts from the story, $F(1, 87) = 6.02, p = .016$, and for the gist of the story, $F(1, 87) = 5.58, p = .020$, than those without MHI. Also, students tended to better recall the theme of the story in the stress condition, $F(1, 87) = 3.34, p = .071$. There were no significant interactions for between-or within-subjects variables for either measure of narrative memory (refer to Table C179 through Table C182).

Visuospatial memory. Recall for visuospatial (Memory for Design; NEPSY, 2007) information was significantly poorer for the delayed recall test as compared to immediate recall, $F(1, 87) = 13.48, p < .001$; however, there was no main effect for MHI history, $F(1, 87) = .01, p = .917$, arousal manipulation condition, $F(1, 87) = .70, p = .406$, nor a significant interaction, $F(1, 87) = .57, p = .452$ (refer to Tables C183 and C184).

Planning. No significant differences between MHI group or arousal manipulation condition were found for either the total number of moves taken to complete the Tower of Hanoi puzzle, the number of errors made, or the total score (DKEFS, 2002) (refer to Table C185 through C192). Although, students with MHI completed the towers faster than students without MHI, $F(1, 87) = 4.14, p = .045$ (refer to Figure 26), performance did not vary as function of condition, $F(1, 87) = .77, p = .384$, nor was there a significant interaction, $F(1, 87) = .32, p = .572$.

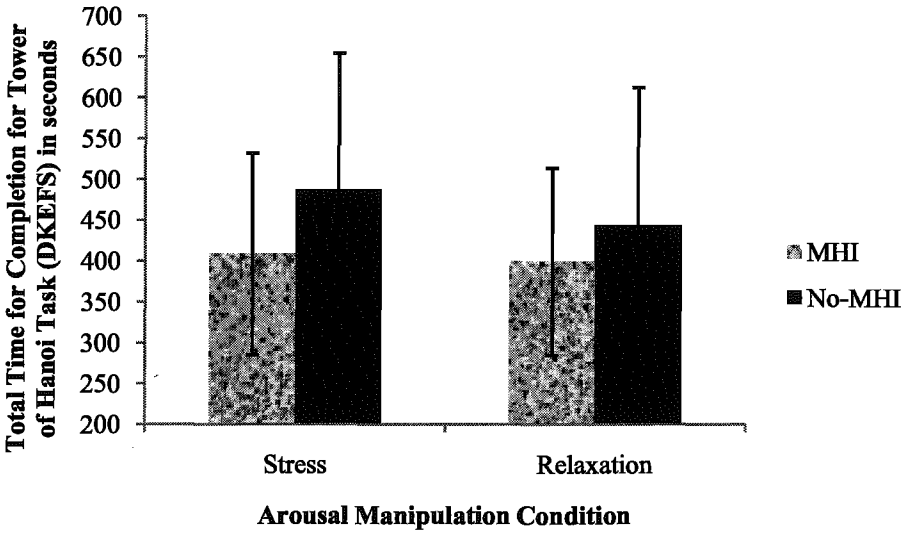

Figure 26. Time for completion for Tower of Hanoi task (DKEFS, 2002) as a function of MHI history and arousal manipulation condition.

Abstract reasoning. Students with MHI demonstrated significantly better abstract reasoning skills (as measured via Pictorial Analogies; CTONI, 1996) than their no-MHI counterparts, F (1, 87) = 5.13, p = .026, which did not vary by arousal manipulation condition, F (1, 87) = 1.76, p = .188, and there was no significant interaction, F (1, 87) = 1.91, p = .17 (refer to Tables C193 and C194). Performance on another abstract reasoning task (i.e., Picture Arrangement; WAIS-III, 1997) did not demonstrate significant differences between MHI history, F (1, 87) = 2.10, p = .151, arousal manipulation conditions, F (1, 87) = .17, p = .678, nor did these factors result in an interaction, F (1, 87) = .09, p = .765 (refer to Tables C195 and C196). Similarly, no significant differences between MHI groups, F (1, 87) = .31, p = .576, or arousal manipulation conditions, F (1, 87) = .01, p = .935, nor an interaction, F (1, 87) = .01, p = .913, were observed for time to complete the task (refer to Tables C197 and C198).

Hypothesis 4: Post-Concussive Symptom Reports in University Students with and without MHI

Self-reports of post-concussion symptoms, especially those that are predominant complaints for persons with trauma to the head, namely concentration and judgment difficulties, headaches, and irritability, are expected to be experienced more often, be of greater intensity and longer duration for students with history of MHI compared to students without MHI.

Separate independent t-tests were conducted (refer to Table C199) to examine if students with MHI more commonly report post-concussive symptoms than students without MHI based on PCSC ratings (Gouvier et al., 1992). Overall, competent university students who acknowledge a history of MHI but have not complained of persistent effects or concerns regarding the MHI nonetheless endorsed significantly more post-concussive symptoms, t (89) = 2.29, p = .024, with greater intensity, t (89) = 2.62, p = .010, and acknowledged experiencing the symptom for longer durations than students without MHI, t (89) = 2.24, p = .028. There was also a trend for the symptoms occurring more often, t (89) = 1.67, p = .098. Refer to Figures 27 to 30.

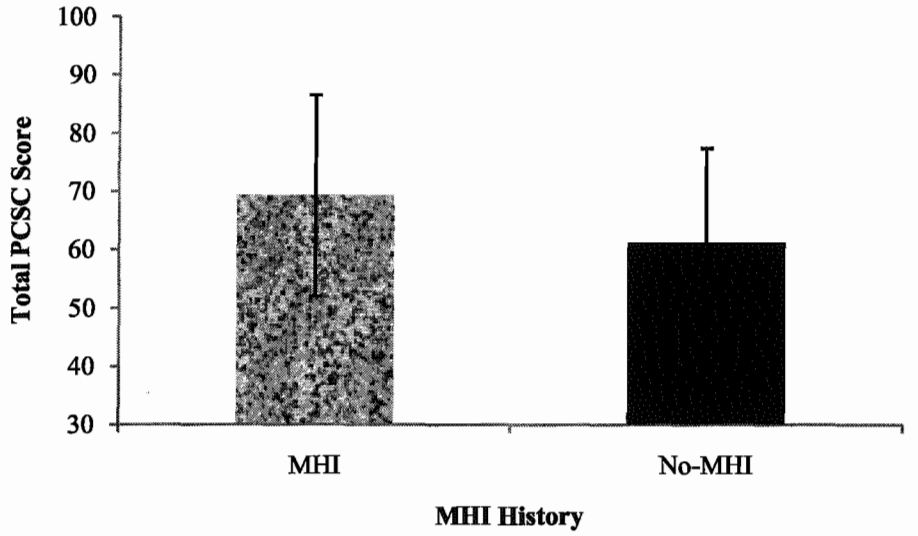

Figure 27. Post-concussive symptom reports for university students with and without MHI.

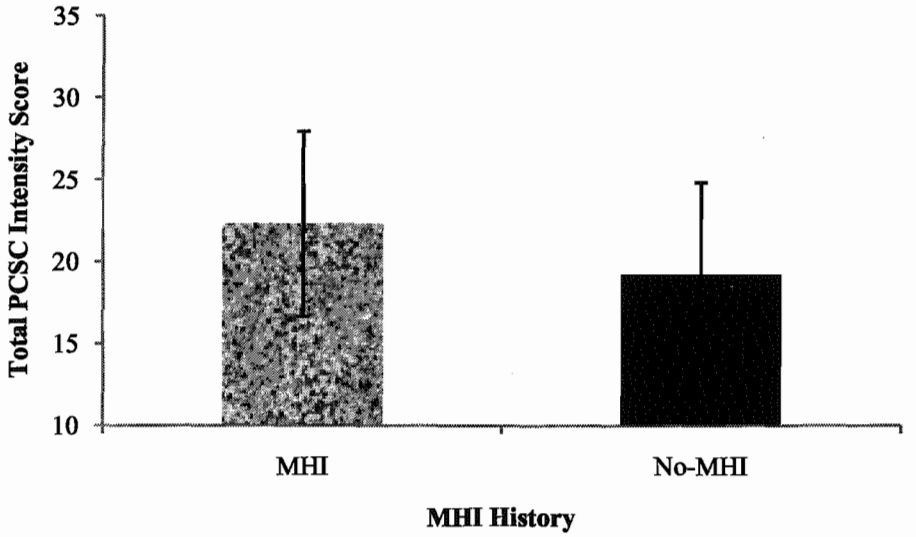

*Figure 28.*Intensity of experiencing post-concussive symptoms for university students with and without MHI.

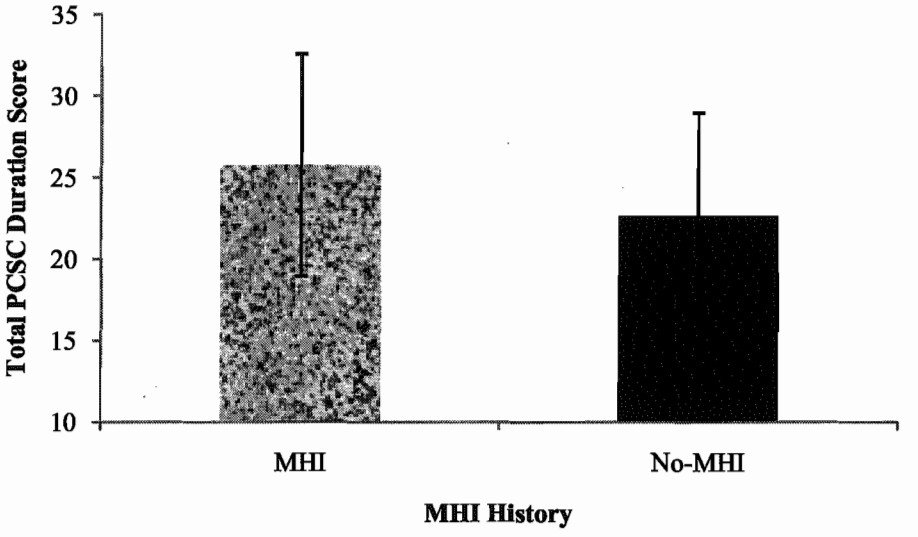

Figure 29. Duration of post-concussive symptoms for university students with MHI and without MHI.

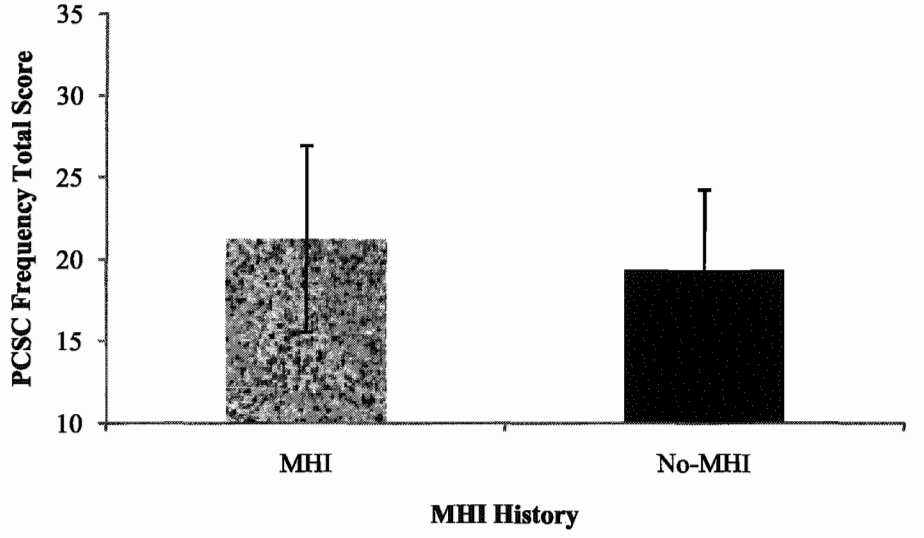

Figure 30. Frequency of experiencing post-concussive symptoms for university students with and without MHI.

More specifically, hypothesized differences in concentration and judgment difficulties, headache reports, and irritability between students with and without MHI were examined via nonparametric analyses (Mann Whitney U).

Students with MHI reported experiencing concentration difficulties significantly more often, with greater intensity and for longer periods of time than students without MHI history. Further, although not always reaching statistical conventions (i.e., $p < .10$, but $> .05$), students with MHI reported being irritable for longer durations, reported greater intensity in difficulties in judgment, and experienced headaches with greater intensity than their no-MHI counterparts (refer to Tables C200 to C201).

Even though we were only expecting to find differences for the aforementioned symptom reports, we also analyzed the other symptoms in a post-hoc fashion. Interestingly, students with MHI reported significantly more visual disturbances, with a trend for experiencing this symptom with greater intensity, and for longer periods of time than students without MHI, independent of visual acuity, χ^2 $(1, N = 91) = .53, p = .466$. Similarly, students with MHI reported being aggravated by noise for significantly longer durations and tended to have more intense aggravation from noise than their cohorts (refer to Table C202). The other symptom reports were not found to differ between students with and without MHI (refer to Tables C203 and C204). In short, the endorsement of post-concussive-like symptoms differs for persons as a function of MHI history in university students primarily in terms of the quality (i.e., intensity and duration) of the experience. Furthermore, independent of time elapsed since injury, and severity of injury (i.e., reported an MHI with a LOC), students with history of an MHI still demonstrated increased post-concussive symptom reports (refer to Table 205).

Post-hoc Analysis

The limited evidence in support of our hypothesis, namely that modifying arousal state would result in differential changes in some measures of cognitive

performance as a function of MHI history, was puzzling to us in light of our previous research (i.e., St. Cyr & Good, 2007; Jung & Good, 2007). As a result, we examined the possibility that some persons with mild head injuries may indeed have 'minor' injuries whereas others may have comparatively more significant ones (e.g., reported loss of consciousness). We, therefore, explored these data as a function of severity of head injury. Similarly, it was deemed appropriate to examine the relationship between changes in physiological arousal (as indicated by EDA response) across time as a function of exposure to the arousal manipulations for persons with varying degrees of head injury severity. Therefore, we assessed severity of head injury for three groups: no-MHI, MHI-with-altered-state-of-consciousness, and MHI-with-LOC. These analyses are entirely exploratory due to a) the small sample size (n = 14) of students who reported an MHI-with-LOC; and, b) the unbalanced distribution of subjects in the design across the arousal manipulations (no-MHI Relaxation group n = 22, Stress group n = 18; MHI-with-altered-state-of-consciousness Relaxation group n = 18, Stress group n = 19; MHI-with-LOC Relaxation group n = 6; Stress group n = 8). Nonetheless it is important to review these relationships, as it is consistent with the essence of our hypotheses, and it may reveal interesting outcomes that were otherwise veiled by possible floor effects.

Similar to the main analyses, post-hoc analyses revealed that students who reported an MHI-with-a-LOC demonstrated even lower self-reported arousal status at baseline than students with an MHI-with-altered-state-of-consciousness and those without an MHI, F (2, 85) = 3.06, p = .052 (refer to Figure 31 and Tables C206 to C207). Participants with self-reported head injury also had significantly higher total scores on the Life Stressors Scale, F (2, 88) = 3.54, p = .033 (refer to Figure 32) and tended to

acknowledge a higher number of life stressors, F (2, 88) = 2.84, p = .064, than those without head injury (refer to Table C208). Although ratings of overall satisfaction with life was not found to differ significantly as a function of MHI severity the means were in a similar direction as the original analysis, F (2, 88) = 1.58, p = .211 (refer to Table C209).

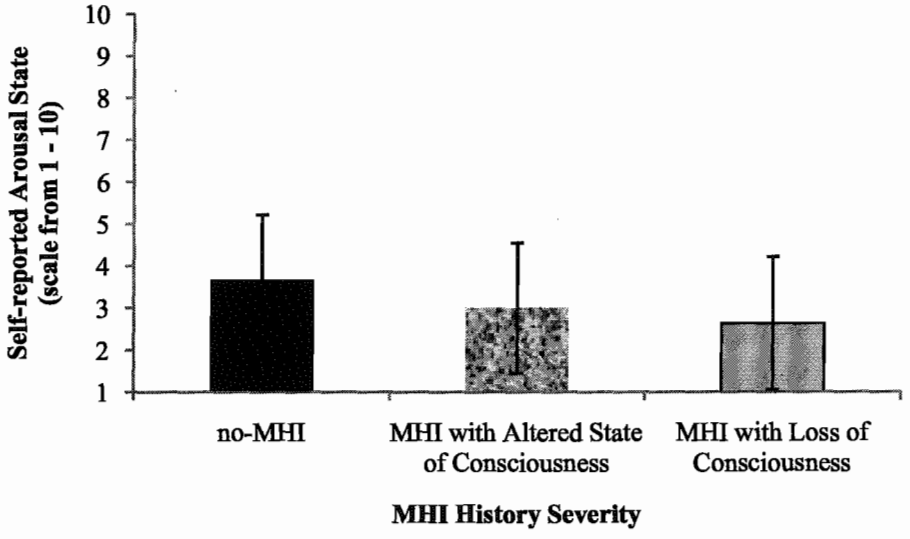

Figure 31. Self-reported arousal state as a function of MHI History severity at baseline.

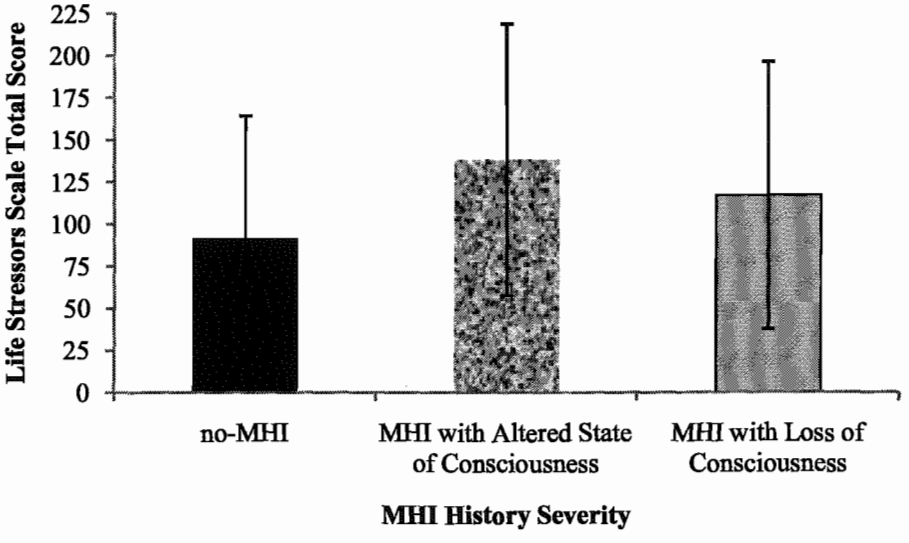

Figure 32. Life Stressors Scale Total Score for students with no-MHI, MHI with altered state of consciousness, and MHI with loss of consciousness.

Post-hoc Analysis of Physiological Arousal at Baseline

To test the hypothesis of lowered resting physiological arousal (i.e. prior to any arousal induction) as a function of MHI history severity (no-MHI, MHI-with-altered-state-of-consciousness, MHI-with-LOC), separate one-way ANOVAs were conducted for each of the physiological measures (EDA, HR, Respiration). In line with previously reported findings, students who acknowledged a MHI-with-LOC demonstrated significantly smaller EDA amplitude responses at baseline than the other groups, and those with no-MHI elicited larger EDA amplitude, $F(2, 88) = 13.89, p < .001$ (see Figure 33 and Tables C210 to C211). Both MHI groups produced significantly slower EDA responses than those with no-MHI, $F(2, 88) = 14.56, p < .001$, although the MHI-with-LOC group did not demonstrate the slowest response (refer to Tables C212 to C213). Heart rate and respiration measures were not found to differ significantly as a function of MHI history severity (refer to Tables C214 to C217).

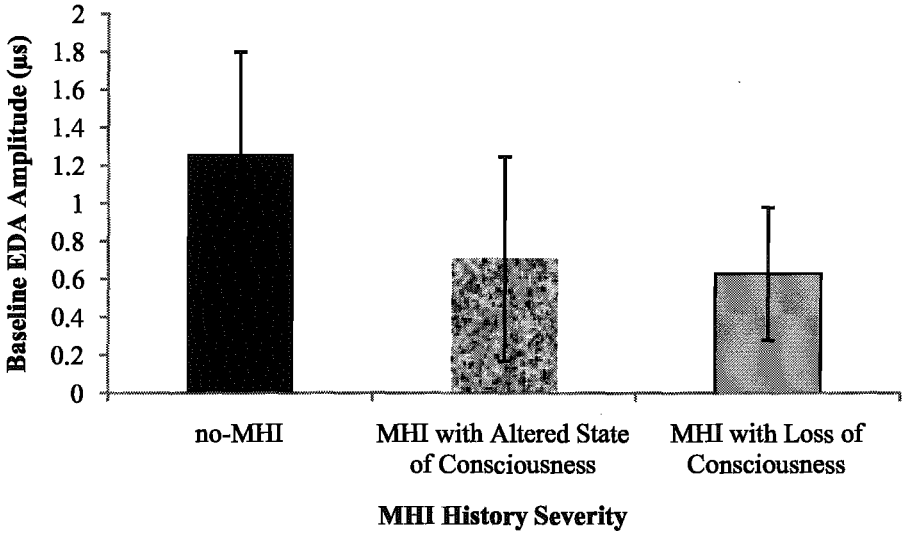

Figure 33. Baseline average EDA amplitude as a function of MHI History severity.

Post-hoc Analysis Hypothesis 2: Responsivity to Arousal Manipulation between MHI History Severity Groups

Separate 3 (MHI History Severity: no-MHI, MHI-with-altered state of consciousness, MHI-with-LOC) X 2 (Arousal Manipulation Condition: Stress, Relaxation) X 2 (Time: Pre-manipulation, Post-manipulation) ANOVAs were conducted for each of the self-report and physiological measures to investigate responsivity to the induction. Students did not differ in their reports of arousal state as a function of MHI history severity, F (2, 85) = 2.13, p = .125, although self-reported arousal was found to differ across time, $F^{G\text{-}G}$ (1, 85) = 13.01, p = .001. Students did report significantly higher arousal in the psychosocial stress condition as compared to the relaxation condition, F (1, 85) = 65.62, p < .001, and the ratings of arousal changed more for the stress condition than the relaxation condition across time, $F^{G\text{-}G}$ (1, 85) = 103.22, p < .001. There was no significant interaction of MHI history severity and arousal manipulation condition, $F^{G\text{-}G}$ (2, 85) = .42, p = .659, nor of MHI history severity and time, $F^{G\text{-}G}$ (2, 85) = 1.13, p = .328, nor did these factors (MHI history severity and arousal manipulation condition) interact across time, $F^{G\text{-}G}$ (2, 85) = .12, p = .887 (refer to Figure 34 and Tables C218 to C219).

With respect to responsivity to the arousal manipulation induction as indicated by physiological response, students produced significantly greater EDA amplitude responses in the psychosocial stress condition than in the relaxation condition, F (1, 85) = 17.47, p < .001, and EDA amplitude responses tended to vary across time, $F^{G\text{-}G}$ (1, 85) = 3.27, p = .074. Similarly, there was a significant interaction of arousal manipulation condition and time, $F^{G\text{-}G}$ (1, 85) = 14.40, p < .001. Students in both MHI groups produced significantly smaller EDA amplitude responses than those without MHI, F (2, 85) = 27.38, p < .001,

and there was a significant interaction of MHI history severity by condition, F (2, 85) = 3.66, p = .030, such that persons with MHI demonstrated less change in EDA amplitude response to the manipulations, and these factors produced a significant 3-way interaction, $F^{G\text{-}G}$ (2, 85) = 3.61, p = .031 (refer to Figure 35 and Tables C220 to C221).

Despite the means being in the projected directions, there were no significant main effects or interactions evident for MHI history severity, arousal manipulation condition, and time (refer to Figure 36 and Tables C222 to C223) for heart rate. Although both students with no-MHI or milder injury (MHI-with-altered-state-of-consciousness) produced faster EDA responses than the students in the MHI-with-LOC group, F (2, 85) = 9.83 , p < .001, and EDA responses were found to vary across time, $F^{G\text{-}G}$ (1, 85) = 52.08, p < .001, there was no significant main effect for arousal manipulation condition, F (1, 85) = .85, p = .358, nor were there any significant interactions (refer to Tables C224 to C225). Also, respiration varied significantly across time, $F^{G\text{-}G}$ (1, 85) = 17.72 p < .001, and across time as a function of arousal manipulation condition, $F^{G\text{-}G}$ (1, 85) = 7.27, p = .008, but no other main effects or interactions were evident (refer to Tables C226 to C227).

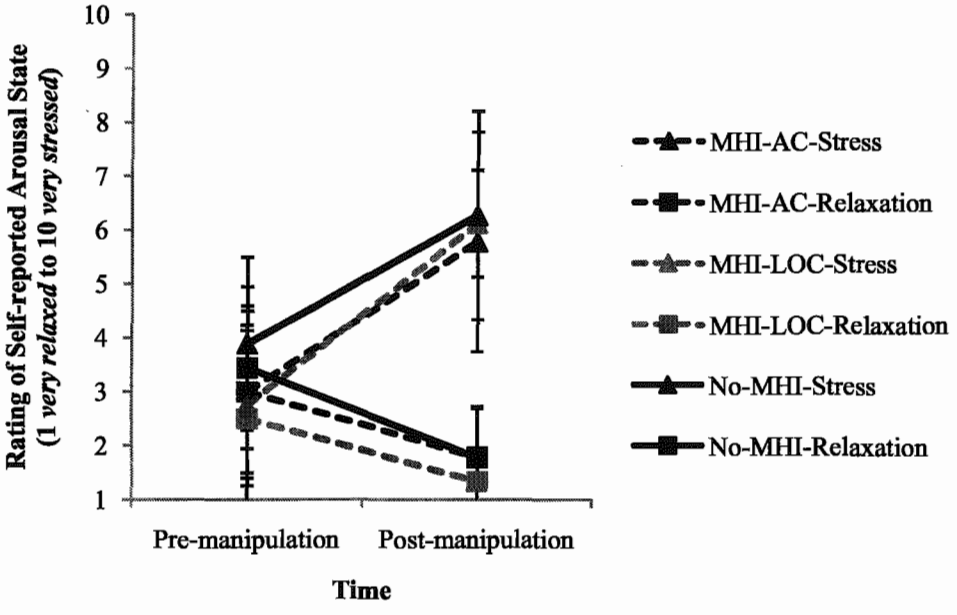

Figure 34. Self-reported arousal state as a function of MHI history severity by arousal manipulation condition across time.

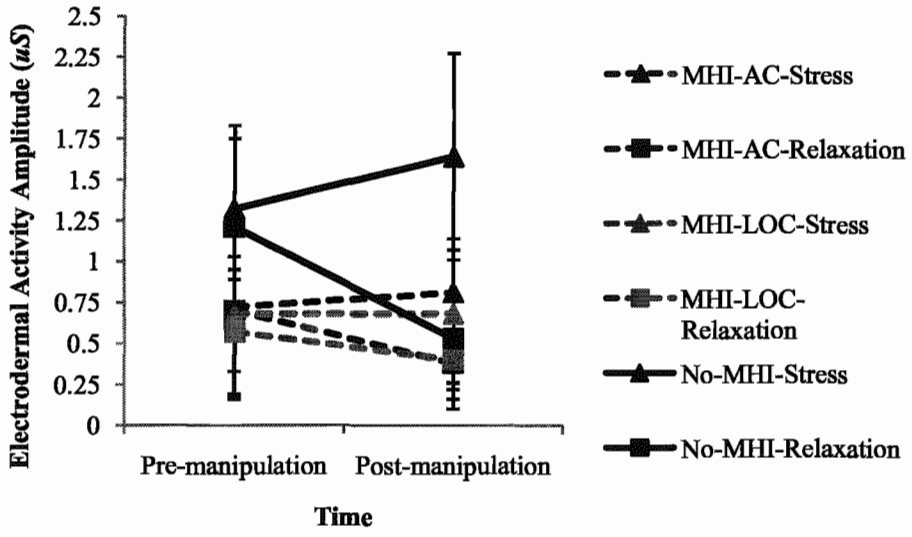

Figure 35. Electrodermal activity amplitude as a function of MHI history severity by arousal manipulation condition across time.

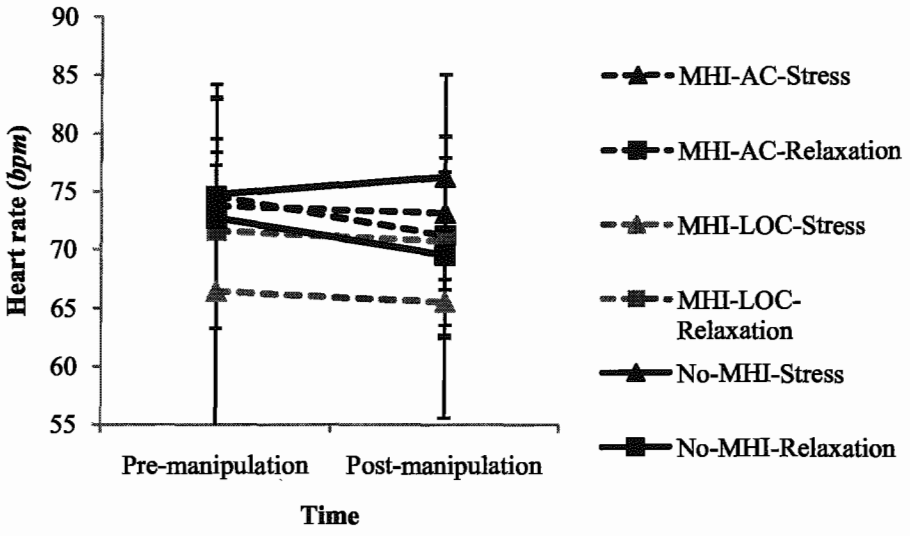

Figure 36. Heart rate frequency as a function of MHI history severity and arousal manipulation condition across time.

Post-hoc analysis of self-report of anxiety (STAI; Spielberger, 1983a). Unlike the trend indicated in the main analysis, the standardized measure of arousal/stress (STAI) did not differ between MHI history severity groups, F (2, 85) = 1.73, p = .183. However, the significant main effect of higher state anxiety reports in the psychosocial stress condition than in the relaxation condition remained, F (1, 85) = 5.94, p = .017. There was no significant interaction, F (2, 85) = 1.31, p = .276 (refer to Tables C228 to C229). Again, no significant differences were observed for the trait anxiety measure.

Post-hoc analysis of response to arousal manipulation across time as a function of MHI history severity. To test the underarousal hypothesis of a decreased physiological stress response in students with MHI compared to students without MHI history, separate 3 (MHI history severity: no-MHI, MHI-with-altered-state-of-consciousness, MHI-with-LOC) X 2 (Arousal Manipulation Condition: stress, relaxation) X 4 (after experimental manipulation, in-between neuropsychological testing, after neuropsychological testing, and

final recording) Mixed Model ANOVAs were conducted for each of the self-reported (self-report of arousal state scale) and physiological measures (EDA, HR, Respiration) of arousal.

Self-report of arousal. Students reported greater arousal in the psychosocial stress condition than in the relaxation condition, $F(1, 85) = 48.29, p < .001$, and ratings of self-reported arousal decreased across the testing session, $F^{G\text{-}G}(3, 255) = 15.11, p < .001$ (refer to Tables C230 to C233). A significant 2-way interaction of time by arousal manipulation condition revealed that the arousal manipulation was effective (i.e., higher ratings of self-reported arousal immediately after psychosocial stress induction that decreased across time, $F^{G\text{-}G}(3, 132) = 69.91, p < .001$; lower self-reported arousal following the relaxation induction that increased across time and returned to baseline levels, $F^{G\text{-}G}(3, 135) = 31.31$, $p < .001$), $F^{G\text{-}G}(3, 255) = 71.87, p < .001$ (refer to Tables C234 to C239). Self-reported arousal did not differ significantly as a function of MHI severity, $F^{G\text{-}G}(2, 85) = 2.34, p = .103$, but there was a tendency for students with MHI to have less of a response to the arousal manipulations than students without MHI, $F(2, 85) = 2.61, p = .080$. There was no significant interaction of time by MHI history severity, $F^{G\text{-}G}(6, 85) = .64, p = .667$; however, a 3-way interaction was observed, $F^{G\text{-}G}(6, 255) = 2.25, p = .051$, (refer to Table C232) and follow-up Mixed Model ANOVAs of self-reported arousal for each MHI history severity group by condition were conducted and revealed that relative to their no-MHI cohorts students with MHI-with-LOC acknowledged less arousal overall in response to the arousal manipulations, $F^{G\text{-}G}(3, 36) = 15.06, p < .001$, than students with MHI-with-altered-state-of-consciousness, $F^{G\text{-}G}(3, 105) = 40.60, p < .001$, and students with no-MHI, $F(3, 114) = 44.39, p < .001$ (refer to Figure 37 and Tables C240 to C248).

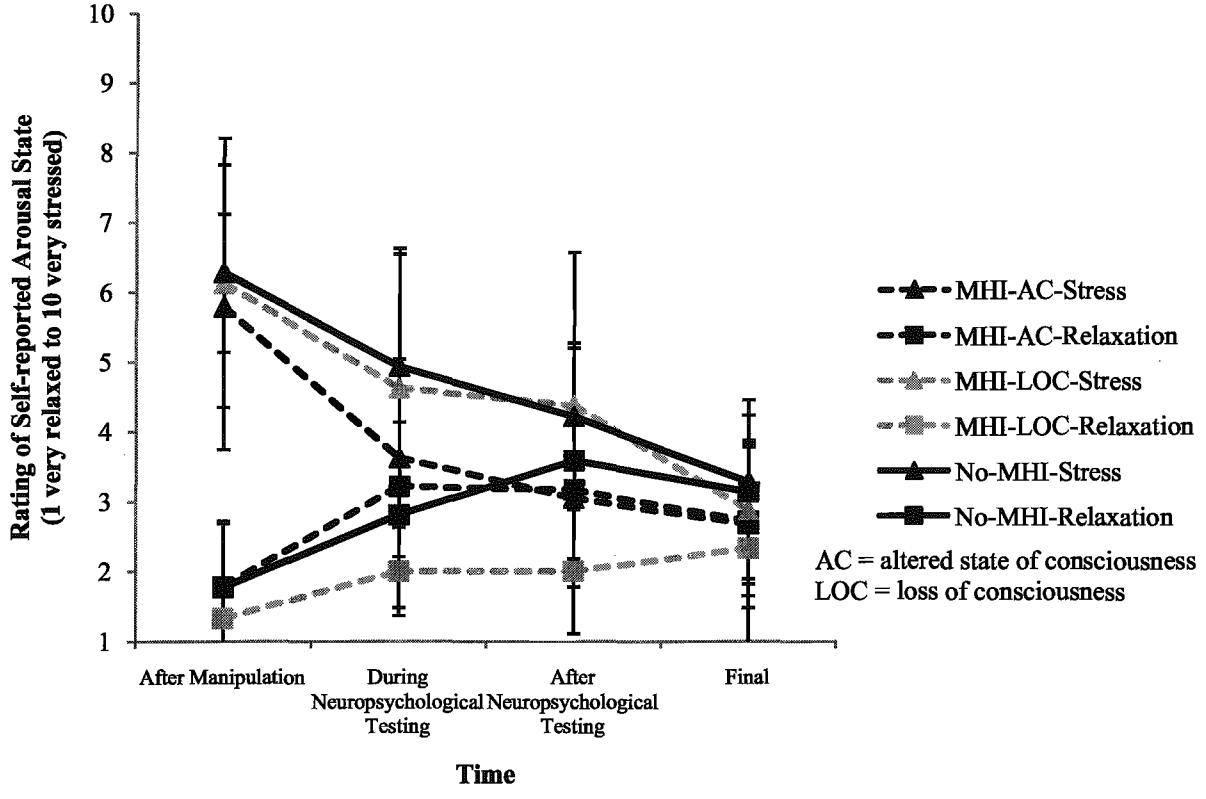

Figure 37. Self-reported arousal across time as a function of MHI history severity and arousal manipulation condition.

Post-hoc analysis of electrodermal activity—frequency. With respect to physiological responsivity to arousal manipulations as a function of arousal manipulation condition and MHI history severity, students in the MHI-with-LOC group produced significantly slower EDA responses than students in the no-MHI group. As well, those with MHI-with-altered-state of consciousness produced significantly slower EDA activity than students in the no-MHI group; however, there was no significant difference between MHI groups (MHI-with-altered-state-of-consciousness, MHI-with-LOC), F (2, 85) = 10.19, $p < .001$. Overall, EDA signals were slower across time, $F^{G\text{-}G}$ (3, 255) = 10.19, $p <$

.001, but did not differ significantly between conditions, F (1, 85) = 1.84, p = .179, and there were no significant interactions evident (refer to Tables C249 to C253).

Post-hoc analysis of electrodermal activity—amplitude. EDA amplitude significantly decreased over time, $F^{G\text{-}G}$ (3, 255) = 6.54, p = .001, and EDA amplitude was smaller in the relaxation condition as compared to the psychosocial stress condition, F (1, 85) = 14.98, p < .001. As anticipated, students with MHI-with-altered-state-of-consciousness and students with MHI-with-LOC produced smaller EDA amplitude than students with no-MHI, F (2, 85) = 30.94, p < .001. The EDA amplitude signal significantly decreased across time as a function of the arousal manipulation condition, $F^{G\text{-}G}$ (3, 255) = 25.12, p < .001, (refer to Tables C254 to C258) and separate repeated measures were conducted for each condition and were found to differ significantly across time in the expected directions for both the psychosocial stress, $F^{G\text{-}G}$ (3, 132) = 35.59, p < .001, and relaxation conditions, $F^{G\text{-}G}$ (3, 135) = 5.70, p = .002 (refer to Tables C259 to C264). Although, the 2-way interaction of time by MHI history severity was not significant, $F^{G\text{-}G}$ (6, 255) = .63, p = .707, there was a significant 3-way interaction, $F^{G\text{-}G}$ (6, 255) = 2.57, p = .020 (refer to Tables C256 to C258).

Follow-up analysis to the significant 3-way interaction (i.e., separate Mixed Model ANOVAs with arousal manipulation condition across time were conducted for each of the no-MHI, MHI-with-altered-state-of-consciousness, MHI-with-LOC groups, refer to Tables C265 to C273) revealed that EDA amplitude significantly decreased across the testing session for students with no-MHI, $F^{G\text{-}G}$ (3, 114) = 6.46, p = .001; it varied as a function of arousal manipulation condition, F (1, 38) = 26.22, p < .001, and there was a significant interaction of time by arousal manipulation condition, $F^{G\text{-}G}$ (3, 114) = 26.46, p < .001

(refer to Tables C265 to C267). However, for students with MHI-with-altered-state-of-consciousness their EDA amplitude signal did not vary significantly across time, $F^{G\text{-}G}(3, 105) = 2.13, p = .122$, but did differ significantly as a function of arousal manipulation condition, $F(1, 35) = 5.02, p = 5.02, p = .031$, and there was a significant interaction of time by arousal manipulation condition, $F^{G\text{-}G}(3, 105) = 10.94, p < .001$ (refer to Tables C268 to C270). Interestingly, the EDA amplitude response of students with MHI-with-LOC did not differ significantly across time, $F^{G\text{-}G}(3, 36) = .83, p = .451$, between arousal manipulation conditions, $F(1, 12) = .17, p = .690$, nor was there a significant interaction of time by arousal manipulation condition, $F^{G\text{-}G}(3, 36) = 2.25, p = .126$, suggesting an even more evident diminished EDA amplitude responsivity overall in comparison to the results discussed above for the MHI-with-altered-state-of-consciousness and no-MHI groups. Students with MHI-with-LOC appear to be non-responsive to the arousal manipulations (refer to Figure 38).

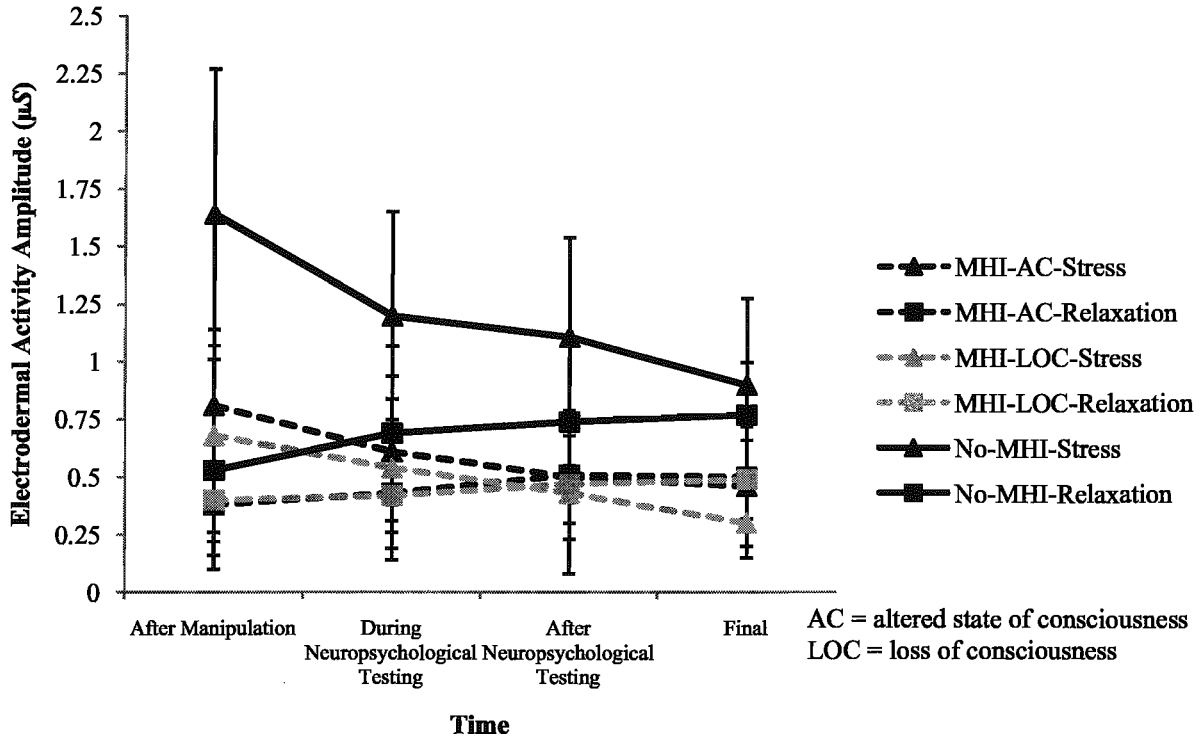

Figure 38. Electrodermal activity amplitude across time as a function of MHI history severity and arousal manipulation condition.

Post-hoc analysis of heart rate—beats per minute. Heart rate significantly decreased across time, F (3, 255) = 3.98, p = .009, but did not differ between arousal manipulation conditions, F (1, 85) = 1.43, p = .607. There were no significant interactions (refer to Tables C274 to C278) again potentially demonstrating a floor effect as in the main analysis. There was a tendency for students with no-MHI to have a higher heart rate than students with history of head injury, F (2, 85) = 2.87, p = .062. More specifically, students with no-MHI produced faster heart rates than students with MHI-with-loss-of-consciousness, but the no-MHI group was not found to differ significantly from the MHI-with-altered-state-of-consciousness group, while the MHI-with-altered-state-of-consciousness and the MHI-with-LOC groups differed with the latter producing slower heart rates (refer to Table C278 for multiple comparisons).

Post-hoc analysis of respiration—frequency. Frequency of respiration (cycles per minute) did not differ across time, $F^{G\text{-}G}$ (3, 255) = .47, p = .679, nor as a function of MHI history severity, F (2, 85) = 1.46, p = .238. Respiration frequency was significantly faster in the psychosocial stress condition than the relaxation condition, F (1, 85) = 4.22, p = .043. There were no significant interactions (refer to Tables C279 to C281).

Post-hoc Analysis of Hypothesis 3: Arousal State, MHI History Severity, and Cognitive Performance

Baseline Cognitive Performance Prior to Presenting Arousal Manipulation

Similar to the main analysis, students with MHI-with-altered-state-of-consciousness or with MHI-with-LOC did not differ on the brief estimate of intelligence capacity (i.e., Block Design, Vocabulary, WAIS-III, 1997) when compared to students with no-MHI (refer to Tables C282 to C285). Separate one-way ANOVAs were conducted to examine if students with MHI history (both severity groups: MHI-with-altered-state-of-consciousness, MHI-with-LOC) performed differently from their no-MHI cohort on tasks of working memory and attention prior to any arousal manipulation induction.

Working memory. Students with a self-reported history of MHI were not found to differ significantly from their no-MHI counterparts on the time for completion or number of errors made on the Trail Making Test Ia (DKEFS, 2002). Similarly, no significant differences were found between MHI history severity group with respect to performance on the Digit Symbol-Copy task (WAIS-III, 1997) as such this data is not presented.

Attention. The three groups tended to differ on attentional tasks as a function of severity of injury. For the more complex attentional switching task (Colour-Word Interference Task; DKEFS, 2002), students tended to take a longer time to complete the

task with increasing severity of injury, F (2, 88) = 2.56, p = .083; however, pairwise comparisons indicated that although students with no-MHI tended to differ from students with MHI-with-altered-state-of-consciousness and students with MHI-with-LOC, there was no difference between students who had sustained an MHI (refer to Tables C286 to C288). Students with history of MHI tended to take longer to complete the word reading task than students with no-MHI, F (2, 88) = 2.92, p = .059, but the no-MHI group was only found to differ from the MHI-with-altered-state-of-consciousness group and not the MHI-with-LOC group (refer to Tables C291 to C293). No significant differences were found for the colour naming task (refer to Tables C289 to C290) or the inhibition task (refer to Tables C294 to C295). In short, students with history of head injury tended to demonstrate poorer performance on a few attentional tasks at baseline testing as compared to students with no-MHI, but not for tasks of working memory.

Post-hoc Investigation of Cognitive Performance as a Function of Arousal Manipulation Condition and MHI History

Cognitive capabilities were examined in three main domains: memory (working, visuospatial, and narrative), attention, and planning/abstract reasoning abilities via either 3 (MHI History Severity: no-MHI, MHI with altered state of consciousness, MHI with LOC) X 2 (Arousal Manipulation Condition: Stress, Relaxation) ANOVAs, Mixed Model ANOVAs for repeated cognitive measures to compare pre- and post-manipulation performance as a function of MHI history severity and arousal manipulation condition, or were investigated in a between-subjects design via 3 (MHI History Severity: no-MHI, MHI with altered state of consciousness, MHI with LOC) X 2 (Arousal Manipulation Condition: Stress, Relaxation) ANOVAs to examine hypothesized interactions. Note that

due to the exploratory nature of these analyses only the effects of interest will be highlighted.

Post-hoc Investigation of Pre-and-Post-Manipulation Comparisons of Cognitive Performance

Working memory. Students produced significantly more symbols (Digit Symbol-Copy; WAIS-III, 1997) with repeated testing, $F(1, 85) = 66.58, p < .001$. There was a trend for a difference in performance between MHI history severity group on the Digit Symbol-Copy test, $F(2, 85) = 2.50, p = .088$, such that students with MHI-with-altered-state-of-consciousness produced significantly less symbols than students with no-MHI but there were no other significant differences between the MHI history severity group. There was no main effect for arousal manipulation condition, $F(1, 85) = 1.21, p = .274$, nor any significant interactions (refer to Tables C296 to C299). As well, post-hoc examination of pre-to-post comparison of performance (time to completion, number of errors) on the Trail Making Test (DKEFS, 2002) was not found to produce any significant main effects or interactions and therefore is not presented in detail.

Attention. For the complex attentional switching task (Colour-Word Naming Interference Task—Switching, DKEFS, 2002) students were significantly faster in time for completion with repeated testing, $F(1, 85) = 57.50, p < .001$. There was a trend for students with MHI to be slower at completing this task than their no-MHI counterparts, $F(2, 85) = 2.42, p = .095$, and follow-up investigation revealed the only significant difference between the MHI history severity group was between students with no-MHI and those with MHI-with-altered-state-of-consciousness. There was a trend for an interaction

of time by arousal manipulation condition, $F(1, 85) = 3.09$, $p = .082$. No other effects were found (refer to Tables C300 to C303).

Although students were significantly faster at naming the colour patches when it was given for a second time, $F(1, 85) = 32.39$, $p < .001$, no other significant main effects or interactions were evident (refer to Tables C304 to C306). There was a trend for students with MHI history to be slower at reading the words, $F(2, 88) = 2.48$, $p = .090$, but follow-up comparisons indicated that only students with no-MHI were significantly different from those with MHI-with-altered-state-of-consciousness. No other significant effects or interactions were evident (refer to Tables C307 to C310). Students were more efficient in performing the inhibition task with repeated testing, $F(1, 85) = 31.74$, $p < .001$, but no other significant effects or interactions were observed (refer to Tables C311 to C313).

Long-term narrative and visuospatial memory. As was previously discussed in the main analysis, there were main effects of poorer delayed than immediate recall of information, and that students with MHI still tended to perform better than their no-MHI cohort for narrative long-term memory (Logical Memory I and II, WMS-III, 1997), but not for visuospatial skills (Memory for Design, NEPSY, 2007). No significant interactions were evident, thus post-hoc analysis of these measures are not presented in detail.

Other post-hoc investigations. No significant interactions of arousal manipulation condition by MHI history severity were evident for post-arousal manipulation measures of working memory (Trail Making Test Part II, DKEFS, 2002), planning (Tower of Hanoi, DKEFS, 2002), abstract reasoning (Pictorial Analogies, CTONI, 1996; Picture Arrangement, WAIS-III, 1997), or cognitive flexibility (Mental Control, WAIS-III, 1997) and as such are not presented. Despite a lack of statistical support, anecdotally, visual

inspection of the means was suggestive in that oftentimes students with MHI-with-LOC appeared to benefit from increased arousal (psychosocial stress condition) as compared to lowered arousal (relaxation condition) more than the MHI-with-altered-state-of-consciousness group, while those with no-MHI appeared to have poorer performance in the psychosocial stress condition as compared to the relaxation condition.

Post-hoc Examination of Hypothesis 4: Post-Concussive Symptom Reports in University Students as a function of MHI History Severity

One-way ANOVAs were conducted to examine potential differences in post-concussive symptom ratings (PCSC; Gouvier et al., 1992) between students with no-MHI and those with a reported history of head injury (i.e., MHI-with-altered-state-of-consciousness, MHI-with-LOC). Overall, students with history of head injury reported higher symptom ratings than students with no-MHI. Post-concussive symptom reports varied significantly as a function of MHI history severity, F (2, 88) = 3.23, p = .044, such that students with MHI-with-altered-state-of-consciousness endorsed significantly more symptoms than students with no-MHI (refer to Tables C315 to C317). Similarly, students with MHI-with-altered-state-of-consciousness reported experiencing the symptoms with greater intensity, F (2, 88) = 3.72, p = .028, and for longer durations, F (2, 88) = 3.32, p = .041, than students with no-MHI. Ratings of symptoms were not found to vary significantly between those with no-MHI and students with MHI-with-LOC, nor between students with MHI-with-altered-state-of-consciousness and those with MHI-with-LOC which may suggest that post-concussion-like symptom reports do not occur in a dose-dependent fashion. Individual symptoms (e.g., headaches, visual disturbances, etc.) are not presented due to the exploratory nature of this analysis.

Summary of Results

As previously described, 56% of students reported a history of sustaining an MHI as a result of sports-related activities or falls and 60.78% of those reported more than one MHI. Notably, the majority only reported an altered state of consciousness and no LOC. For those who did report an LOC the duration was less than 30 minutes (and the majority reported an LOC for less than 5 minutes) which meets criteria as described by Kay et al. (1993) and Cantu (1986). Furthermore, less than half of the students reported receiving medical treatment for their injury. It is important to note that students were not recruited based on history of head injury and had not complained of persistent effects of their injury and 70.50% had experienced their injury more than one year ago. Nonetheless, university students who acknowledged a previous MHI reported post-concussive symptoms more often, experienced them with greater intensity and for longer durations, than students without MHI, independent of severity of injury or length of time since injury occurred.

As hypothesized, at baseline, students with a history of sustaining an MHI are physiologically underaroused relative to students with no-MHI and also reported lowered arousal state despite increased reports of experiential stressors and a tendency to report more positive ratings of life satisfaction. With respect to residual cognitive performance decrements following MHI, we expected that students with MHI would perform poorly relative to their no-MHI counterparts at baseline and found this to be the case for certain working memory and attentional tasks. Whereas, intelligence capacity (i.e., brief estimate of intelligence as measured by subtests of the WAIS-III) and performance on other cognitive tasks (i.e., abstract reasoning, narrative memory) for persons with reported

history of MHI remains comparable to, and often better than, that of students with no reported MHI.

We expected that students with MHI would respond differentially to the arousal manipulations, and although, as noted, we may have produced a floor effect with the relaxation manipulation, students with MHI did demonstrate less variation (range) of physiological response (as measured by EDA amplitude) than students without MHI for both the stress and the relaxation induction manipulations supporting the underarousal hypothesis, i.e., the proposal that competent persons with reported subtle head injuries are physiologically underaroused or less responsive compared to their cohorts. However, they do not differ from their no-MHI cohort with self-reported arousal state in response to the manipulations across time; despite a main effect of lowered self-reported arousal and a trend for experiencing less anxiety as compared to students without MHI.

We predicted that for certain cognitive tasks students who have a history of MHI may be subtly disadvantaged compared to their no-MHI cohorts and further that the cognitive performance for skills associated with working memory, attention, and cognitive flexibility of students with MHI would benefit via increased arousal through the introduction of a psychosocial stressor and would be impaired following a relaxation induction, in contrast to students without MHI. A trend for this cross-over interaction was found for tasks involving cognitive flexibility, but was not significant for other measures of ability and the trends and main effects of poorer performance as a function of MHI history remained for a few of these cognitive measures. The primary hypothesis that cognitive performance would vary as a function of manipulated arousal by history of MHI was not clearly supported, despite the arousal data indicating patterns consistent with this

hypothesis. Furthermore, rather than globally depressed scores for students with MHI as compared to students without MHI, we expected that some abilities would remain unaffected. In line with this, performance was not poorer for measures of long-term memory (narrative and visuospatial) or planning/abstract reasoning skills, and in fact, students with MHI performed equal to, or sometimes, significantly better than their no-MHI cohort. Students with MHI also, at times, demonstrated faster reaction times than their no-MHI cohort. This speaks to the competency of the sample (i.e., university students) and the subtle nature of the lowered performance observed in working memory and attentional tasks.

Summary of post-hoc analyses. The post-hoc analyses presented here provide direction for future research. In light of the lack of support for Hypothesis 3 (i.e., differential cognitive performance as a function of manipulated arousal state and MHI history) we examined these data in a post-hoc fashion as a function of severity of injury thereby creating three groups (no-MHI, MHI-with-altered-state-of-consciousness, MHI-with-LOC). Most strikingly, students with greater severity of injury (i.e., MHI-with-LOC) demonstrated evidence of greater underarousal than those with altered state of consciousness. Physiological responsivity to arousal manipulation across time (EDA amplitude, EDA frequency, and heart rate) was similar to the main analyses with the MHI-with-LOC group showing even lower arousal and a poorer range of responsivity than the other two groups, despite showing a similar response in self-report of arousal. As well, students with MHI-with-LOC demonstrated a pattern of producing the lowest and poorest range of physiological response as compared to the other groups following arousal manipulation. Notably, the EDA amplitude signal of students with MHI-with-LOC did not

vary across time, as a function of arousal manipulation condition, nor were there any significant interactions; perhaps demonstrating a floor effect. Even though the MHI-with-altered-state-of-consciousness group demonstrated lower physiological arousal than the no-MHI group, they both appeared to be influenced by the arousal manipulations, unlike the MHI-with-LOC group. Although scores on the standardized measure of stress (i.e., STAI, Speilberger, 1983a) were suggestive of lower anxiety for students with MHI history as compared to those with no-MHI, there were no main effects or interactions evident one-hour post-manipulation induction.

Cognitive performance on a few measures varied as a function of MHI history severity but there was no significant evidence to support Hypothesis 3. As anticipated, there was no significant difference between students with MHI-with-altered-state-of-consciousness, MHI-with-LOC, or no-MHI on the brief estimate of intelligence capacity (Block Design, Vocabulary, WAIS-III, 1997). Unlike the main analysis which evidenced effects and trends for differences in working memory and attentional performance as a function of MHI history, the post-hoc analysis revealed only a tendency for poorer performance by the MHI-with-LOC as compared to the other two groups for attentional and not working memory tasks.

The primary reason for conducting the post-hoc analysis was to examine evidence for differential cognitive performance as a function of MHI history severity and the arousal manipulation which was unfortunately not supported but will provide direction for future research. Although not reaching statistical conventions, there is a subgroup of students (i.e., the MHI-with-LOC group) that appear to cognitively benefit from increased arousal/stress as compared to lowered arousal/relaxation, albeit anecdotally. It appears that

our sample of students reporting MHI may be heterogeneous in terms of the benefits to cognitive performance via increased arousal (this can be interpreted in terms of their lowered baseline arousal via the Yerkes-Dodson (1908) arousal-performance inverted U relationship). Yet, the limited and somewhat non-responsivity of students with MHI-with-LOC as compared to students with MHI-with-altered-state-of-consciousness and those with no-MHI may have restricted the hypothesized arousal manipulation condition by MHI history interaction on cognitive performance and we will further examine the possibilities of such in later research. Lastly, post-concussive symptom reports were found to vary as a function of MHI history severity such that students with MHI-with-altered-state-of-consciousness reported significantly more symptoms, with greater intensity and for longer durations than students with no-MHI, but were not found to differ for the other groups, nor produce a dose-dependent pattern.

Discussion

The general purpose of this thesis was to investigate the potential underarousal (as measured via self-report and physiological arousal measures) of university students who reported sustaining a MHI as compared to students without a MHI; to examine possible differences in responsivity to arousal manipulations as a function of MHI history; to investigate the effects of experimentally modified arousal state on cognitive performance in university students with and without MHI (nominally the benefits of increased arousal for persons with MHI); and, explore post-concussive symptom reports in this high-functioning population as a function of MHI history. We also examined the prevalence and etiology of self-reported MHI in university students as research on this age-group is limited. Each of these objectives will be discussed in turn.

First, it is important to note differences in investigating persons with MHI. Most investigations of persons with MHI use patients with diagnosed MHI or MTBI with or without complaints of post-concussive symptoms who have been referred, typically by the treating medical facility, for assessment to a neuropsychologist or to an out-patient clinic for treatment (e.g., Belanger, Curtiss, Demery, Lebowitz, & Vanderploeg, 2005; Bryant & Harvey, 1999; Chan, 2005; McCauley et al., 2007; Mathias, Beall, & Bigler, 2004; Raskin et al., 1998). As well, some of the patients may be involved in litigation during the time course of the study which may or may not affect symptom reporting and overall performance (e.g., Belanger et al., 2005; Binder & Rohling, 1996). Similarly, the sports literature often compares concussed and non-concussed athletes on neurocognitive correlates of function via neuroimaging techniques across a season of games and oftentimes this research is focused on returning athletes to competition (e.g., Ptito, Chen, & Johnston, 2007; Chen, Johnston, Petrides, & Ptito, 2008; Johnston et al., 2004). Both approaches also have typically assessed persons with clinically diagnosed MTBI in the acute post-injury period perhaps because the literature regarding long-standing impairments in cognitive function and other domains following milder brain injuries has been highly controversial (refer to Iverson & Lange, in press [b] for recent discussion; Carr, 2007; McCauley et al., 2007). Note that both of these approaches pre-screen and select for persons with history of head injury and often compare performance on various measures to that of an assigned control group. Oftentimes the control group does not complete questionnaires (e.g., assessing PCS complaints) or other information that may be assumed to be contingent on history of head injury. Typically, control participants are

selected for age, education, sex, intelligence capacity or other factors to match patients or athletes with MHI.

Our approach, however, has been different in the following ways: 1) we did not recruit participants on basis of head injury history; 2) participants were high-functioning university students and those who reported a history of MHI were not complaining about persistent symptoms or complications following their head injury; 3) to our knowledge participants were not involved in litigation as a result of their head injury; 4) the majority of participants had passed the post-acute injury phase (i.e., 86.30%, $n = 44$); 5) all participants were administered the same neuropsychological test battery as well as completed the same questionnaires regardless of history of head injury; and, 6) participants were not informed that the purpose of the study was to examine various cognitive, emotional, and physical aspects of MHI until all testing was completed in order to avoid the impact of diagnosis threat on performance (see Suhr & Gunstad, 2002, 2005).

There is limited information regarding the prevalence of MHI for the high risk period of birth to 25 years of age (McKinlay et al., 2008). Our sample is representative of retrospective self-report of mild head injury in university students and, given the aforementioned considerations, is unique. As previously discussed, the prevalence of self-reported MHI was found to be 56%, with 60.58% of those reporting more than one MHI. Although the prevalence of MHI found in our study is dissimilar to the incidence rate reported elsewhere (e.g., Chuah et al., 2004; Segalowitz & Lawson, 1995), research from the Brock University Neuropsychology Cognitive Research Lab has found similar proportions of head injury in a university student population when using the liberal criteria of 'altered state of consciousness' (adapted from Kay et al., 1993). Note that the majority

(70.59%) reported only an altered state of consciousness and no LOC for their most recent injury. Less than half reported receiving medical treatment for their injury (note that Segalowitz & Lawson (1995) found that 81% of university students reported they were not admitted to the treating medical facility for their head injury; 90% of our sample did not stay overnight in a medical facility). The MHI criteria used in our study was not based on hospital admissions and thus revealed a larger proportion reporting history of MHI (e.g., Sosin et al., 1996) and may present a more realistic picture of reports of sustaining a head injury sufficient to produce an altered state of consciousness in this population.

Furthermore, head injuries occur quite frequently for young adults as compared to other age groups (e.g., Cassidy et al., 2004; Kraus & Nourjah, 1988) and, thus, the increased prevalence in our sample could be a function of the selection of post-secondary students. Perhaps if the prevalence was adjusted for sex ratio (i.e., more males reported MHI than females as expected—see Kraus & Nourjah, 1988) or a more rigid or different definition of MHI was used, the prevalence would be lower. Nonetheless, the etiology of MHI in our sample followed similar patterns to that of others examining this age group (McKinlay et al., 2008; CIHR, 2006) with sports-related injuries most commonly reported, followed by falls. However, another common cause of traumatic brain injuries in this age cohort is motor vehicle collisions (CIHR, 2006; McKinlay et al., 2008), but only one participant in our study reported her head injury as a result of motor vehicle collision 6 years prior. The etiology of injuries, as well as the fact that all participants who reported an LOC experienced it for less than 30 minutes (most reporting an LOC experienced it for less than 5 minutes), also speaks to the milder end of the spectrum of brain injury and is well within the criteria set by Kay et al. (1993).

The prognosis of mild brain injury is typically good and usually post-concussion-like symptoms subside for most persons within one week post-injury (Levin et al., 1987; McCrea et al., 2003) and are most often resolved by 3 months (Lannsjo et al., 2009; Levin et al., 1987). It has been commonly cited (e.g., Alexander, 1995; Binder, 1986) that 15 - 20% or more of persons who have sustained a MHI will continue to experience post-concussive symptoms amongst other cognitive and affective difficulties beyond 3 months and in a persistent fashion. Yet, some of the literature (e.g., Iverson & Lange, 2003; in press [b]) suggest that this is an overestimate which should be downgraded to approximately 10% and may reflect the fact that the constellation of concussion symptoms are not specific to mild head injury and are commonly reported by the general healthy, non-head injured population (e.g., Gouvier, Uddo-Crane, & Brown, 1988; Iverson & Lange, 2003; Wong, Regennitter, & Barrios, 1994). However, in the current thesis, despite the subtle nature of the head injury and the competency of the sample (i.e., university students), compellingly, students who acknowledged a history of an MHI reported experiencing post-concussive symptoms more often, with greater intensity and for longer periods of time than their no-MHI cohorts. As hypothesized, ratings of symptom reports were significantly different as a function of MHI history[17] particularly with respect to the more *qualitative* aspects (i.e., intensity and duration) of the symptoms experienced rather than the frequency of experiencing the symptoms. Furthermore, students with MHI endorsed symptoms more often independent of increased injury severity or the length of time that had elapsed since the injury. As such, persistent long-term post-concussive

[17] *Note.* Ratings of the intensity, duration, and frequency of post-concussive symptoms in our no-MHI group matched that of baserate symptom ratings of other healthy, young adults (e.g., Wong, Regennitter, & Barrios, 1994).

symptoms are evident in young adults who endorsed previous history of sustaining an MHI as compared to their no-MHI cohort.

We suggest that this finding may indicate that the underlying cause of the symptoms are most likely due to biological effects (i.e., due to neural disruption) of the injury and may not be transient. Moreover, the increased ratings of post-concussive symptoms of students with a history of sustaining a MHI are less likely to be due to experiencing the potential increased stress of university student life, motivated by litigation pursuits, or result from psychogenic maintenance. As a whole, university or college students may experience more stress and as such may endorse more cognitive, affective, and somatic complaints (Gouvier et al., 1992); however, in our study we compared university students with and without an MHI to equate the potential effects of stressful university life on symptom reports. Even so, university students who reported having sustained an MHI reported greater experience of post-concussive symptoms than university students with no reported MHI. Further, to our knowledge, the university students with reported MHI in the current study were not reporting symptoms in response to compensation via litigation, nor would they have any incentive to endorse more symptoms (i.e., were not malingering). Students were not informed as to the primary use of this questionnaire (questionnaire titles were removed for administration) and most likely would not have linked the symptom reports to the much previous (i.e., tested 2.5 hours prior) questions regarding head injury that were interleaved with other health-related questions; nor would they have likely made a connection between the head injury and any potential cognitive, affective, or physical consequences (i.e., refer to Gordon et al., 1998) since to their knowledge that was not the focus of the study. As such, it remains that

students who reported sustaining an MHI endorsed post-concussion-like symptoms more often and experienced them qualitatively differently from students with no MHI.

Further, we suggest that the symptom reports may not be as "nonspecific" as previously suggested (e.g., Iverson & Lange, 2003; Wong et al., 1994) in that students who endorsed a history of a previous MHI reported experiencing concentration difficulties significantly more often, with greater intensity and for longer periods of time than students without MHI history. Similarly, students with MHI reported being irritable for longer durations, reported greater intensity in difficulties in judgment, and experienced headaches with greater intensity than their no-MHI counterparts[18]. Post-hoc investigation of individual symptoms also revealed students with MHI reported experiencing symptoms of visual disturbances and being aggravated by noise with greater intensity and for longer periods of time than their cohorts. These symptom reports are consistent with PCS or PCD criteria (e.g., International Classification of Diseases (ICD)-10; World Health Organization, 1992; 1993; DSM-IV; American Psychiatric Association, 1994) and although may overlap with other presentations, the ratings of post-concussive-like symptoms in our study were found to be higher for those with self-reported history of subtle MHI (and not any clinical diagnosis e.g., MTBI) as compared their no-MHI counterparts.

In line with the long-lasting effects of neural disruption, we obtained several consistent findings that demonstrated students who reported having previously sustained an MHI are underaroused relative to their no-MHI cohort, both in terms of self-report and physiological measures, yet they reported significantly more experiential life stressors and

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[18] $p < .10$, but $> .05$.

tended to be more satisfied with their life in general. More specifically, our hypothesis was supported in that prior to any arousal manipulation, students with a history of a MHI rated themselves as having a significantly lower arousal state, demonstrated less autonomic emotional arousal (i.e., slower average EDA frequency signals (cpm) and attenuated average EDA amplitude [μS]) than students who had not reported an MHI. The underarousal of students with self-reported MHI is suggested to reflect subtle OFC or ventromedial PFC dysfunction as a result of the previous head trauma. As previously mentioned, this region is most likely to undergo disruption during traumatic brain injury as a result of its close proximity to the bony protruberances of the cribiform plate (King, 1997; Mateer & D'Arcy, 2000, Morales et al., 2007). Research of persons with more moderate-to-severe traumatic brain injury to the ventromedial PFC has pointed to this region as playing an important role in the modulation of autonomic responses (e.g., Tranel & Damasio, 1994); therefore, if the ventromedial PFC is damaged or its rich axonal connectivity to other areas (e.g., limbic, sensory, etc.) is disrupted, this could very likely account for the underarousal of persons with self-reported MHI, as is found with more severe injuries.

Moreover, students with self-reported MHI may experience a lessened ability to interpret emotional signals (e.g., Damasio's somatic marker hypothesis), or may be less aware of stressors in their environment, as they showed a mismatch between increased reports of life stressors, yet produced lower baseline self-reported and physiological arousal levels. As previously discussed, the amygdala has rich connections with the hypothalamus, pre-ganglionic sympathetic nervous system, as well as the ventromedial PFC (see Kringelbach & Rolls, 2007; Wallis, 2007 for reviews) and damage to the

ventromedial PFC may result in altered communication with the amygdala which typically initiates the stress response. As such, persons with MHI may be less likely to have heightened autonomic arousal at resting state as was evidenced in the current study. More recently, a study by Bay, Sikorskii, and Gao (2009) reported, amidst their other findings, that cortisol profiles in persons with mild-to-moderate traumatic brain injury (TBI) are dysregulated indicating dysfunctional stress responsivity similar to what was found in the current study. More specifically, the authors stated that persons with mild-to-moderate TBI showed evidence of hypocortisolemia (they mentioned that this profile is typically seen in patients with chronic pain, PTSD, or HPA-axis problems) and demonstrated flat diurnal trends. The authors interpreted the hypocortisolemia of patients with brain injury as potentially a result of chronic stress; although, persons with mild-to-moderate TBI reported more stress, the authors did not find a significant relationship between cortisol measures and the psychological stress measure they used. We would like to suggest that their findings of lower cortisol levels despite increased reports of life stressors in persons with mild-to-moderate TBI are similar to our findings that persons with self-reported MHI present with underarousal (via physiological and self-report measures of arousal) despite acknowledging increased experiential life stressors.

Furthermore, perhaps the underarousal despite increased experiential stressors is because persons with MHI, like persons with more severe brain injuries, are less able to interpret [emotional] body states (Damasio, Tranel, & Damasio, 1998—somatic marker hypothesis) and this results in an altered perception of stressful experiences. Primarily the somatic marker hypothesis put forward by Damasio and colleagues (1990; 1998) is concerned with decision making and how a lack of physiological/visceral feedback impairs

such processes. Perhaps an extension of Damasio's theory is that persons with MHI experience a reduction in arousal and affective status as a result of lessened feedback involving 'emotional' somatic markers to the OFC given its connections to limbic and visceral regions that are potentially disrupted following injury to the head. Thus deficient or disrupted feedback of 'emotional' markers may contribute to the altered perception of stressful experiences and the lowered arousal status despite the cognitive reality of being able to appropriately and rationally recognize the presence of stressful events and, in the current research, report an increased incidence of stressful life events as evidence in persons with MHI.

With respect to the responsivity to experimentally manipulated arousal of students with MHI as compared to their no-MHI cohort, we found an impressively reduced range of physiological response to the psychosocial stressor on several physiological measures (namely EDA and HR). Students with and without MHI similarly reported heightened arousal (more stress) immediately following the psychosocial stressor (despite a main effect showing lower arousal between MHI groups), yet students with MHI demonstrated flatter physiological responses (as shown by EDA amplitude and heart rate measures) than their no-MHI cohort. This finding is similar to that shown in persons with more moderate-to-severe traumatic brain injury. Tranel and Damasio (1994) demonstrated that patients with damage to the ventromedial PFC had poorer electrodermal skin conductance responses, particularly in response to affective/psychological stimuli (highly-charged visual stimuli), but still elicited responses to physical stimuli (a loud clap). In our study, students showed dampened physiological responsivity if they reported a previous MHI compared to their no-MHI cohort. Further, while there was evidence of a floor effect to the

relaxation manipulation, there were indications of reduced responsivity for the MHI group as well.

With respect to cognitive performance as a function of MHI, we found, as expected, that students with MHI tended to perform more poorly on working memory and attentional tasks (i.e., at baseline and prior to any arousal manipulation). We also hypothesized that modifying the arousal status of persons with MHI through increased stress would benefit their cognitive performance, whereas relaxation would further hinder their performance, in contrast to persons without MHI. In our study, this interaction was only evidenced as a trend for tasks requiring cognitive flexibility. Despite suggestive evidence of being influenced by the arousal manipulation, students with MHI continued to perform more poorly on working memory or attentional tasks than no-MHI students post-manipulation. Further, students with MHI did not reliably show poorer cognitive performance overall as poorer performance was not seen for narrative or visuospatial memory, nor tasks tapping abstract thought or planning abilities, and at times performed better than students without MHI. This speaks to the mild nature of the reported head injury of the sample, and the fact that these measures of abstract reasoning and memory ability, neither of which are specifically associated with OFC function, may reflect the otherwise preserved competence of other areas of the frontal lobe. To this end, students with and without MHI did not differ in terms of the abbreviated measure of intelligence capacity, the amount of assistance required throughout their academic career, nor their current student status.

The post-hoc analysis of baseline/resting physiological status (i.e. EDA amplitude, EDA frequency, HR) and physiological responsivity to arousal manipulations provided

striking evidence of a gradient of underarousal in students with MHI-with-altered-state-of-consciousness followed by even less arousal in students with MHI-with-LOC. Most interesting is that students with MHI-with-LOC failed to produce significant changes in their EDA amplitude signals across time as a function of the arousal manipulation. Students with MHI-with-altered-state-of-consciousness, but more so, students with MHI-with-LOC demonstrated reduced responsivity to the arousal manipulation conditions across time as compared to those with no history of MHI. A floor effect may have been produced to the relaxation manipulation, and in the case of the MHI-with-LOC there was also evidence of little impact of either of the arousal manipulations on physiological response to both the psychosocial stressor and the relaxation technique.

Even with the additional post-hoc analysis we failed to find significant effects in support of our cross-over interaction hypothesis—although in doing so we illuminated a potential subgroup of persons (MHI-with-LOC) who appear (anecdotally) to cognitively benefit from increased arousal/stress as compared to relaxation, in contrast to persons with no-MHI. We will further examine this group and the potential effects of modifying arousal status in our future research. On another note, post-concussion symptom reports were found to differ as a function of MHI history severity, particularly for students with MHI-with-altered-state-of-consciousness as compared to students with no-MHI, but did not differ between the other groups significantly.

The post-hoc analysis has raised more questions than answers in that the physiological underarousal of persons with MHI history appears to be in a dose-dependent fashion, whereas the post-concussion symptom reports are not. Further, we will have to

revisit the arousal manipulation condition by MHI history interaction with respect to cognitive functioning in another sample, possibly one with greater severity indices.

The failure to find an effect of arousal manipulation overall may be due to the lack of effectiveness of the manipulations. Although physiological and self-report measures demonstrated that the manipulations were effective in inducing changes in arousal status, the effect may have been insufficient in terms of longevity to modify cognitive performance over the testing session of 2.5 hours, the manipulation effect returned to baseline and was not sufficiently maintained during neuropsychological testing blocks. Our stressor was mild compared to some manipulations (e.g., videotaping performance) and brief (i.e., most other tests using this manipulation last 30 minutes). Further, the relaxation manipulation may have reached a floor—which prohibited any further change. Finally, the majority of the literature reporting impairments or enhancements in cognitive domains via manipulated arousal have focused on pharmacologically-altered inductions or hormonal-activation as compared to the induced-psychosocial stress in our study.

Conclusions

The findings from this study have consistently supported the hypotheses of underarousal and lessened stress responsivity of persons who have sustained a MHI (similar to moderate-to-severe TBI), as well as demonstrating increased post-concussive symptom reports in a university sample as a function of self-reported MHI history. Most outstanding is the finding that arousal status differs as a function of self-reported history of MHI, although to a lesser degree than those with more severe TBI. These findings are interpreted as demonstrating that students who have experienced a mild, but notable, injury to the head may have a lessened ability to interpret and respond to stress possibly as a

function of subtle disruption to the ventromedial PFC as this region has been implicated in modulating emotional and autonomic responses. To our knowledge this is the only study with a detailed examination of physiological and self-reported arousal in persons with milder head injuries and further replication will add to the current literature.

The heightened experience of post-concussive symptoms in students who report having sustained a previous MHI may interfere with their ability to perform optimally as a university student, particularly with respect to problems in concentration and judgment both of which are requirements for success in academics. Further, the underarousal of students with MHI may hinder their cognitive performance and boosting arousal status may lead to improved outcome, even though this interaction was not found to be significant in the current study. As well, the decreased perception of stress despite increased reports of life stressors may suggest that persons who have sustained a MHI may be less aware of emotional events as a function of reduced feedback, or recognition, of emotional indicators to the OFC which may lead to potential difficulties in everyday life. Research in our lab is currently examining the effects of underarousal of students with MHI as evidenced in this thesis with respect to decision-making and social competency which may further impact everyday choices as well as interactions with others.

The support for our hypothesis of modified cognitive performance as a function of arousal manipulation condition and MHI history was limited in that while, as expected, students with MHI tended to perform better in the stress condition than in the relaxation condition, whereas students without MHI performed better in the relaxation condition—this was only observed as a trend for a task requiring cognitive flexibility. Perhaps support for this hypothesis was limited as a function of 1) the subtly of the head trauma; 2) the

neuropsychological tests not being sensitive enough to detect the subtle, residual cognitive effects (that were evident in working memory and attentional tasks); and 3) the longevity of 5 years post-injury (median = 2 years) for this population such that effects on cognition may not be as prominent and may require more power (i.e., increase N) to be detected. Nonetheless, preliminary examination of the expected cross-over interaction of arousal manipulation condition as a function of the severity of injury (i.e., no-MHI, MHI-with-altered-state-of-consciousness, MHI-with-LOC) on cognitive performance provided direction for future research in that, anecdotally, a subset of students who have sustained a MHI (i.e., MHI-with-LOC) may benefit from increased arousal as compared to lowered arousal. We will continue to examine this effect as a function of severity of injury in future research.

Other limitations of our research must also be mentioned. The generalizability of the current study is limited in that the sample is restricted to high-functioning individuals with subtle injury. MHI does not appear to be a hindrance to educational pursuits (i.e., over half of our sample had MHI, but all had achieved post-secondary status, and half were in 2nd year or above). The sample, however, may not be representative of those students who have sustained MHI in 1st year university or those who have had to drop out due to academic difficulties possibly as a function of previous injury. Similarly, persons who sustain a head injury and later go on to become university students may be a selective group in that they may have been more intelligent than their cohort prior to the injury as following the injury they pursue post-secondary education. Further, persons who have sustained trauma to the head may be hypersensitive to their environment and may find the university environment is too stimulating for them and may have withdrawn from

university. Therefore, it is possible that our self-reported MHI sample consists of those who are not hyperaroused, and therefore may only be comprised of those who are hypoaroused, and perhaps this is why they presented with an underaroused profile and our findings may not be replicated in the general population as persons with head trauma may be either hyperaroused or hypoaroused. As such, the generalizability of our findings are limited. Additionally, two-thirds of our sample were female, whereas head-injured individuals are more likely to be male (e.g., Kraus & Nourjah, 1988) and are therefore underrepresented in the sample. Additionally, self-reports of head injury may be inaccurate and gaining information from collateral sources (i.e., hospital records, family members, witnesses of the head injury, and so forth) may be more reliable. Regardless of the manner in which the history of sustaining a head injury was acquired (i.e., self-report and not via medical records), and perhaps even more impressively, our results show that simply endorsing criteria of a history of an altered state of consciousness as a result of injury to the head presents with a profile different than that of students who did not report such history.

The causality of the underarousal evidenced in persons with MHI is debatable; with correlational data it is hard to tell which came first, the lowered arousal, or the MHI. It may be argued that persons with MHI in our sample possess some personality trait that accounts for their lowered arousal, especially due to the cross-sectional approach used in the current study. However, the post-hoc analysis of severity indices indicated that the underarousal may be in a severity of injury-dependent fashion. Moreover, the findings of increased post-concussive symptom reports may also be argued to be attributed to personality characteristics. Other factors such as sensation seeking that could predispose

an individual to sustaining an MHI might account for their lowered arousal. Although we acknowledge this may be the case, given the consistency of the findings of underarousal across various measures (i.e., EDA, self-report ratings, STAI) it is unlikely. Furthermore, the post-hoc analysis indicated evidence of a gradient of underarousal based on injury severity. Therefore, their underarousal relative to their no-MHI cohort is easily linked to their history of sustaining an altered state of consciousness. Despite these limitations, we suggest that our results demonstrate that the effects of a MHI are not transient and are organic in nature.

Future studies should examine potential confounds and the use of different approaches with respect to examining arousal status and post-concussive symptom reports in persons who have and have not sustained trauma to the head. As well, the findings of underarousal and increased post-concussive symptom reports for persons with self-reported MHI should be replicated and potential confounds should be further examined. Future studies would benefit from examining recreational drug use in university students with MHI to rule out its effects on arousal status as the current study did not address this potential confound. Future research should also further examine personality characteristics (e.g., DeBono & Good, 2008) potentially related to underarousal in persons with MHI, although we argue it is most likely that the underarousal effect is due to previous neural disruption. As well, it would be interesting to examine if persons with MHI who evidence underarousal and lessened responsivity to a psychosocial stressor still produce responses to physical stressors which would provide more credence to the suggestion of ventromedial

PFC disruption (as in Tranel & Damsio, 1994)[19]. It would also be interesting to examine amotivational aspects in persons with MHI and how this presentation may or may not be related to underarousal. Sex differences should also be examined especially because it is documented that men and women respond differently to stressors (see McCormick, 2007 for review), but due to the limited number of male participants in our study future research should address this. However, we did conduct all of the main analyses with sex as a covariate and this was not found to change to the pattern of the results reported here. As well, longitudinal research would address causality issues encountered with cross-sectional, correlational research. The causality of the relationship between MHI and underarousal could be examined via animal studies, particularly with animals with prefrontal regions. Lastly, this study should be replicated with clinically diagnosed brain injured populations rather than self-reported injury and it would be expected that the underarousal would be even more pronounced with less subtle injury. Even so, the findings from our study are striking especially because of the liberal criteria of sustaining an altered state of consciousness as a result of head trauma.

Despite these limitations, and the need for future examination, this exploratory, cross-sectional study demonstrated that simply acknowledging previously sustaining a head injury with an altered state of consciousness presents with differential physiological and self-reported arousal status while reporting increased life stressors as compared to those without an MHI. As well, simply endorsing a history of head injury showed increased ratings of post-concussive symptoms as compared to those with no MHI. An altered state of consciousness, therefore, should not be treated lightly because non-

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[19] It has been noted (e.g., Tranel & Damasio, 1994) that persons with damage to the anterior cingulate evidenced abnormal skin conductance responses to both physical and psychological stimuli.

transient effects are evident. Further examination of these findings will lead to a better understanding of the limitations and difficulties persons with milder head injuries encounter. Future research should continue to examine this population with a focus on how to improve their overall functioning even many years post-injury.

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Appendix A: Data Collection Materials

BROCK UNIVERSITY
Department of Psychology

Application for Access to the Psychology Research Pool

All studies posted to the Psychology Research Pool website must have Research Ethics Board (REB) approval.

INSTRUCTIONS:

Please complete the information below about your study and then email this form to (lindap@brocku.ca) with the subject line RESEARCH POOL. Using the information you have provided I will create an account for you on the Psychology Research Pool website. The system will automatically email you your login and password information. You will then be able to login to the system and input all the information about your study. The only information I will be inputting will be the researcher name, contact information, title of study and REB number. You will be responsible for setting up the rest of the study including appointment times, rooms, etc.

****

*****NAME OF THE RESEARCHER WHO WILL CONDUCT MOST OF THE TESTING:

Julie St. Cyr-Baker
Julie Klerkx

RESEARCHER CONTACT INFORMATION :

TELEPHONE NUMBER: (905) 688-5550
OFFICE NUMBER: PL 621 ext. 3556
EMAIL: **js01cb@brocku.ca**
jk04qz@brocku.ca

FACULTY ADVISOR (if applicable): Dr. Dawn Good
Dawn.Good@brocku.ca
(905) 688-5550 ext. 3869

TITLE OF STUDY: Cognitive Abilities and Arousal State

BRIEF DESCRIPTION: This study is investigating cognitive performance in relation to arousal state. Participants will be asked to participate in tasks that induce either heightened arousal or relaxation. Participants will complete tasks that measure various cognitive abilities. Physiological recordings of heart rate and electrodermal response will be recorded. Participants will be tested individually in one session for approximately 2.5 hours.

IS THIS A TWO PART STUDY? no

LENGTH OF STUDY: 2.5 hours

SELECTION CRITERIA:

ETHICS APPROVAL NUMBER (REB #): 07-204

Attention Study

We are currently recruiting participants for a study on
COGNITIVE ABILITIES AND AROUSAL STATE

What is Involved?

- Completion of questionnaires and cognitive tasks during different arousal states (i.e. relaxation, or increased vigilance)
- Physiological measurement recording such as heart rate, blood pressure, and electrodermal response.

Requirements

- Current Brock Student

Other

- Accounts for ***at least 2 Research Participation Hours***

SIGN UP ON SONA TODAY
http://brocku.sonasystems.com/

OR
CONTACT

Dr. Dawn Good
Psychology Faculty Supervisor
Dawn.Good@brocku.ca

Julie St. Cyr-Baker
MA Candidate
js01cb@brocku.ca
(905) 688-5550 ext. 3556

Neuropsychology Cognitive Research Lab, Brock University **(905) 688-5550 ext. 3556**
This study has received ethics clearance **REB file # 07-204**
Brock University 500 Glenridge Avenue, St.Catharines, Ontario, Canada

Cognitive Abilities & Arousal State Study
js01cb@brocku.ca
688-5550 x. 3556

Everyday Living Questionnaire (2008)[20]

Please fill in or circle an answer for each of the following:

1. How old are you? ____

2. Gender? M___ F____

3. What is the highest level of education you have presently completed?
   a Less than high school
   b. High School/Grade 12
   c. University 1 2 3 4 4+ (Years)
   d. College 1 2 3 4 4+

4. Handedness
   a. Right
   b. Left
   c. Both

5. Have you ever been hospitalized for (circle any that apply):
   a. Fractures Y N
   b. Illness Y N
   c. Surgery Y N
   d. Neurological complications Y N

6. Have you ever been diagnosed with a neurological or psychiatric condition?
   Y N

7. Are you currently taking any prescribed medications for a neurological or psychiatric condition? Y N

8. Have you ever hit your head with a force sufficient to alter your consciousness (e.g., loss of consciousness, vomiting, dizziness)? Y N

9. **If yes**, please answer the following questions (if you have had more than one instance, the *most recent* time you hit your head):

   a. How did you hit your head?

      i. [ ] Motor vehicle collision
      ii. [ ] Sports-related injury
      iii. [ ] Falling

---

[20] Designed by St. Cyr-Baker & Good (2008) for the Brock University Neuropsychology Cognitive Research Lab

iv. [ ] Other Please
Specify:_____

b. With the *most recent head injury* did you experience a loss of consciousness?
Y [ ] N [ ]

i. If yes, how long was the loss of consciousness?
1. [ ] < 5 minutes
2. [ ] > 5 minutes but less than 30 minutes
3. [ ] < 24 hours
4. [ ] < 1 week
5. [ ] < 1 month
6. [ ] > 1 month

c. Did the head injury result in a concussion? Y N

d. Did it require stitches? Y N

e. Did you receive medical treatment for your injury? Y N

f. Did you stay overnight in the hospital? Y N

g. Approximately how old were you at the time ___

h. How many months or year(s) have past since you hit your head? ___

10. Have you hit your head more than once? Y N

11. **If yes**, how many times? ___

12. **If yes** (to question 10),

a. How did you hit your head *previously*?

i. [ ] Motor vehicle collision
ii. [ ] Sports-related injury
iii. [ ] Falling
iv. [ ] Other Please
Specify:_____

b. With the *less recent head injury* did you experience a loss of consciousness?
Y [ ] N [ ]

i. If yes, how long was the loss of consciousness?

1. [ ] < 5 minutes
2. [ ] > 5 minutes but less than 30 minutes
3. [ ] < 24 hours
4. [ ] < 1 week
5. [ ] < 1 month
6. [ ] > 1 month

c. Did it result in a concussion? Y N

d. Did it require stitches? Y N

e. Did you receive medical treatment for your injury? Y N

f. Did you stay overnight at the hospital? Y N

g. Approximately how old were you at the time(s) ___

h. How many months or year(s) have past since you hit your head? ___

13. Have you ever experienced any other neural trauma (e.g., stroke, anoxia)? Y N
If yes, please explain:

_____

_____

14. Do you smoke cigarettes? Y N

If yes, approximately how many a day? _____

15. Did you consume caffeine today (e.g., coffee, tea, energy drink, chocolate)? Y N

If yes, how much?

1 2 3 more than 3

b. **If yes**, how much time has past since you last consumed caffeine today?

Less than 1 hour More than 1 hour

16. Do you have sensitivity to perfumes or scents? Y N

If yes, please rate your sensitivity:

Not at all Very
1 2 3 4 5 6 7 8 9

17. Do you have any skin sensitivity to lotions or cleansing products? Y N

If yes, please rate your sensitivity:

Not at all Very
1 2 3 4 5 6 7 8 9

18. Do you wear glasses or contacts? Y N

19. Do you have a valid driver's license? Y N

a. **If yes,** how long have you had a driver's license? 1-3 years 4-6 years 7+ years

20. Do you live: on your own with roommates other

with parents/guardians with partner

21. How many university credits (courses) are you taking this semester?

0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6

22. How many academic assignments or exams have you completed in the past month?

1 2 3 4 5 6 7 8 9 10

11 12 13 14 15 16 17 18 19 20

23. On a scale of 1 to 9 rate your enjoyment of academics:

Not at all Very
1 2 3 4 5 6 7 8 9

24. Have you ever received any extra assistance during your educational history? Y N

If yes, please circle any that apply and indicate when you received the assistance:

E = Elementary school H = High school U = University

25. Learning resource teacher E H U
26. Tutor E H U
27. Educational assistant E H U
28. Speech Language Pathologist E H U

29. Occupational Therapist E H U
30. Physical Therapist E H U
31. Other: Please Specify:_____ E H U

32. On a scale of 1 to 9 rate your enjoyment of your life situation:

Not at all Very
1 2 3 4 5 6 7 8 9

33. On a scale of 1 to 9 how stressful would you rate your day-to-day life:

Not at all Very
1 2 3 4 5 6 7 8 9

26. Do you regularly engage in relaxation techniques (e.g., deep breathing or yoga):
Y N

a. **If yes,** how many times a week do you engage in relaxation methods? _____
Please describe:

_____

27. Do you exercise regularly? Y N

a. **If yes,** how many times a week do you exercise? _____
Please describe:

_____

28. Was last night's sleep typical for you? Y N

If No, what was different (better, worse) ?

_____

Why was it different? (stress, room temperature, noise, etc.)

_____

Please indicate how well you slept last night by circling a number:

Worst Possible Sleep 1 2 3 4 5 6 7 Best Possible Sleep

Please indicate how you feel right now by circling a number:

Very Sleepy 1 2 3 4 5 6 7 Very Alert

29. Have you had anything out of the ordinary occur in the past day or so? Y N
If yes, please explain:

_____

_____

30. Circle any of the following that apply to your experience over the past 6 months:

Moved	Death of a family member
New Job	Death of a close friend
Loss of Job	Financial Difficulties
Loss of Relationship	Illness of someone close to you
New Relationship	Personal Illness/Injury
Reconciliation with partner	New Baby
Reconciliation with Family	Wedding/ Engagement (self)
Divorce (of self or parents)	Vacation
Entered 1st year at university	Disrupted Sleep

31. Please indicate how your day has been so far by circling a number:

Calm	1	2	3	4	5	6	7	8	9	10	Busy
Pleasant	1	2	3	4	5	6	7	8	9	10	Unpleasant
NOT Stressful	1	2	3	4	5	6	7	8	9	10	VERY Stressful

Question 30 format adapted from Holmes, T. & Rahe, R (1967). "Holmes-Rahe Social Readjustment Life Changes Scale". *Journal of Psychosomatic Research*, Vol. 11, 213-218.

POSTCONCUSSION SYNDROME CHECKLIST (PCSC)

NAME_____ DATE_____

Please rate the frequency, intensity and duration of each of the following symptoms based on how they have affected you today according to the following scale:

FREQUENCY	INTENSITY	DURATION
1 = Not at all	1 = Not at all	1 = Not at all
2 = Seldom	2 = Vaguely present	2 = A few seconds
3 = Often	3 = Clearly present	3 = A few minutes
4 = Very often	4 = Interfering	4 = A few hours
5 = All the time	5 = Crippling	5 = Constant

	FREQUENCY	INTENSITY	DURATION
Headache	_____	_____	_____
Dizziness	_____	_____	_____
Irritability	_____	_____	_____
Memory Problems	_____	_____	_____
Difficulty Concentrating	_____	_____	_____
Fatigue	_____	_____	_____
Visual Disturbances	_____	_____	_____
Aggravated by Noise	_____	_____	_____
Judgment Problems	_____	_____	_____
Anxiety	_____	_____	_____

Thank you for your time and effort in the completion of this form.

Gouvier et al. (1992). Postconcussion symptoms and daily stress in normal and head-injured college populations. *Archives of Clinical Neurospychology, 7,* 193-211.

BROCK UNIVERSITY

Informed Consent Letter-A

Title of Study: Cognitive Abilities and Arousal State

Principal Student Investigator:
Julie St. Cyr-Baker, M.A. Candidate
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Brock University
js01cb@brocku.ca,
(905) 688-5550 ext. 3556

Principal Investigator:
Dr. Dawn Good, Ph.D., C. Psych
Department of Psychology,
Brock University
Dawn.Good@brocku.ca,
(905) 688-5550, ext. 3869

Co-investigator: Julie Klerkx
Undergraduate Thesis Student
jk04qz@brocku.ca

You are being invited to participate in a research study. This study is investigating whether individual differences in cognitive function are influenced by level of arousal. In addition, evaluation of emotional factors in relation to these skills will be examined. This research is facilitated by Julie St. Cyr-Baker, Julie Klerkx, and Dr. Dawn Good. Your participation in this study is voluntary; you may decline to participate at any time without consequences to yourself. You may choose to withdraw at any time during the 2.5 hour experimental session; if you choose to do so, please inform the researcher and you will be credited with appropriate research participation hours reflecting your participation to that point. If you withdraw from the study before data collection is completed, your data will be omitted from the analysis and your response forms will be shredded. Please note that data cannot be removed after the session as responses are not linked to individuals. You also have the right to omit any answer(s) that you choose.

In this study, first you will be provided with two copies of this consent form that will be read to you and you may ask any questions about this research at that time. After reading the consent form you will be asked to sign both copies, one for the researcher and one for your own records. If you decide to participate, you will next be asked to complete a brief demographic questionnaire and do various cognitive tests (e.g., memory tasks). Each test will be described as they are introduced. One of the cognitive tasks will be observed by another researcher. You will be informed prior to the task that is to be observed. If you are uncomfortable with having your performance observed by another researcher please advise the researcher. In addition, physiological measures (i.e., heart rate and electrodermal response) will be recorded via electrodes. The areas of your skin such as your hand and earlobe will be cleansed prior to, and after, electrode placement. Please advise the researcher if you have any dermal sensitivity. **You may ask questions at this time and at any time throughout the entire study.** Your participation in this study will take approximately two and one-half hours. Once you have completed the tests, the purpose of the study will be explained and you will be provided a debriefing form.

Although there are no foreseeable risks for participating in this study it is possible that you may feel uncomfortable experiencing test performance anxiety as the tests are designed to be very challenging. You are welcome to ask the researcher questions, you may contact any of the counselling contact services on your debriefing form, or remain in the lab room, or contact the principal investigator, Dr. Dawn Good, Registered Psychologist, should you choose.

Your name will be associated only with this form. All information collected will be confidential and kept separately from this consent form, and coded by a number assignment. All consent forms, task data, and notes taken will be kept in a locked, secure lab at all times and will be destroyed after 5 years. Only Julie St.Cyr-Baker, Julie Klerkx, Dr. Good, and research assistants will have access to this data. All research assistants have completed confidentiality agreements. In addition, any information gathered from this study used in discussions, publishable articles, or presentations will be summarized and refer only to group results, preserving anonymity.

By participating in this study you may benefit from a better understanding of how psychological research is conducted due to your first-hand experience. The information from this study will help with the completion of a Master's and honours thesis project and will contribute to research on arousal state and cognitive performance. You will be invited to view the results of this study at its completion (by August 31, 2009). Also, you may contact the researcher via e-mail if you wish to view the results of the study.

If you have questions at any time about the study or the procedures, or you experience adverse effects as a result of participating in this study, please feel free to contact us.

[ ] I have read and understand the above information regarding this study.
[ ] I have received a copy of this form.
[ ] I understand that I may ask questions in the future.
[ ] I agree to participate in this study.

Participant's name (please print) _____

Participant's signature _____ **Date:** _____

[ ] I have explained this study to the participant

Researcher's signature _____ **Date:** _____

[ ] I acknowledge that I am participating in this study for a maximum of two research participation hours in a psychology course (see below) and will not receive monetary payment for this study.

COURSE (please circle only one course):

PSYC 1F90 2P12 2P20 2F23 2P36 2P37 3P39 Other: _____

Participant's signature _____ **Date:** _____

****PLEASE KEEP A COPY OF THIS CONSENT FORM FOR YOUR RECORDS****

This project has been reviewed and received ethics clearance through the Office of Research Ethics Board (REB File #:07-204). If you have any pertinent questions regarding your rights as a participant, please contact the Research Ethics Officer via e-mail at reb@brocku.ca or you may call (905) 688-5550 extension 3035.

*** THANK YOU FOR YOUR PARTICIPATION!***

BROCK UNIVERSITY

Informed Consent Letter-R

Title of Study: Cognitive Abilities and Arousal State

Principal Student Investigator:
Julie St. Cyr-Baker, M.A. Candidate
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Principal Investigator:
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Dawn.Good@brocku.ca,
(905) 688-5550 ext. 3869

Co-investigator: Julie Klerkx
Undergraduate Thesis Student
jk04qz@brocku.ca

You are being invited to participate in a research study. This study is investigating whether individual differences in cognitive function are influenced by level of arousal. In addition, evaluation of emotional factors in relation to these skills will be examined. This research is facilitated by Julie St. Cyr-Baker, Julie Klerkx, and Dr. Dawn Good. Your participation in this study is voluntary; you may decline to participate at any time without consequences to yourself. You may choose to withdraw at any time during the 2.5 hour experimental session; if you choose to do so, please inform the researcher and you will be credited with appropriate research participation hours reflecting your participation to that point. If you withdraw from the study before data collection is completed, your data will be omitted from the analysis and your response forms will be shredded. Please note that data cannot be removed after the session as responses are not linked to individuals. You also have the right to omit any answer(s) that you choose.

In this study, first you will be provided with two copies of this consent form that will be read to you and you may ask any questions about this research at that time. After reading the consent form you will be asked to sign both copies, one for the researcher and one for your own records. If you decide to participate, you will next be asked to complete a brief demographic questionnaire and do various cognitive tests (e.g., memory tasks). Each test will be described as they are introduced. You will also be asked to participate in a relaxation task during which you will listen to a compact disc recording in a relaxing setting. An aromatherapy scent will be present during the relaxation task. Please inform the researcher if you have any sensitivity to scents and if so, aromatherapy will not be used. In addition, physiological measures (i.e., heart rate and electrodermal response) will be recorded via electrodes. The areas of your skin such as your hand and earlobe will be cleansed prior to, and after, electrode placement. Please advise the researcher if you have any dermal sensitivity. **You may ask questions at this time and at any time throughout the entire study.** Your participation in this study will take approximately two and one-half hours. Once you have completed the tests, the purpose of the study will be explained and you will be provided a debriefing form.

Although there are no foreseeable risks for participating in this study it is possible that you may feel uncomfortable experiencing test performance anxiety as the tests are designed to be very challenging. You are welcome to ask the researcher questions, you may contact any of the

counselling contact services on your debriefing form, or remain in the lab room, or contact the principal investigator, Dr. Dawn Good, Registered Psychologist, should you choose.

Your name will be associated only with this form. All information collected will be confidential and kept separately from this consent form, and coded by a number assignment. All consent forms, task data, and notes taken will be kept in a locked, secure lab at all times and will be destroyed after 5 years. Only Julie St.Cyr-Baker, Julie Klerkx, Dr. Good, and research assistants will have access to this data. All research assistants have completed confidentiality agreements. In addition, any information gathered from this study used in discussions, publishable articles, or presentations will be summarized and refer only to group results, preserving anonymity.

By participating in this study you may benefit from a better understanding of how psychological research is conducted due to your first-hand experience. The information from this study will help with the completion of a Master's and honours thesis project and will contribute to research on arousal state and cognitive performance. You will be invited to view the results of this study at its completion (by August 31, 2009). Also, you may contact the researcher via e-mail if you wish to view the results of the study.

If you have questions at any time about the study or the procedures, or you experience adverse effects as a result of participating in this study, please feel free to contact us.

[ ] I have read and understand the above information regarding this study.
[ ] I have received a copy of this form.
[ ] I understand that I may ask questions in the future.
[ ] I agree to participate in this study.

Participant's name (please print) _____

Participant's signature _____ **Date:** _____

[ ] I have explained this study to the participant

Researcher's signature _____ **Date:** _____

[ ] I acknowledge that I am participating in this study for a maximum of two research participation hours in a psychology course (see below) and will not receive monetary payment for this study.

COURSE (please circle only one course):

PSYC 1F90 2P12 2P20 2F23 2P36 2P37 3P39 Other: _____

Participant's signature _____ **Date:** _____

****PLEASE KEEP A COPY OF THIS CONSENT FORM FOR YOUR RECORDS****

This project has been reviewed and received ethics clearance through the Office of Research Ethics Board (REB File #:07-204). If you have any pertinent questions regarding your rights as a participant, please contact the Research Ethics Officer via e-mail at reb@brocku.ca or you may call (905) 688-5550 extension 3035.

*** THANK YOU FOR YOUR PARTICIPATION!***

VERBAL SCRIPT FOR PSYCHOSOCIAL STRESS-INDUCTION

"Now I am going to ask you to participate in a speeded mathematical task. For this task, and this task only, there will be an observer who is a research assistant. He will be evaluating your performance on this task through the one-way mirror. The task I'm going to ask you to participate in is a verbal task which involves speeded subtraction.

If it is ok with you I will inform the observer that we will be proceeding shortly and to enter the observation gallery now.

[Researcher leaves the testing room momentarily; upon return researcher responds to the window, nods and verbalizes "We will begin now."]

This is an arithmetic test that is highly correlated with important aspects of intellectual functioning. I am going to give you a number and ask you to count backwards by another number. For example, I could ask you to begin at 100 and count backward by 3's. (e.g., 100, 97, 94, ...and so forth). As this task will be timed, I will ask that you do this as quickly and accurately as you can. Note that each time you make a mistake I will say 'wrong', give you the last number you got correct, and you will continue counting backward from that point. Your score will be based on your speed and number correct. Do you have any questions?

Are you ready to begin?

Now begin at 800 and count backward by 8s. Go."

For second and the additional presentations: "I am going to give you a new start number and a new digit to count backwards by. Again your performance will be measured by your speed and accuracy. Are you ready to begin? Start at #### and count backward by ##. Go."

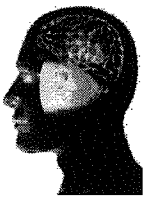
[After testing for the mathematical verbal task has been completed, the researcher will turn towards the window and state "the testing is now complete" and then will excuse him/herself from the testing room to suggest to the participant that the observer is leaving the observation gallery.]

Task adapted from Shostak and Peterson (1990); Wymer (1996)

A	B	C	D	E
8	**6**	**12**	**14**	**16**
800	**550**	**2400**	**1700**	**1200**
792	544	2388	1686	1184
784	538	2376	1672	1168
776	532	2364	1658	1152
768	526	2352	1644	1136
760	520	2340	1630	1120
752	514	2328	1616	1104
744	508	2316	1602	1088
736	502	2304	1588	1072
728	496	2292	1574	1056
720	490	2280	1560	1040
712	484	2268	1546	1024
704	478	2256	1532	1008
696	472	2244	1518	992
688	466	2232	1504	976
680	460	2220	1490	960
672	454	2208	1476	944
664	448	2196	1462	928
656	442	2184	1448	912
648	436	2172	1434	896
640	430	2160	1420	880
632	424	2148	1406	864
624	418	2136	1392	848
616	412	2124	1378	832
608	406	2112	1364	816
600	400	2100	1350	800
592	394	2088	1336	784
584	388	2076	1322	768
576	382	2064	1308	752
568	376	2052	1294	736
560	370	2040	1280	720
Errors:	**Errors:**	**Errors:**	**Errors:**	**Errors:**
Time:	**Time:**	**Time:**	**Time:**	**Time:**

VERBAL SCRIPT FOR RELAXATION INDUCTION

" Now, I am going to ask you to participate in a relaxation task. I will ask you to listen to a CD which will guide you through deep breathing and mental imagery to relax. In addition, I will dim the lighting, and aromatic scent will be dispersed. I am going to leave the room so you can relax, but remember the purpose is to relax and not to fall asleep. I will return when the CD has finished playing. Please enjoy this relaxation".



BROCK UNIVERSITY
NEUROPSYCHOLOGY COGNITIVE RESEARCH LABORATORY
Debriefing Statement-A

Dear Participant:

Thank you for your participation in this research study. As you are aware, this research study was conducted by Julie St. Cyr-Baker, Julie Klerkx, and Dr. Dawn Good in the Psychology Department at Brock University. This study is investigating whether individual differences in cognitive function are influenced by level of arousal, specifically stress and relaxation. The purpose of this study was to investigate whether stress, as well as relaxation, effects cognitive functions in university students who have/have not experienced a previous mild head injury.

This study examined whether induced stress and relaxation influence cognitive performance and whether this interacted with a prior history of concussions. Previous research has shown that between 25% and 45% of undergraduate students have sustained a mild head injury and research from our lab (Brock University Neuropsychology Cognitive Research Lab) has shown that individuals with mild head injury are underaroused (less stressed relative to their peers). Our research has suggested that when higher levels of arousal are reported by individuals with mild head injury, their cognitive performance has shown to be optimally enhanced. Thus, we are examining if cognitive performance can be modified by altering arousal levels by induced-stress or induced-relaxation in persons who have/have not sustained a mild head injury.

The standardized neuropsychological tests chosen for this study were subtests of the Wechsler Memory Scale-III (1997), Wechsler Adult Intelligence Scale – III (1997), the Delis Kaplan Executive Function System (2002), the Comprehensive Test of Nonverbal Intelligence (1996), the NEPSY-II (2007). These tests were used as they involve executive functions such as abstract reasoning, working memory, cognitive flexibility, attention, and planning. Additionally, some of the subtests assess immediate and delayed verbal, logical, and visuospatial memory abilities. The State-Trait Anxiety Inventory (STAI, Spielberger, 1983) was administered to obtain an index of state and trait anxiety. Mild head injury symptoms were assessed via the Post-Concussive Symptom Checklist (Gouvier et al., 1992) and demographic questionnaire. Heart rate and electrodermal activity were recorded as physiological measures of stress/relaxation response.

To induce stress, you were asked to perform a verbal math task under time constraints while being observed and assessed by another researcher. In fact, no one was observing you. Justifiable deception was included in this study as part of the manipulation for stress induction in order to accent the performance requirement of the simulated exercise, by introducing a greater demand (having others judge your ability, capacity), in order to provide, or otherwise produce, a heightened level of stress vigilance which is the precise effect being investigated. In another condition of this study, relaxing breathing techniques accompanied by restful sounds, smells, and dimmed lighting were used to induce relaxation.

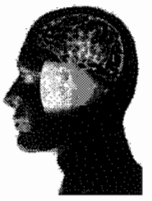
Your participation is important for us to be able to understand the relationship between subtle changes in brain functions and everyday stimuli in the environment, such as arousal state. Please feel free to ask any questions. You are invited to view the results of the study by its completion (August 31, 2009).

If you experienced any negative emotions as a result of participating in this research study and wish to speak with a counsellor please contact: **Brock University Counselling Services, ST 400, (905) 688-5550 extension 3240** or the principal investigator Dr. Dawn Good, Registered Psychologist. If you feel you have not been treated according to the descriptions in this form, or your rights as a participant in research have been violated during the course of this project, you may contact the **Research Ethics Officer** at (905) 688-5550, extension 3035, please cite REB file #: 07-204.

Thank you again for your time and participating in this study!!!

If you have any questions or concerns please feel free to contact us:

Julie St. Cyr-Baker	Dr. Dawn Good	Julie Klerkx
(905) 688-5550 extension 3556	(905) 688-5550 extension 3869	(905) 688-5550 extension 3556
js01cb@brocku.ca	Dawn.Good@brocku.ca	jk04qz@brocku.ca



BROCK UNIVERSITY
NEUROPSYCHOLOGY COGNITIVE RESEARCH LABORATORY

Debriefing Statement-R

Dear Participant:

Thank you for your participation in this research study. As you are aware, this research study was conducted by Julie St. Cyr-Baker, Julie Klerkx, and Dr. Dawn Good in the Psychology Department at Brock University. This study is investigating whether individual differences in cognitive function are influenced by level of arousal, specifically relaxation and stress. The purpose of this study was to investigate whether relaxation, as well as stress, affects cognitive functions in university students who have/have not experienced a previous mild head injury.

This study examined whether induced stress and relaxation influence cognitive performance and whether this interacted with a prior history of concussions. Previous research has shown that between 25% and 45% of undergraduate students have sustained a mild head injury and research from our lab (Brock University Neuropsychology Cognitive Research Lab) has shown that individuals with mild head injury are underaroused (less stressed relative to their peers). Our research has suggested that when higher levels of arousal are reported by individuals with mild head injury, their cognitive performance has shown to be optimally enhanced. Thus, we are examining if cognitive performance can be modified by altering arousal levels by induced-stress or induced-relaxation in persons who have/have not sustained a mild head injury.

The standardized neuropsychological tests chosen for this study were subtests of the Wechsler Memory Scale-III (1997), Wechsler Adult Intelligence Scale – III (1997), the Delis Kaplan Executive Function System (2002), the Comprehensive Test of Nonverbal Intelligence (1996), and the NEPSY-II (2007). These tests were used as they involve executive functions such as abstract reasoning, working memory, cognitive flexibility, attention, and planning. Additionally, some of the subtests assess immediate and delayed verbal, logical, and visuospatial memory abilities. The State-Trait Anxiety Inventory (STAI, Spielberger, 1983) was administered to obtain an index of state and trait anxiety. Mild head injury symptoms were assessed via the Post-Concussive Symptom Checklist (Gouvier et al., 1992) and the demographic questionnaire. Heart rate and electrodermal activity were recorded as physiological measures of stress/relaxation response. Relaxing breathing techniques accompanied by restful sounds, smells, and dimmed lighting were used to induce relaxation. In a separate condition of this study we induced stress via performing a verbal math task under time constraints while being observed and assessed by another researcher.

Your participation is important for us to be able to understand the relationship between subtle changes in brain functions and everyday stimuli in the environment, such as arousal state, particularly how relaxation may effect cognitive functions in persons with and without mild head injury. Please feel free to ask any questions regarding the study. You are invited to view the results of the study by its completion (August 31, 2009).

If you experienced any negative emotions as a result of participating in this research study and wish to speak with a counsellor please contact: **Brock University Counselling Services, ST 400, (905) 688-5550 extension 3240** or the principal investigator Dr. Dawn Good, Registered Psychologist. If you feel you have not been treated according to the descriptions in this form, or your rights as a participant in research have been violated during the course of this project, you may contact the **Research Ethics Officer** at (905) 688-5550, extension 3035, please cite REB file #: 07-204.

Thank you again for your time and participating in this study!!!
If you have any questions or concerns please feel free to contact us:

Julie St. Cyr-Baker	Dr. Dawn Good	Julie Klerkx
(905) 688-5550 extension 3556	(905) 688-5550 extension 3869	(905) 688-5550 extension 3556
js01cb@brocku.ca	Dawn.Good@brocku.ca	jk04qz@brocku.ca

Appendix B: Brock University Research Ethics Board Clearance

DATE: February 12, 2008

FROM: Michelle McGinn, Chair
Research Ethics Board (REB)

TO: Dr. Dawn GOOD, Psychology
Julie St.Cyr-Baker, Julie Klerkx

FILE: 07-204 GOOD

TITLE: The effects of arousal state on cognitive performance

The Brock University Research Ethics Board has reviewed the above research proposal.

DECISION: Accepted as is (with notes)

Please Note

- **Please note on the consent form that data cannot be removed after the session as responses cannot be linked to individuals.**
- **Please indicate on the consent form that participants who withdraw from the study will be eligible for pro-rated research participation credit.**

This project has received ethics clearance for the period of February 12, 2008 to September 30, 2009 subject to full REB ratification at the Research Ethics Board's next scheduled meeting. The clearance period may be extended upon request. ***The study may now proceed.***

Please note that the Research Ethics Board (REB) requires that you adhere to the protocol as last reviewed and cleared by the REB. During the course of research no deviations from, or changes to, the protocol, recruitment, or consent form may be initiated without prior written clearance from the REB. The Board must provide clearance for any modifications before they can be implemented. If you wish to modify your research project, please refer to http://www.brocku.ca/researchservices/forms to complete the appropriate form Revision or Modification to an Ongoing Application.

Adverse or unexpected events must be reported to the REB as soon as possible with an indication of how these events affect, in the view of the Principal Investigator, the safety of the participants and the continuation of the protocol.

If research participants are in the care of a health facility, at a school, or other institution or community organization, it is the responsibility of the Principal Investigator to ensure that the ethical guidelines and clearance of those facilities or institutions are obtained and filed with the REB prior to the initiation of any research protocols.

The Tri-Council Policy Statement requires that ongoing research be monitored. A Final Report is required for all projects upon completion of the project. Researchers with projects lasting more than one year are required to submit a Continuing Review Report annually. The Office of Research Services will contact you when this form *Continuing Review/Final Report* is required.

Please quote your REB file number on all future correspondence.

Kate Williams
Research Ethics Assistant
Office of Research Ethics, MC D250A
Brock University
Office of Research Services
500 Glenridge Avenue
St. Catharines, Ontario, Canada L2S 3A1
phone: (905)688-5550, ext. 3035 fax: (905)688-0748
email: reb@brocku.ca
http://www.brocku.ca/researchservices/ethics/humanethics/

Appendix C: Statistical Analyses
(refer to appended CD)

Table of Contents

Participant Information

Table C1

Mean Age and University Course Enrollment

Variable	Mean	Standard Deviation
Age	21.01	3.20
Current Course Credits	4.02	1.33

Table C2

Reported Years of Education Presently Completed

Education	*n*	*Percentage*
Completed High school or College Education (i.e. currently in 1st year)	29	31.90
Completed 1st Year University	22	24.20
Completed 2nd Year University	25	27.50
Completed 3rd Year University	6	6.60
Completed 4th Year University	6	6.60
Completed Greater than 4 years of University	3	3.30

Table C3

Sex and Handedness of Sample

Variable		Percentage (*n*)
Sex		
	Female	69.20 (63)
	Male	30.80 (28)
Handedness		
	Right	93.40 (85)
	Left	6.60 (6)

Table C4

Chi-Square Analyses of Years of Education (Upper and Lower Year Students) and Arousal Manipulation Condition by Sex

Arousal Manipulation Condition	*Years of Education*	*Percentage (n)*		χ^2	*df*	*p*
Relaxation		*Sex*				
($n = 46$)						
	Lower Year Students	Male	Female			
		33.30 (4)	66.70 (8)			
	Upper Year Students	32.40 (11)	67.60 (23)			
				.01	1	.950[a]
Stress		*Sex*				
($n = 45$)						
	Lower Year Students	Male	Female			
		23.50 (4)	76.50 (13)			
	Upper Year Students	32.10 (9)	67.90 (19)			
				.38	1	.737[a]

Note. Values in parentheses represent *n;* [a] Fisher's Exact Test values used.

Intelligence Capacity as a function of MHI History

Table C5

Mean WAIS-III (1997) Scaled Vocabulary Score by Assigned Arousal Manipulation Condition and MHI History

MHI History	Assigned Arousal Manipulation Condition		Marginal Means
	Stress	Relaxation	
MHI	13.37 (2.53)	13.88 (2.32)	13.62 (*SE* = .33)
No-MHI	12.17 (1.89)	13.72 (2.55)	12.95 (*SE* = .37)
Marginal Means	12.89 (*SE* = .36)	13.80 (*SE* = .35)	

Note. Values in parentheses are standard deviation; *SE* = standard error.

Table C6

A 2 (MHI History: MHI, No-MHI) X 2 (Assigned Arousal Manipulation Condition: Stress, Relaxation) ANOVA on WAIS-III (1997) Vocabulary Scaled Scores

Source	*df*	*F*	*p*	*ηp2*
		Between Subjects		
MHI	1	1.85	.177	.020
Condition	1	4.32	.041*	.047
MHI X Condition	1	1.13	.291	.013
Error	87			

Table C7

Mean WAIS-III (1997) Scaled Block Design Score by Assigned Arousal Manipulation Condition and MHI History

MHI History	Assigned Arousal Manipulation Condition		Marginal Means
	Stress	Relaxation	
MHI	11.52 (3.02)	12.58 (2.41)	12.02 (*SE* = .39)
No-MHI	11.67 (2.59)	12.09 (2.84)	11.90 (*SE* = .44)
Marginal Means	11.59 (*SE* = .42)	12.34 (*SE* = .41)	

Note. Values in parentheses are standard deviation; *SE* = standard error.

Table C8

A 2 (MHI History: MHI, No-MHI) X 2 (Assigned Arousal Manipulation Condition: Stress, Relaxation) ANOVA on WAIS-III (1997) Block Design Scaled Scores

Source	*df*	*F*	*p*	*ηp2*
		Between Subjects		
MHI	1	.09	.768	.001
Condition	1	1.64	.204	.018
MHI X Condition	1	.30	.583	.003
Error	87			

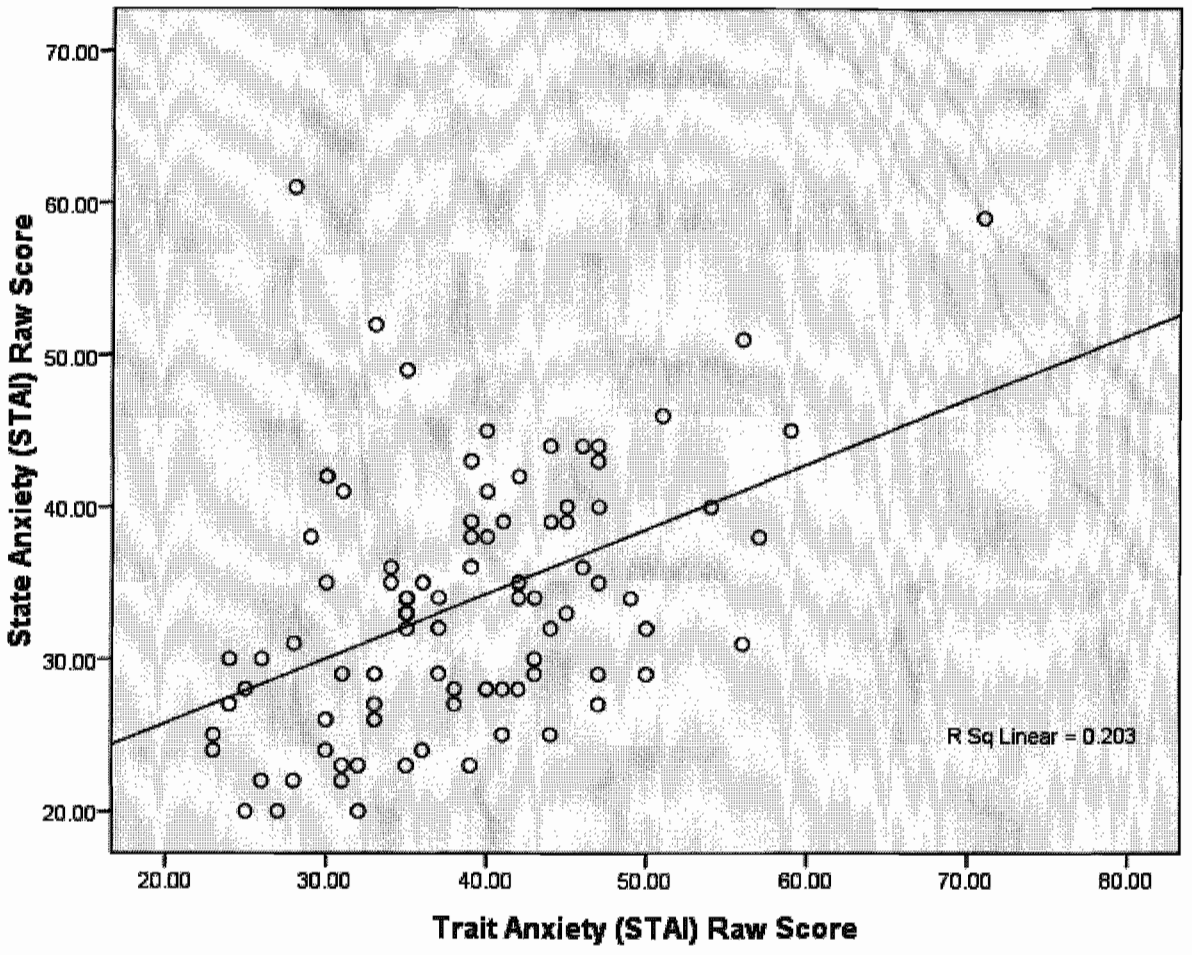


Figure C1. Correlation of State and Trait Anxiety Total Score (STAI; Spielberger, 1983a).

Table C9

Means and Standard Deviations across time (Baseline, Before and After Arousal Manipulation) for MHI History and Arousal Manipulation Condition on Self-reported Arousal State

Time		*MHI History*	
		MHI	No-MHI
Baseline			
	Relaxation	2.88 (1.51)	3.45 (1.50)
	Stress	2.93 (1.54)	3.89 (1.60)
Before Manipulation			
	Relaxation	3.29 (1.49)	4.13 (1.58)
	Stress	3.59 (1.47)	3.83 (1.46)
After Manipulation			
	Relaxation	1.67 (.87)	1.77 (.92)
	Stress	5.89 (1.78)	6.28 (1.93)
Marginal Means		No-MHI	3.89 (*SE* = .19)
		MHI	3.37 (*SE* = .17)
		Relaxation	2.87 (*SE* = .18)
		Stress	4.40 (*SE* = .18)
		Baseline	3.27 (*SE* = .16)
		Before Manipulation	3.71 (*SE* = .16)
		After Manipulation	3.90 (*SE* = .15)

Note. Values in parentheses are standard deviations; *SE* = standard error.

Table C10

A 2 (MHI History: MHI, No-MHI) X 2 (Arousal Manipulation Condition: Stress, Relaxation) X 3 (Time: Baseline, Before, and After Arousal Manipulation) ANOVA on Self-reported Arousal State

Source	*df*	*F*	*p*	*ηp2*
		Between Subjects		
MHI	1	4.16	.044*	.046
Condition	1	36.19	< .001*	.294
MHI X Condition	1	.01	.968	.001
Error	87			
		Within Subjects		
Time	2	7.50	.001*	.079
Time X MHI	2	1.30	.275	.015
Time X Condition	2	113.40	< .001*	.566
Time X MHI X Condition	2	1.39	.251	.016
Error	174			

Note. Greenhouse-Geisser correction used.

Table C11

Means and Standard Deviations across time (Baseline, Before, During, and After Manipulation) for MHI History and Arousal Manipulation Condition on Electrodermal Activity Frequency

Time		*MHI History*	
		MHI	No-MHI
Baseline			
	Relaxation	5.56 (3.16)	9.55 (3.31)
	Stress	6.01 (2.11)	8.50 (2.92)
Before Manipulation			
	Relaxation	7.67 (5.23)	11.73 (5.25)
	Stress	8.20 (4.02)	10.47 (2.90)
During Manipulation			
	Relaxation	8.44 (4.73)	11.95 (3.70)
	Stress	10.31 (3.63)	14.67 (5.83)
After Manipulation			
	Relaxation	10.13 (5.73)	12.39 (5.61)
	Stress	11.69 (3.89)	14.42 (4.64)
Marginal Means		No-MHI	11.71 (*SE* = .47)
		MHI	8.50 (*SE* = .41)
		Relaxation	9.68 (*SE* = .44)
		Stress	10.53 (*SE* = .45)
		Baseline	7.40 (*SE* = .31)
		Before Manipulation	9.52 (*SE* = .48)
		During Manipulation	11.34 (*SE* = .48)
		After Manipulation	12.15 (*SE* = .53)

Note. Values in parentheses are standard deviations; *SE* = standard error.

Table C12

A 2 (MHI History: MHI, No-MHI) X 2 (Arousal Manipulation Condition: Stress, Relaxation) X 4 (Time: Baseline, Before, During, and After Arousal Manipulation) ANOVA on Electrodermal Activity Frequency

Source	*df*	*F*	*p*	*ηp2*
	Between Subjects			
MHI	1	26.38	< .001*	.233
Condition	1	1.87	.173	.021
MHI X Condition	1	.16	.693	.002
Error	87			
	Within Subjects			
Time	3	30.36	< .001*	.259
Time X MHI	3	.59	.623	.007
Time X Condition	3	3.27	.022*	.036
Time X MHI X Condition	3	.76	.516	.009
Error	261			

Note. Greenhouse-Geisser correction used.

Table C13

Means and Standard Deviations across time (Baseline, Before, During, and After Manipulation) for MHI History and Arousal Manipulation Condition on Electrodermal Activity Amplitude

Time		*MHI History*	
		MHI	No-MHI
Baseline			
	Relaxation	.67 (.49)	1.21 (.62)
	Stress	.71 (.50)	1.32 (.43)
Before Manipulation			
	Relaxation	.39 (.18)	1.02 (.41)
	Stress	.52 (.32)	1.11 (.41)
During Manipulation			
	Relaxation	.39 (.40)	.62 (.35)
	Stress	.94 (.47)	1.77 (.46)
After Manipulation			
	Relaxation	.38 (.27)	.53 (.27)
	Stress	.77 (.33)	1.64 (.63)
Marginal Means		No-MHI	1.15 (*SE* = .05)
		MHI	.60 (*SE* = .04)
		Relaxation	.65 (*SE* = .04)
		Stress	1.10 (*SE* = .04)
		Baseline	.98 (*SE* = .06)
		Before Manipulation	.76 (*SE* = .04)
		During Manipulation	.93 (*SE* = .05)
		After Manipulation	.83 (*SE* = .04)

Note. Values in parentheses are standard deviations; *SE* = standard error.

Table C14

A 2 (MHI History: MHI, No-MHI) X 2 (Arousal Manipulation Condition: Stress, Relaxation) X 4 (Time: Baseline, Before, During and After Manipulation) ANOVA on Electrodermal Activity Amplitude

Source	*df*	*F*	*p*	*ηp2*
		Between Subjects		
MHI	1	82.49	< .001*	.487
Condition	1	52.93	< .001*	.378
MHI X Condition	1	7.68	.007*	.081
Error	87			
		Within Subjects		
Time	3	6.98	.001*	.074
Time X MHI	3	.39	.759	.004
Time X Condition	3	30.51	< .001*	.260
Time X MHI X Condition	3	6.73	< .001*	.072
Error	261			

Note. Greenhouse-Geisser correction used.

Table C15

Means and Standard Deviations across time (Baseline to after Arousal Manipulation) for MHI History and Arousal Manipulation Condition on Heart Rate (beats per minute [bpm])

Time		*MHI History*	
		MHI	No-MHI
Baseline			
	Relaxation	73.79 (7.75)	72.68 (6.83)
	Stress	71.56 (11.19)	74.69 (8.38)
Before Manipulation			
	Relaxation	69.77 (9.76)	69.82 (6.85)
	Stress	67.52 (11.08)	74.11 (9.05)
During Manipulation			
	Relaxation	72.06 (8.21)	72.02 (7.01)
	Stress	75.89 (9.15)	77.36 (9.43)
After Manipulation			
	Relaxation	71.15 (8.11)	69.61 (7.15)
	Stress	70.94 (8.31)	76.48 (9.19)
Marginal Means		No-MHI	73.33 (*SE* = 1.24)
		MHI	71.59 (*SE* = 1.10)
		Relaxation	71.36 (*SE* = 1.15)
		Stress	73.55 (*SE* = 1.19)
		Baseline	73.18 (*SE* = .94)
		Before Manipulation	70.31 (*SE* = 1.00)
		During Manipulation	74.33 (*SE* = .90)
		After Manipulation	72.00 (*SE* = .86)

Note. Values in parentheses are standard deviations; *SE* = standard error.

Table C16

A 2 (MHI History: MHI, No-MHI) X 2 (Arousal Manipulation Condition: Stress, Relaxation) X 4 (Time: Baseline, Before, During, and After Arousal Manipulation) ANOVA on Heart Rate (bpm)

Source	*df*	*F*	*p*	*ηp2*
		Between Subjects		
MHI	1	1.11	.296	.013
Condition	1	1.74	.191	.020
MHI X Condition	1	2.10	.151	.024
Error	87			
		Within Subjects		
Time	3	13.02	< .001*	.130
Time X MHI	3	1.50	.217	.017
Time X Condition	3	4.95	.002*	.054
Time X MHI X Condition	3	1.70	.168	.019
Error	261			

Table C17

Means and Standard Deviations across time (Baseline, Before, During, and After Arousal Manipulation) for MHI History and Arousal Manipulation Condition on Respiration Frequency

Time		*MHI History*	
		MHI	No-MHI
Baseline			
	Relaxation	16.46 (3.01)	16.30 (5.84)
	Stress	16.27 (4.28)	14.86 (6.13)
Before Manipulation			
	Relaxation	16.65 (4.60)	16.64 (4.91)
	Stress	17.48 (4.60)	18.22 (6.52)
During Manipulation			
	Relaxation	21.73 (5.91)	24.39 (6.20)
	Stress	24.76 (5.81)	23.67 (6.73)
After Manipulation			
	Relaxation	16.85 (6.72)	16.70 (4.25)
	Stress	20.46 (6.49)	20.78 (6.13)
Marginal Means		No-MHI	18.94 (*SE* = .58)
		MHI	18.83 (*SE* = .51)
		Relaxation	18.21 (*SE* = .54)
		Stress	19.56 (*SE* = .55)
		Baseline	15.97 (*SE* = .51)
		Before Manipulation	17.25 (*SE* = .54)
		During Manipulation	23.64 (*SE* = .65)
		After Manipulation	18.70 (*SE* = .64)

Note. Values in parentheses are standard deviations; *SE* = standard error.

Table C18

A 2 (MHI History: MHI, No-MHI) X 2 (Arousal Manipulation Condition: Stress, Relaxation) X 4 (Time: Baseline, Before, During, and After Manipulation) ANOVA on Respiration Frequency

Source	*df*	*F*	*p*	*ηp2*
	Between Subjects			
MHI	1	.02	.886	.001
Condition	1	3.06	.084	.034
MHI X Condition	1	.38	.542	.004
Error	87			
	Within Subjects			
Time	3	42.88	< .001*	.330
Time X MHI	3	.42	.740	.005
Time X Condition	3	3.47	.017*	.038
Time X MHI X Condition	3	1.02	.386	.012
Error	261			

Representation across MHI Groups, Sex, and Arousal Manipulation Condition

Table C19

Chi-Square Analysis of Representation across Sex, MHI History, and Arousal Manipulation Condition

Variable	*Percentage*		χ^2	*df*	*p*
	History of MHI				
	MHI	*No-MHI*			
Sex					
(*n* = 91)					
Female	49.20 (31)	50.80 (32)			
Male	71.40 (20)	28.60 (8)			
			3.89	1	.049*
	History of MHI				
Condition	*MHI*	*No-MHI*			
Stress	F = 53.10 (17)	F = 46.90 (15)			
(*n* = 45)	M = 76.90 (10)	M = 23.10 (3)			
Relaxation	F = 45.20 (14)	F = 54.80 (17)			
(*n* = 46)	M = 66.70 (10)	M = 33.30 (5)			
			0.36	1	.686[a]
			0.40	1	.617[a]

Note. Values in parentheses represent *n*; M = males; F = females
[a]*Note.* Fisher's Exact Test values as cell counts are less than 5.

Table C20

Representation across Arousal Manipulation Condition by MHI History or Sex

Variable	*Percentage*		χ^2	*df*	*p*
($N = 91$)	*History of MHI*				
Condition	*MHI*	*No-MHI*			
Stress	60.00 (27)	40.00 (18)			
Relaxation	52.20 (24)	47.80 (22)			
			0.57	1	.452
(N =91)	*Sex*				
Condition	*Male*	*Female*			
Stress	28.90 (13)	71.10 (32)			
Relaxation	32.60 (15)	67.40 (31)			
			0.15	1	.701

Note. Values in parentheses represent *n*.

Table C21

Chi-Square Analyses of Years of Education (Upper and Lower Year Students) and Arousal Manipulation Condition by MHI Group

Years of Education	*Arousal Manipulation Condition*	*Percentage (n)*		χ^2	*df*	*p*
Lower Year Students ($n = 29$)						
		MHI History				
		MHI	No-MHI			
	Relaxation	58.30 (7)	41.70 (5)			
	Stress	64.70 (11)	35.30 (6)			
				.12	1	.728
Upper Year Students ($n = 62$)						
		MHI History				
		MHI	No-MHI			
	Relaxation	50.00 (17)	50.00 (17)			
	Stress	57.10 (16)	42.90 (12)			
				.32	1	.575

Note. Values in parentheses represent *n*.

Table C22

Time Since Most Recent Head Injury (in months) for Relaxation Condition

Assigned Arousal Manipulation Condition	Time Since Injury (months)		Frequency	Percent	Valid Percent	Cumulative Percent
Relaxation			22	100.0		
($n = 46$)	Valid	1	1	4.2	4.2	4.2
		1.5	1	4.2	4.2	8.3
		2	1	4.2	4.2	12.5
		2.5	1	4.2	4.2	16.7
		4	1	4.2	4.2	20.8
		5	1	4.2	4.2	25.0
		12	2	8.3	8.3	33.3
		18	1	4.2	4.2	37.5
		24	5	20.8	20.8	58.3
		36	2	8.3	8.3	66.7
		48	1	4.2	4.2	70.8
		60	1	4.2	4.2	75.0
		72	2	8.3	8.3	83.3
		84	1	4.2	4.2	87.5
		216	3	12.5	12.5	100.0
		Total	24	100.0	100.0	

Table C23

Time Since Most Recent Head Injury (in months) for Stress Condition

Assigned Arousal Manipulation Condition	Time Since Injury (months)		Frequency	Percent	Valid Percent	Cumulative Percent
Stress			18	100.0		
($n = 45$)	Valid	0.5	1	3.7	3.7	3.7
		1	1	3.7	3.7	7.4
		1.5	1	3.7	3.7	11.1
		7	1	3.7	3.7	14.8
		8	1	3.7	3.7	18.5
		12	2	7.4	7.4	25.9
		14	1	3.7	3.7	29.6
		18	1	3.7	3.7	33.3
		24	4	14.8	14.8	48.1
		48	1	3.7	3.7	51.9
		60	2	7.4	7.4	59.3
		72	1	3.7	3.7	63.0
		84	1	3.7	3.7	66.7
		108	2	7.4	7.4	74.1
		120	2	7.4	7.4	81.5
		132	1	3.7	3.7	85.2
		144	1	3.7	3.7	88.9
		156	1	3.7	3.7	92.6
		192	1	3.7	3.7	96.3
		276	1	3.7	3.7	100.0
		Total	27	100.0	100.0	

Table C24

Chi-Square Analysis of Hospitalization History across MHI Groups and Arousal Manipulation Condition

Measure	*Variable*	*Percentage (n)*		χ^2	*df*	*p*
		History of MHI				
History of Hospitalization ($n = 57$)	*Condition*	*MHI*	*No-MHI*			
	Stress	35.70 (10)	64.30 (18)			
	Relaxation	55.20 (16)	44.80 (13)			
				.49	1	.483
		History of MHI				
No History of Hospitalization ($n = 34$)	*Condition*	*MHI*	*No-MHI*			
	Stress	52.90 (9)	47.10 (8)			
	Relaxation	47.10 (8)	52.90 (9)			
				.12	1	.732

Table C25

Chi-Square Analysis of Stimulant Usage (Caffeine) for MHI History and Arousal Manipulation Condition

Measure	*Variable*	*Percentage (n)*		χ^2	*df*	*p*
		History of MHI				
Consumed Caffeine	*Condition*	*MHI*	*No-MHI*			
(*n* = 40)						
	Stress	54.50 (12)	45.50 (10)			
	Relaxation	72.20 (13)	27.80 (5)	3.40	1	.251
		History of MHI				
Did Not Consume Caffeine	*Condition*	*MHI*	*No-MHI*			
(*n* = 51)	Stress	65.20 (15)	34.80 (8)			
	Relaxation	39.30 (11)	60.70 (17)			
				1.32	1	.065

Note. Values in parentheses represent *n.*

Table C26

Chi-Square Analysis of Stimulant Usage (Nicotine) for MHI History and Arousal Manipulation Condition

Measure	*Variable*	*Percentage (n)*		χ^2	*df*	*p*
		History of MHI				
Smokes Cigarettes (n = 10)	*Condition*	*MHI*	*No-MHI*			
	Stress	50.00 (3)	50.00 (3)			
	Relaxation	75.00 (3)	25.00 (1)			
				.63	1	.571[a]
		History of MHI				
Does not Smoke Cigarettes (n = 81)	*Condition*	*MHI*	*No-MHI*			
	Stress	61.50 (24)	38.50 (15)			
	Relaxation	50.00 (21)	50.00 (21)			
				1.09	1	.296

Note. Values in parentheses represent *n*.
[a]*Note.*Fisher's Exact Test used as cell counts less than 5.

Table C27

Chi-Square Analysis of Use of Relaxation Techniques (e.g. deep breathing, yoga) for MHI History and Arousal Manipulation Condition

Measure	*Variable*	*Percentage (n)*		χ^2	*df*	*p*
Use Relaxation Techniques (n = 22)		*History of MHI*				
	Condition	*MHI*	*No-MHI*			
	Stress	30.80 (4)	69.20 (9)			
	Relaxation	55.60 (5)	44.40 (4)			
				.43	1	.662[a]
Does Not Use Relaxation Techniques (n = 69)		*History of MHI*				
		MHI	*No-MHI*			
	Condition					
	Stress	56.20 (18)	43.80 (14)			
	Relaxation	51.40 (19)	48.60 (18)			
				.17	1	.684

[a]*Note.*Fisher's Exact Test used as cell counts less than 5.

Table C28

Chi-Square Analysis of Exercise History for MHI History and Arousal Manipulation Condition

Measure	*Variable*	*Percentage (n)*		χ^2	*df*	*p*
Regularly Exercise ($n = 59$)		*History of MHI*				
	Condition	*MHI*	*No-MHI*			
	Stress	75.90 (22)	24.10 (7)			
	Relaxation	53.30 (16)	46.70 (14)			
				3.27	1	.071
Do Not Exercise Regularly ($n = 32$)						
		History of MHI				
	Condition	*MHI*	*No-MHI*			
	Stress	31.20 (5)	68.80 (11)			
	Relaxation	50.00 (8)	50.00 (8)			
				1.17	1	.280

Table C29

Chi-Square Analysis of Typical Sleep Prior to Testing Day for MHI History and Condition

Measure	*Variable*	*Percentage (n)*		χ^2	*df*	*p*
Typical Sleep ($n = 60$)		*History of MHI*				
	Condition	*MHI*	*No-MHI*			
	Stress	65.60 (21)	34.40 (11)			
	Relaxation	50.00 (14)	50.00 (14)			
				1.50	1	.221
Not Typical Sleep ($n = 31$)						
		History of MHI				
	Condition	*MHI*	*No-MHI*			
	Stress	46.20 (6)	53.80 (7)			
	Relaxation	55.60 (10)	44.40 (8)			
				.27	1	.605

Table C30

Means and Standard Deviations for Reported Rating of Sleep Quality by Arousal Manipulation Condition and Mild Head Injury History

MHI History	Arousal Manipulation Condition		Marginal Means
	Stress	Relaxation	
MHI	5.00 (1.12)	4.87 (.90)	4.94 (*SE* = .17)
No-MHI	5.06 (1.06)	4.77 (1.27)	4.91 (*SE* = .17)
Marginal Means	5.03 (*SE* = .17)	4.82 (*SE* = .16)	

Note. Values in parentheses represent standard deviation; *SE* is standard error; Likert scale 1 *worst* to 7 *best* sleep.

Table C31

A 2 (MHI history: MHI, no-MHI) X 2 (Arousal Manipulation Condition: Stress, Relaxation) Analysis of Variance on Rating of Sleep Quality

Source	*df*	*F*	*p*	*ηp2*
	Between Subjects			
MHI	1	.01	.920	.001
Condition	1	.78	.380	.009
MHI X Condition	1	.12	.734	.001
Error	87			

Table C32

Mean Reported of Level of Alertness by Arousal Manipulation Condition and Mild Head Injury History

MHI History	Arousal Manipulation Condition		Marginal Means
	Stress	Relaxation	
MHI	4.93 (1.14)	4.79 (1.14)	4.86 (*SE* = .17)
No-MHI	4.56 (1.50)	5.23 (1.02)	4.89 (*SE* = .19)
Marginal Means	4.74 (*SE* = .18)	5.01 (*SE* = .18)	

Note. Values in parentheses represent standard deviation; *SE* = standard error; Likert scale 1 *very sleepy* to 7 *very alert.*

Table C33

A 2 (MHI history: MHI, no-MHI) X 2 (Condition: Stress, Relaxation) Analysis of Variance on Current Level of Alertness

Source	*df*	*F*	*p*	*ηp2*
	Between Subjects			
MHI	1	0.02	.898	.000
Condition	1	1.13	.291	.013
MHI X Condition	1	2.53	.115	.028
Error	87			

Table C34

Psychiatric or Neurological History and Arousal Manipulation Condition by Presence of MHI

Measure	*Variable*	*Percentage (n)*		χ^2	*df*	*p*
Psychiatric or Neurological Condition for MHI group (n = 51)		Yes	No			
	Condition					
	Stress	14.80 (4)	85.20 (23)			
	Relaxation	4.20 (1)	95.80 (23)			
				1.63	1	.354[a]
Psychiatric or Neurological Condition for no-MHI group (n = 40)						
	Condition					
	Stress	27.80 (5)	72.20 (13)			
	Relaxation	4.50 (1)	95.50 (21)			
				4.19	1	.073[a]

[a] Fisher's Exact Test value used as cell counts are less than 5.

Table C35

Medication Usage for Psychiatric or Neurological History and Manipulation Condition by Presence of MHI

Measure	*Variable*	*Percentage (n)*		χ^2	*df*	*p*
Medication use for Psychiatric or Neurological Condition		Yes	No			
($n = 91$)	*History of MHI*					
	MHI	5.90 (3)	94.10 (48)			
	No-MHI	7.50 (3)	92.50 (37)			
				.10	1	.999[a]
($n = 91$)	*Condition*					
	Stress	11.10 (5)	88.90 (40)			
	Relaxation	2.20 (1)	97.80 (45)			
				2.95	1	.111[a]

[a] Fisher's Exact Test value used as cell counts are less than 5.

Table C36

Chi-Square Analyses for MHI Group and Living Situation

Measure			χ^2	*df*	*p*
($N = 91$)	*History of MHI*				
	MHI	*No-MHI*			
Living Situation	*Percentage (n)*	*Percentage (n)*			
With Roommates	52.90 (27)	37.50 (15)			
With Parents or Guardians	27.50 (14)	30.00 (12)			
With Partner	5.90 (3)	20.00 (8)			
On Own	13.70 (7)	12.50 (5)			
			4.93	3	.192[a]
($N = 91$)	Condition				
	Stress	Relaxation			
Living Situation	*Percentage (n)*	*Percentage (n)*			
With Roommates	51.10 (23)	41.30 (19)			
With Parents or Guardians	22.20 (10)	34.80 (16)			
With Partner	13.30 (6)	10.90 (5)			
On Own	13.30 (6)	13.00 (6)			
			1.85	3	.605

[a]*Note.* Fisher's Exact Test used as cell counts are less than 5.

Table C37

Educational Assistance History across MHI Group

Variable	*Measure*		χ^2	*df*	*p*
($N = 91$)		Received Educational Assistance			
		Yes	No		
History of MHI	MHI	49.00 (25)	51.00 (26)		
	No-MHI	40.00 (16)	60.00 (24)		
				1.09	1	.297

Table C38

Means and Standard deviations for Independent t-test Analyses for Current Number of Course Credits

Measure	*Variable*	*Mean*	*Standard Deviation*	*t*	*df*	*p*
Current Number of Course Credits						
	History of MHI					
	MHI	4.06	1.35			
	No-MHI	3.98	1.31			
				.30	89	.767
	Condition					
	Stress	4.00	1.27			
	Relaxation	4.04	1.40			
				.16	89	.877

Table C39

Means and Standard Deviations for Independent t-test Analyses for Enjoyment of Academics

Measure	*Variable*	*Mean*	*Standard Deviation*	*t*	*df*	*p*
Enjoyment of Academics						
	History of MHI					
	MHI	6.88	1.61			
	No-MHI	6.78	1.37			
				.34	89	.737
	Condition					
	Stress	6.62	1.68			
	Relaxation	7.04	1.28			
				1.34	89	.182

Time of Day and Semester of Data Collection

Table C40

Representation of Time of Day for Data Collection for MHI Group and Arousal Manipulation Condition

MHI History	*Variable*	*Percentage (n)*		χ^2	*df*	*p*
MHI ($n = 51$)						
		Condition				
	Time of Day	Stress	Relaxation			
	Morning	42.30 (11)	57.70 (15)			
	Afternoon	64.00 (16)	36.00 (9)			
				2.41	1	.121
No-MHI ($n = 40$)						
		Condition				
	Time of Day	Stress	Relaxation			
	Morning	46.20 (12)	53.80 (14)			
	Afternoon	42.90 (6)	57.10 (8)			
				.04	1	.842

Table C41

Representation of Semester of Data Collection for MHI Group and Arousal Manipulation Condition

Measure	*Variable*	*Percentage (n)*		χ^2	*df*	*p*
		Condition				
MHI (n = 51)		Stress	Relaxation			
Semester of Data Collection	Winter	54.50 (12)	45.50 (10)			
	Spring	100.00 (2)	0.00 (0)			
	Summer	0.00 (0)	100.00 (1)			
	Fall	50.00 (13)	50.00 (13)			
				3.02	3	.558[a]
No-MHI (n = 40)		*Condition*				
Semester of Data Collection		Stress	Relaxation			
	Winter	47.40 (9)	52.60 (10)			
	Spring	0.00 (0)	100.00 (1)			
	Summer	66.70 (2)	33.30 (1)			
	Fall	41.20 (7)	58.80 (10)			
				1.53	3	.795[a]

[a]*Note.* Fisher's Exact Test used due to cells with expected count less than 5.

Table C42

Means and Standard Deviations for Baseline Self-Report of Arousal across Arousal Manipulation Condition, Time of Day of Testing and MHI History

Arousal Manipulation Condition		*MHI History*	
		MHI	No-MHI
Relaxation			
	Morning	2.67 (1.29)	3.43 (1.45)
	Afternoon	3.22 (1.85)	3.50 (1.69)
Stress			
	Morning	3.18 (1.47)	3.58 (1.68)
	Afternoon	2.75 (1.61)	4.50 (1.38)

Note. Values in parentheses are standard deviations.

Table C43

Marginal Means for Baseline Self-Report of Arousal across Arousal Manipulation Condition, Time of Day of Testing and MHI History

Marginal Means	
MHI	2.96 (*SE* = .22)
No-MHI	3.75 (*SE* = .26)
Stress	3.50 (*SE* = .25)
Relaxation	3.20 (*SE* = .24)
Morning	3.19 (*SE* = .23)
Afternoon	3.28 (*SE* = .27)

Note. *SE* = standard error.

Table C44

A 2 (MHI group: MHI, no-MHI) X 2 (Arousal Manipulation Condition: Stress, Relaxation) X 2 (Time of day of data collection: morning, afternoon) ANOVA on Baseline Self-Reported Arousal State

Source	*df*	*F*	*p*	*ηp2*
	Between Subjects			
MHI	1	5.45	.022*	.060
Condition	1	.77	.383	.009
Time of Day	1	.66	.418	.007
MHI X Condition	1	.66	.418	.007
MHI X Time of Day	1	.40	.529	.004
Condition X Time of Day	1	.01	.917	.000
MHI X Condition X Time of Day	1	1.80	.184	.020
Error	83			

Table C45

Means and Standard Deviations for Baseline Electrodermal Activity Frequency across Conditions and MHI History

Arousal Manipulation Condition		*MHI History*	
		MHI	No-MHI
Relaxation			
	Morning	5.47 (2.94)	8.68 (2.85)
	Afternoon	5.72 (3.68)	11.06 (3.70)
Stress			
	Morning	6.43 (1.59)	7.63 (2.55)
	Afternoon	5.72 (2.42)	10.25 (3.03)
Marginal Means		MHI	5.84 (*SE* = .41)
		No-MHI	9.40 (*SE* = .47)
		Stress	7.51 (*SE* = .45)
		Relaxation	7.73 (*SE* = .43)
		Morning	7.03 (*SE* = .55)
		Afternoon	7.51 (*SE* = .51)

Note. Values in parentheses are standard deviations; *SE* = standard error.

Table C46

A 2 (MHI group: MHI, no-MHI) X 2 (Arousal Manipulation Condition: Stress, Relaxation) X 2 (Time of day of data collection: morning, afternoon) ANOVA on Baseline Electrodermal Activity Frequency

Source	*df*	*F*	*p*	*ηp2*
	Between Subjects			
MHI	1	32.91	< .001*	.269
Condition	1	.13	.717	.001
Time of Day	1	3.34	.071	.027
MHI X Condition	1	1.30	.259	.010
MHI X Time of Day	1	4.82	.031*	.039
Condition X Time of Day	1	.08	.771	.001
MHI X Condition X Time of Day	1	.24	.628	.002
Error	83			

Table C47

Simple Effects Analysis Means and Standard Deviations for Baseline Electrodermal Activity Frequency across Time of Day for No-MHI Group

Time of Day	*Mean*	*Standard Deviation*
Morning	8.19	2.72
Afternoon	10.71	3.33

Table C48

Simple Effects Analysis for Baseline Electrodermal Activity Frequency by Time of Day of Data Collection for No-MHI Group

Source	*df*	*F*	*p*	*ηp2*
	Between Subjects			
Time of Day	1	6.70	.014*	.150
Error	38			

Table C49

Means and Standard Deviations for Baseline Electrodermal Activity Frequency across Time of Day of Data Collection for MHI Group

Time of Day	*Mean*	*Standard Deviation*
Morning	5.88	2.47
Afternoon	5.72	2.85

Table C50

Simple Effects Analysis for Baseline Electrodermal Activity Frequency by Time of Day of Data Collection for MHI Group

Source	*df*	*F*	*p*	*ηp2*
	Between Subjects			
Time of Day	1	.04	.836	.001
Error	49			

Table C51

Means and Standard Deviations for Baseline Electrodermal Activity Amplitude across Arousal Manipulation Condition and MHI History

Arousal Manipulation Condition		*MHI History*	
		MHI	No-MHI
Relaxation			
	Morning	.52 (.39)	1.06 (.61)
	Afternoon	.92 (.55)	1.48 (.58)
Stress			
	Morning	.90 (.68)	1.22 (.30)
	Afternoon	.57 (.28)	1.52 (.59)
Marginal Means		MHI	.73 (*SE* = .07)
		No-MHI	1.32 (*SE* = .08)
		Stress	1.05 (*SE* = .08)
		Relaxation	1.00 (*SE* = .08)
		Morning	.91 (*SE* = .09)
		Afternoon	.99 (*SE* = .10)

Note. Values in parentheses are standard deviations; *SE* = standard error.

Table C52

A 2 (MHI group: MHI, no-MHI) X 2 (Arousal Manipulation Condition: Stress, Relaxation) X 2 (Time of day of data collection: morning, afternoon) ANOVA on Baseline Electrodermal Activity Amplitude

Source	*df*	*F*	*p*	*ηp2*
		Between Subjects		
MHI	1	29.56	< .001*	.263
Condition	1	.28	.597	.002
Time of Day	1	3.36	.070	.003
MHI X Condition	1	.15	.697	.001
MHI X Time of Day	1	2.23	.139	.018
Condition X Time of Day	1	3.64	.060	.029
MHI X Condition X Time of Day	1	1.95	.166	.016
Error	83			

Table C53

Means and Standard Deviations for Baseline Respiration across Conditions and MHI History

Arousal Manipulation Condition		*MHI History*	
		MHI	No-MHI
Relaxation			
	Morning	15.87 (3.01)	16.93 (6.89)
	Afternoon	17.44 (2.91)	15.19 (3.48)
Stress			
	Morning	16.98 (5.02)	14.58 (6.81)
	Afternoon	15.78 (3.79)	15.42 (5.00)
Marginal Means		MHI	16.52 (*SE* = .71)
		No-MHI	15.33 (*SE* = .82)
		Stress	15.69 (*SE* = .78)
		Relaxation	16.36 (*SE* = .75)
		Morning	16.09 (*SE* = 1.10)
		Afternoon	15.99 (*SE* = 1.02)

Note. Values in parentheses are standard deviations; *SE* = standard error.

Table C54

A 2 (MHI group: MHI, no-MHI) X 2 (Arousal Manipulation Condition: Stress, Relaxation) X 2 (Time of day of data collection: morning, afternoon) ANOVA on Baseline Respiration

Source	*df*	*F*	*p*	*ηp2*
	Between Subjects			
MHI	1	.83	.364	.009
Condition	1	.38	.539	.004
Time of Day	1	.02	.904	.000
MHI X Condition	1	.13	.719	.001
MHI X Time of Day	1	.09	.767	.001
Condition X Time of Day	1	.01	.963	.000
MHI X Condition X Time of Day	1	1.53	.220	.018
Error	83			

Table C55

Means and Standard Deviations for Baseline Heart Rate across Arousal Manipulation Condition and MHI History

Arousal Manipulation Condition		*MHI History*	
		MHI	No-MHI
Relaxation			
	Morning	71.83 (8.48)	72.57 (7.50)
	Afternoon	77.06 (5.26)	72.88 (5.97)
Stress			
	Morning	72.45 (8.96)	74.42 (9.98)
	Afternoon	70.93 (12.75)	75.25 (4.38)
Marginal Means		MHI	73.07 (*SE* = 1.29)
		No-MHI	73.78 (*SE* = 1.49)
		Stress	73.26 (*SE* = 1.42)
		Relaxation	73.58 (*SE* = 1.37)
		Morning	72.76 (*SE* = 1.66)
		Afternoon	73.41 (*SE* = 1.81)

Note. Values in parentheses are standard deviations; *SE* = standard error.

Table C56

A 2 (MHI group: MHI, no-MHI) X 2 (Arousal Manipulation Condition: Stress, Relaxation) X 2 (Time of day of data collection: morning, afternoon) ANOVA on Baseline Respiration

Source	*df*	*F*	*p*	*ηp2*
	Between Subjects			
MHI	1	.13	.720	.001
Condition	1	.03	.872	.001
Time of Day	1	.38	.541	.004
MHI X Condition	1	1.52	.221	.018
MHI X Time of Day	1	.11	.745	.001
Condition X Time of Day	1	.62	.433	.007
MHI X Condition X Time of Day	1	.850	.359	.010
Error	83			

Hypothesis 1: Decreased Arousal at Baseline for Students with MHI

Table C57

Means and Standard Deviations for Self-reported Arousal State across MHI History and Assigned Arousal Manipulation Condition at Baseline

Assigned Arousal Manipulation Condition	*MHI History*		*Marginal Means*
	MHI	No-MHI	
Relaxation	2.88 (1.51)	3.45 (1.50)	3.17 (*SE* = .23)
Stress	2.93 (1.54)	3.89 (1.60)	3.41 (*SE* = .23)
Marginal Means	2.90 (*SE* = .22)	3.67 (*SE* = .24)	

Note. Values in parentheses are standard deviation; *SE* = standard error.

Table C58

2 (MHI History: MHI, No-MHI) X 2 (Assigned Arousal Manipulation Condition: Stress, Relaxation) Analysis of Variance on Self-reported Arousal State at Baseline

Source	*df*	*F*	*p*	*ηp2*
	Between Subjects			
MHI	1	5.60	.020*	.060
Condition	1	.55	.459	.006
MHI X Condition	1	.35	.558	.004
Error	87			

Table C59

Means and Standard Deviations for Independent t-tests for Self-reported Life Stressors and Life Satisfaction for MHI Groups

Measure		*Mean*	*Standard Deviation*	*t*	*df*	*p*
Frequency of Life Stressors						
	History of MHI					
	MHI	3.63	1.91			
	No-MHI	2.72	1.88			
				2.26	84	.027*[a]
Total Score for Life Stressors Scale						
	History of MHI					
	MHI	132.39	80.15			
	No-MHI	91.50	72.77			
				2.51	89	.014*

[a]*Note.* Equal variances not assumed.

Table C60

Means and Standard Deviations for Independent t-tests for Ratings of Day-to-Day Life Stress and Overall Life Satisfaction for MHI Groups

Measure		*Mean*	*Standard Deviation*	*t*	*df*	*p*
Rating of Day-to-Day Life Stress						
	History of MHI					
	MHI	4.90	2.02			
	No-MHI	5.45	1.80			
				1.35	89	.181
Overall Satisfaction with Life						
	History of MHI					
	MHI	7.63	1.11			
	No-MHI	7.22	1.16			
				1.67	82	.099[a]

[a]*Note.* Equal variances not assumed.

Table C61

Means and Standard Deviations for Independent t-tests for Current Day Factors Ratings Prior to Testing Session

Measure	*Mean*	*Standard Deviation*	*t*	*df*	*p*
Rating of Stress for Current Day					
(1 *not stressful* to 10 *very stressful*)					
History of MHI					
MHI	4.27	2.13			
No-MHI	4.00	2.08			
			.62	89	.538
Condition					
Stress	5.44	2.58			
Relaxation	4.61	2.38			
			1.61	89	.112
Rating of Busyness of Current Day					
(1 *calm* to 10 *busy*)					
History of MHI					
MHI	5.00	2.45			
No-MHI	5.05	2.60			
			.09	89	.925

Table C62

Means and Standard Deviations for Independent t-test for Ratings of Overall Pleasantness of the Day of the Testing Session between MHI Groups

Measure	*Mean*	*Standard Deviation*	*t*	*df*	*p*
Rating of Pleasantness of Current Day					
(1 *more pleasant* to 10 *less pleasant*)					
History of MHI					
MHI	3.45	1.95			
No-MHI	3.85	2.08			
			.94	89	.350
Condition					
Stress	3.62	1.96			
Relaxation	3.63	2.08			
			.02	89	.985

Table C63

Chi-Square Analysis of Occurrence of Out-of-the-Ordinary Event in Days Prior to Testing Session

Measure	*Variable*	*Percentage (n)*		χ^2	*df*	*p*
Occurrence of Out-of-the-Ordinary Event		Yes	No			
	MHI History					
	MHI	70.60 (12)	52.70 (39)			
	No-MHI	29.40 (5)	47.30 (35)			
				1.80	1	.180
		Yes	No			
	Condition					
	Stress	64.70 (11)	45.90 (34)			
	Relaxation	35.30 (6)	54.10 (40)			
				1.95	1	.163

Baseline Physiological Arousal

Table C64

Means and Standard Deviations for MHI Group for Baseline Electrodermal Activity Frequency

Group	*Mean*	*Standard Deviation*
MHI	5.80	2.64
No-MHI	9.08	3.15

Table C65

One-way ANOVA for MHI Group on Baseline Electrodermal Activity Frequency

Source	*df*	*F*	*p*	*ηp2*
		Between Subjects		
MHI	1	29.15	< .001*	.247
Error	89			

Table C66

Means and Standard Deviations for MHI Groups for Baseline Electrodermal Activity Amplitude

Group	*Mean*	*Standard Deviation*
MHI	.69	.49
No-MHI	1.26	.54

Table C67

One-way ANOVA for MHI Group for Baseline Electrodermal Activity Amplitude

Source	*df*	*F*	*p*	*ηp2*
		Between Subjects		
MHI	1	28.06	< .001*	.240
Error	89			

Table C68

Means and Standard Deviations for MHI Group for Baseline Heart Rate

Group	*Mean*	*Standard Deviation*
MHI	72.61	9.69
No-MHI	73.59	7.54

Table C69

One-way ANOVA for Heart Rate at Baseline as a function of MHI History

Source	*df*	*F*	*p*	*ηp2*
	Between Subjects			
MHI	1	.28	.600	.003
Error	89			

Table C70

Means and Standard Deviations for MHI Group for Baseline Respiration

Group	*Mean*	*Standard Deviation*
MHI	16.36	3.70
No-MHI	15.65	5.94

Table C71

One-way ANOVA for MHI Group for Baseline Respiration

Source	*df*	*F*	*p*	*ηp2*
	Between Subjects			
MHI	1	.48	.488	.005
Error	89			

Table C72

Relationships between Self-reported Arousal State and Physiological Indices of Arousal at Baseline Measurement

Variable	1	2	3	4	5
1. Self-reported Arousal State	–	.05	.22*	.28*	-.02
2. Respiration frequency		–	.04	.02	-.01
3. EDA frequency			–	.49*	.08
4. EDA amplitude				–	.18
5. HR frequency					-

*$p < .05$

Hypothesis 2: Responsivity to Arousal Manipulation between MHI Groups

Responsivity to Arousal Manipulation as a function of MHI History

Table C73

Means, Standard Deviations, and Marginal Means for Self-reported Arousal State by MHI History and Arousal Manipulation Condition across Time

Time		Condition	
		Stress	Relaxation
Pre-manipulation	MHI	2.93 (1.54)	2.88 (1.51)
	No-MHI	3.89 (1.60)	3.45 (1.50)
Post-manipulation	MHI	5.89 (1.78)	1.67 (.87)
	No-MHI	6.28 (1.93)	1.77 (.92)
			Standard Error
Marginal Means	MHI	3.34	.19
	No-MHI	3.85	.17
	Stress	4.75	.18
	Relaxation	2.44	.18
	Pre-manipulation	3.29	.16
	Post-manipulation	3.90	.15

Note. Values in parentheses are standard deviation.

Table C74

2 (MHI history: MHI, no-MHI) X 2 (Arousal Manipulation Condition: Stress, Relaxation) X 2 (Time: Pre-manipulation, Post-manipulation Analysis of Variance for Self-reported Arousal State

Source	*df*	*F*	*p*	*ηp2*
		Between Subjects		
MHI	1	3.94	.050*	.043
Condition	1	80.50	< .001*	.481
MHI X Condition	1	.42	.518	.005
Error	87			
		Within Subjects		
Time	1	11.11	.001*	.113
Time X MHI	1	2.01	.160	.023
Time X Condition	1	124.58	< .001*	.589
Time X MHI X Condition	1	.02	.892	.001
Error	87			

Note. Greenhouse-Geisser correction used.

Table C75

Means, Standard Deviations, and Marginal Means for Electrodermal Activity Amplitude by MHI History and Arousal Manipulation Condition across Time

Time		Condition	
		Stress	Relaxation
Pre-manipulation	MHI	.71 (.50)	.67 (.49)
	No-MHI	1.32 (.43)	1.21 (.62)
Post-manipulation	MHI	.77 (.33)	.38 (.27)
	No-MHI	1.64 (.63)	.53 (.27)
			Standard Error
Marginal Means	MHI	.63	.05
	No-MHI	1.18	.05
	Stress	1.11	.05
	Relaxation	.70	.05
	Pre-manipulation	.98	.05
	Post-manipulation	.83	.04

Note. Values in parentheses are standard deviation.

Table C76

2 (MHI history: MHI, no-MHI) X 2 (Arousal Manipulation Condition: Stress, Relaxation) X 2 (Time: Pre-manipulation, Post-manipulation) Analysis of Variance for Electrodermal Activity Amplitude

Source	*df*	*F*	*p*	*ηp2*
		Between Subjects		
MHI	1	55.53	< .001*	.390
Condition	1	31.86	< .001*	.268
MHI X Condition	1	7.57	.007*	.080
Error	87			
		Within Subjects		
Time	1	5.46	.022*	.059
Time X MHI	1	.32	.573	.004
Time X Condition	1	29.57	< .001*	.254
Time X MHI X Condition	1	6.94	.010*	.074
Error	87			

Note. Greenhouse-Geisser correction used.

Table C77

Means, Standard Deviations, and Marginal Means for Heart Rate (beats per minute) by MHI History and Arousal Manipulation Condition across Time

Time		Condition	
		Stress	Relaxation
Pre-manipulation	MHI	71.56 (11.19)	73.79 (7.75)
	No-MHI	74.69 (8.38)	72.68 (6.83)
Post-manipulation	MHI	70.94 (8.31)	71.15 (8.11)
	No-MHI	76.31 (8.78)	69.61 (7.15)
			Standard Error
Marginal Means	MHI	71.86	1.08
	No-MHI	73.32	1.22
	Stress	73.38	1.17
	Relaxation	71.81	1.13
	Pre-manipulation	73.18	.94
	Post-manipulation	72.00	.86

Note. Values in parentheses are standard deviation.

Table C78

2 (MHI history: MHI, no-MHI) X 2 (Arousal Manipulation Condition: Stress, Relaxation) X 2 (Time: Pre-manipulation, Post-manipulation) Analysis of Variance for Heart Rate (beats per minute)

Source	*df*	*F*	*p*	*ηp2*
		Between Subjects		
MHI	1	.81	.371	.009
Condition	1	.93	.339	.011
MHI X Condition	1	2.93	.091	.033
Error	87			
		Within Subjects		
Time	1	2.14	.124	.027
Time X MHI	1	.35	.555	.004
Time X Condition	1	4.89	.030*	.053
Time X MHI X Condition	1	.76	.386	.009
Error	87			

Table C79

Means, Standard Deviations, and Marginal Means for Electrodermal Activity Frequency by MHI History and Arousal Manipulation Condition across Time

MHI History	Condition	Marginal Means	
		Stress	Relaxation
Pre-manipulation	MHI	6.01 (2.11)	5.56 (3.16)
	No-MHI	8.50 (2.92)	9.55 (3.31)
Post-manipulation	MHI	11.68 (3.89)	10.13 (5.73)
	No-MHI	14.42 (4.64)	12.39 (5.61)
			Standard Error
Marginal Means	MHI	8.35	.42
	No-MHI	11.21	.48
	Stress	10.15	.46
	Relaxation	9.41	.44
	Pre-manipulation	7.40	.31
	Post-manipulation	12.15	.53

Note. Values in parentheses are standard deviation.

Table C80

2 (MHI history: MHI, no-MHI) X 2 (Arousal Manipulation Condition: Stress, Relaxation) X 2 Analysis of Variance for Electrodermal Activity Frequency across Time

Source	*df*	*F*	*p*	*ηp2*
		Between Subjects		
MHI	1	20.24	< .001*	.189
Condition	1	1.38	.244	.016
MHI X Condition	1	.16	.689	.002
Error	87			
		Within Subjects		
Time	1	66.05	< .001*	.432
Time X MHI	1	.40	.528	.005
Time X Condition	1	3.21	.077	.036
Time X MHI X Condition	1	.71	.403	.008
Error	87			

Note. Greenhouse-Geisser correction used.

Table C81

Means, Standard Deviations, and Marginal Means for Respiration Frequency by MHI History and Arousal Manipulation Condition across Time

MHI History	Condition	Marginal Means	
		Stress	Relaxation
Pre-manipulation	MHI	16.27 (4.28)	16.46 (3.01)
	No-MHI	14.86 (6.13)	16.30 (5.84)
Post-manipulation	MHI	20.46 (6.49)	16.85 (6.72)
	No-MHI	20.78 (6.13)	16.70 (4.25)
			Standard Error
Marginal Means	MHI	17.16	.72
	No-MHI	17.51	.64
	Stress	18.09	.69
	Relaxation	16.58	.67
	Pre-manipulation	15.97	.51
	Post-manipulation	18.70	.64

Note. Values in parentheses are standard deviation.

Table C82

2 (MHI history: MHI, no-MHI) X 2 (Arousal Manipulation Condition: Stress, Relaxation) X 2 Analysis of Variance for Respiration Frequency across Time

Source	*df*	*F*	*p*	*ηp2*
		Between Subjects		
MHI	1	.13	.715	.002
Condition	1	2.49	.118	.028
MHI X Condition	1	.04	.839	.001
Error	87			
		Within Subjects		
Time	1	17.71	< .001*	.169
Time X MHI	1	.45	.505	.005
Time X Condition	1	12.87	.001	.129
Time X MHI X Condition	1	.43	.512	.005
Error	87			

Table C83

Relationships between Self-reported Arousal State and Physiological Indices of Arousal after Arousal Manipulation

Variable	1	2	3	4	5
1. Self-reported Arousal State	–	.28*	.24*	.59*	.15
2. Respiration frequency		–	.04	.23*	.22*
3. EDA frequency			–	.36*	.09
4. EDA amplitude				–	.18[a]
5. HR frequency					-

*$p < .05$

[a]*Note.* Trend at $p = .09$.

Table C84

Relationships between Self-reported Arousal State and Physiological Indices of Arousal During Neuropsychological Testing

Variable	1	2	3	4	5
1. Self-reported Arousal State	–	.14	.40*	.42*	.14
2. Respiration frequency		–	.12	.07	.22*
3. EDA frequency			–	.45*	.16
4. EDA amplitude				–	.26*
5. HR frequency					-

*$p < .05$

Table C85

Relationships between Self-reported Arousal State and Physiological Indices of Arousal After Neuropsychological Testing

Variable	1	2	3	4	5
1. Self-reported Arousal State	–	.18[a]	.23*	.24*	.15
2. Respiration frequency		–	.01	.06	.12
3. EDA frequency			–	.28*	.16
4. EDA amplitude				–	.23*
5. HR frequency					-

*$p < .05$

[a]*Note.* Trend at $p = .08$.

Table C86

Relationships between Self-reported Arousal State and Physiological Indices of Arousal at Final Measurement

Variable	1	2	3	4	5
1. Self-reported Arousal State	–	.19[a]	.18[a]	.32*	.13
2. Respiration frequency		–	.06	.05	.01
3. EDA frequency			–	.30*	.01
4. EDA amplitude				–	.11
5. HR frequency					-

*$p < .05$

[a]*Note.* Trend at $p = .08$.

Table C87

Means, Standard Deviations, and Marginal Means for State Anxiety by Arousal Manipulation Condition and MHI History

MHI History	Condition		Marginal Means
	Stress	Relaxation	
MHI	34.04 (8.66)	30.71 (6.48)	32.37 (*SE* = 1.17)
No-MHI	37.17 (10.67)	33.54 (7.38)	35.36 (*SE* = 1.32)
Marginal Means	35.60 (*SE* = 1.26)	32.13 (*SE* = 1.23)	

Note. Values in parentheses are standard deviation; *SE*= standard error.

Table C88

2 (MHI history: MHI, no-MHI) X 2 (Arousal Manipulation Condition: Stress, Relaxation) Analysis of Variance for State Anxiety

Source	*df*	*F*	*p*	*ηp2*
	Between Subjects			
MHI	1	2.87	.094	.031
Condition	1	3.90	.052*	.042
MHI X Condition	1	.01	.934	.001
Error	87			

Table C89

Means, Standard Deviations, and Marginal Means for Trait Anxiety by Condition and Mild Head Injury History

MHI History	Condition		Marginal Means
	Stress	Relaxation	
MHI	38.26 (9.79)	37.42 (9.01)	37.84 (*SE* = 1.27)
No-MHI	39.94 (11.00)	39.00 (5.94)	39.47 (*SE* = 1.44)
Marginal Means	39.10 (*SE* = 1.38)	38.21 (*SE* = 1.34)	

Note. Values in parentheses are standard deviation. *SE* = standard error.

Table C90

2 (MHI history: MHI, no-MHI) X 2 (Arousal Manipulation Condition: Stress, Relaxation) Analysis of Variance for Trait Anxiety

Source	*df*	*F*	*p*	*ηp2*
	Between Subjects			
MHI	1	.72	.398	.008
Condition	1	.22	.643	.002
MHI X Condition	1	.01	.979	.001
Error	87			

Response to Arousal Manipulation across time as a function of MHI History

Table C91

Means and Standard Deviations for MHI Groups and Arousal Manipulation Condition on Self-reported Arousal State across Time

Time	*History of MHI*	*Arousal Condition*	*Mean*	*Standard Deviation*
After manipulation	No-MHI	Relaxation	1.77	.92
		Stress	6.28	1.93
	MHI	Relaxation	1.67	.87
		Stress	5.89	1.78
During Neuropsychological Testing	No-MHI	Relaxation	2.82	1.33
		Stress	4.94	1.70
	MHI	Relaxation	2.92	1.32
		Stress	3.92	1.62
After Neuropsychological Testing	No-MHI	Relaxation	3.59	1.62
		Stress	4.22	1.06
	MHI	Relaxation	2.88	1.19
		Stress	3.44	1.67
Final	No-MHI	Relaxation	3.14	1.32
		Stress	3.28	.96
	MHI	Relaxation	2.62	1.17
		Stress	2.74	1.13

Table C92

Marginal Means for MHI Groups and Arousal Manipulation Condition on Self-reported Arousal State across Time

	Marginal Means		
	No-MHI	3.76	(.18)
	MHI	3.26	(.16)
	Relaxation	2.68	(.17)
	Stress	4.34	(.17)
	After Manipulation	3.90	(.15)
	During Testing	3.65	(.16)
	After Testing	3.53	(.15)
	Final	2.95	(.12)

Note. Values in parentheses are standard error.

Table C93

Mixed Model Analysis of Variance for Self-reported Arousal across Time by MHI History and Arousal Manipulation Condition

Source	*df*	*F*	*p*	*ηp2*
		Between Subjects		
MHI	1	4.22	.043*	.046
Condition	1	47.88	< .001*	.355
MHI X Condition	1	.60	.442	.007
Error	87			
		Within Subjects		
Time	3	17.08	< .001*	.164
Time x MHI	3	1.10	.345	.012
Time x Condition	3	93.43	< .001*	.518
Time x MHI x Condition	3	1.69	.179	.019
Error	261			

Note. Greenhouse-Geisser correction used.

Table C94

Pairwise Comparisons of Self-reported Arousal State across Time

Comparison of Self-Report of Arousal State		*Mean Difference*	*Standard Error*	*p*	*95% Confidence Interval*	
					Lower Bound	*Upper Bound*
After manipulation to	During Neuropsychological Testing	.25	.14	.074	-.03	.53
	After Neuropsychological Testing	.37	.16	.026*	.05	.69
	Final	.96	.16	< .001*	.64	1.27
During Neuropsychological Testing to	After Neuropsychological Testing	.12	.11	.289	-.10	.34
	Final	.71	.14	< .001*	.43	.99
After Neuropsychological Testing to	Final	.59	.11	< .001*	.36	.82

Table C95

Means and Standard Deviations of Self-reported Arousal State across Time for Relaxation Condition

Time	*Mean*	*Standard Deviation*
After manipulation	1.72	.89
During Neuropsychological Testing	2.87	1.31
After Neuropsychological Testing	3.22	1.44
Final	2.89	1.26

Table C96

Repeated Measures Analysis for Self-reported Arousal State across Time for Relaxation Condition

Source	*df*	*F*	*p*	*ηp2*
		Within Subjects		
Time	3	31.31	< .001*	.410
Error	135			

Note. Greenhouse-Geisser correction used.

Table C97

Pairwise Comparisons for Self-reported Arousal State across Time for Relaxation Condition

Comparison of Self-Report of Arousal State		*Mean Difference*	*Standard Error*	*p*	*95% Confidence Interval*	
					Lower Bound	*Upper Bound*
After manipulation to	During Neuropsychological Testing	-1.15	.15	< .001*	-1.46	-.85
	After Neuropsychological Testing	-1.50	.18	< .001*	-1.86	-1.14
	Final	-1.15	.16	< .001*	-1.48	-.83
During Neuropsychological Testing to	After Neuropsychological Testing	-.35	.16	.034*	-.67	-.03
	Final	.00	.20	1.00	-.40	.40
After Neuropsychological Testing to	Final	.35	.14	.017*	.07	.63

Table C98

Means and Standard Deviations for Stress Condition on Self-reported Arousal State across Time

Time	*Mean*	*Standard Deviation*
After manipulation	6.04	1.83
During Neuropsychological Testing	4.33	1.70
After Neuropsychological Testing	3.76	1.49
Final	2.96	1.09

Table C99

Repeated Measures Analysis for Self-reported Arousal across Time for Stress Condition

Source	*df*	*F*	*p*	*ηp2*
		Within Subjects		
Time	3	69.91	< .001*	.614
Error	132			

Note. Greenhouse-Geisser correction used.

Table C100

Pairwise Comparisons for Stress Condition for Self-reported Arousal State across Time

Comparison of Self-Report of Arousal State		*Mean Difference*	*Standard Error*	*p*	*95% Confidence Interval*	
					Lower Bound	*Upper Bound*
After manipulation to	During Neuropsychological Testing	1.71	.23	< .001*	1.25	2.18
	After Neuropsychological Testing	2.29	.27	< .001*	1.74	2.84
	Final	3.09	.27	< .001*	2.55	3.62
During Neuropsychological Testing to	After Neuropsychological Testing	.58	.16	.001*	.25	.90
	Final	1.38	.20	< .001*	.97	1.78
After Neuropsychological Testing to	Final	.80	.18	< .001*	.15	1.15

Table 101

Means and Standard Deviations for MHI Groups and Arousal Manipulation Condition on Electrodermal Activity Frequency across Time

Time	*History of MHI*	*Arousal Condition*	*Mean*	*Standard Deviation*
After manipulation	No-MHI	Relaxation	12.39	5.61
		Stress	14.42	4.64
	MHI	Relaxation	10.13	5.73
		Stress	11.68	3.89
During Neuropsychological Testing	No-MHI	Relaxation	9.38	2.37
		Stress	13.06	3.01
	MHI	Relaxation	8.83	3.38
		Stress	9.04	3.00
After Neuropsychological Testing	No-MHI	Relaxation	10.77	3.32
		Stress	12.28	4.73
	MHI	Relaxation	9.08	3.96
		Stress	8.89	3.20
Final	No-MHI	Relaxation	10.77	3.90
		Stress	10.36	2.50
	MHI	Relaxation	7.81	3.82
		Stress	8.15	2.76

Table C102

Marginal Means for MHI Groups and Arousal Manipulation Condition on Electrodermal Activity Frequency across Time

Marginal Means			
	No-MHI	11.68	(.41)
	MHI	9.20	(.36)
	Relaxation	9.90	(.38)
	Stress	10.98	(.39)
	After Manipulation	12.15	(.53)
	During Testing	10.08	(.32)
	After Testing	10.26	(.40)
	Final	9.27	(.35)

Note. Values in parentheses are standard error.

Table C103

Mixed Model Analysis of Variance for Electrodermal Activity Frequency by MHI History and Arousal Manipulation Condition across Time

Source	*df*	*F*	*p*	*ηp2*
		Between Subjects		
MHI	1	20.39	< .001*	.190
Condition	1	3.93	.051*	.043
MHI X Condition	1	1.24	.268	.014
Error	87			
		Within Subjects		
Time	3	12.29	< .001*	.124
Time x MHI	3	.04	.991	.001
Time x Condition	3	1.84	.140	.021
Time x MHI x Condition	3	1.67	.174	.019
Error	261			

Note. Greenhouse-Geisser correction used.

Table C104

Pairwise Comparisons of Electrodermal Activity Frequency across Time

Comparison of Electrodermal Activity Frequency		*Mean Difference*	*Standard Error*	*p*	*95% Confidence Interval*	
					Lower Bound	*Upper Bound*
After manipulation to	During Neuropsychological Testing	2.08	.55	< .001*	.98	3.17
	After Neuropsychological Testing	1.90	.55	.001*	.80	2.99
	Final	2.88	.55	< .001*	1.79	3.97
During Neuropsychological Testing to	After Neuropsychological Testing	-.18	.46	.698	-1.08	.73
	Final	.80	.40	.048*	.01	1.60
After Neuropsychological Testing to	Final	.98	.42	.020*	.16	1.81

Table C105

Means and Standard Deviations for MHI Groups and Condition for Electrodermal Activity Amplitude across Time

Time	*History of MHI*	*Arousal Condition*	*Mean*	*Standard Deviation*
After manipulation	No-MHI	Relaxation	.52	.27
		Stress	1.64	.63
	MHI	Relaxation	.38	.26
		Stress	.77	.33
During Neuropsychological Testing	No-MHI	Relaxation	.68	.38
		Stress	1.20	.45
	MHI	Relaxation	.43	.22
		Stress	.59	.29
After Neuropsychological Testing	No-MHI	Relaxation	.74	.34
		Stress	1.10	.43
	MHI	Relaxation	.50	.24
		Stress	.48	.25
Final	No-MHI	Relaxation	.77	.23
		Stress	.90	.38
	MHI	Relaxation	.50	.27
		Stress	.42	.24

Table C106

Marginal Means for MHI Groups and Condition for Electrodermal Activity Amplitude across Time

Marginal Means			
	No-MHI	.95	(.04)
	MHI	.51	(.04)
	Relaxation	.57	(.04)
	Stress	.89	(.04)
	After Manipulation	.83	(.04)
	During Testing	.73	(.04)
	After Testing	.71	(.03)
	Final	.65	(.03)

Note. Values in parentheses are standard error.

Table C107

Mixed Model Analysis of Variance for Electrodermal Activity Amplitude across Time by MHI History and Arousal Manipulation Condition

Source	*df*	*F*	*p*	*ηp2*
	Between Subjects			
MHI	1	62.59	< .001*	.418
Condition	1	34.02	< .001*	.281
MHI X Condition	1	14.42	< .001*	.142
Error	87			
	Within Subjects			
Time	3	9.95	< .001*	.103
Time x MHI	3	1.21	.304	.014
Time x Condition	3	41.15	< .001*	.321
Time x MHI x Condition	3	5.06	.004*	.055
Error	261			

Note. Greenhouse-Geisser correction used.

Table C108

Pairwise Comparisons for EDA Amplitude across Time

Comparison of EDA Amplitude		*Mean Difference*	*Standard Error*	*p*	*95% Confidence Interval*	
					Lower Bound	*Upper Bound*
After Manipulation to	During Neuropsychological Testing	-.10	.03	< .001*	.05	.16
	After Neuropsychological Testing	.13	.04	.003*	.04	.21
	Final	.19	.04	< .001*	.11	.26
During Neuropsychological Testing to	After Neuropsychological Testing	.02	.04	.579	-.05	.10
	Final	.08	.03	.012*	.02	.14
After Neuropsychological Testing to	Final	.06	.03	.052*	.01	.12

Table C109

Means and Standard Deviations for Stress Condition on EDA Amplitude across Time

Time	*Mean*	*Standard Deviation*
After Manipulation	1.12	.63
During Neuropsychological Testing	.84	.47
After Neuropsychological Testing	.73	.45
Final	.61	.38

Table C110

Repeated Measures Analysis for EDA Amplitude across Time for Stress Condition

Source	*df*	*F*	*p*	*ηp2*
		Within Subjects		
Time	3	35.59	< .001*	.447
Error	132			

Note. Greenhouse-Geisser correction used.

Table C111

Pairwise Comparisons for Stress Condition EDA Amplitude across Time

Comparison of EDA Amplitude		*Mean Difference*	*Standard Error*	*p*	*95% Confidence Interval*	
					Lower Bound	*Upper Bound*
After Manipulation to	During Neuropsychological Testing	.28	.05	< .001*	.19	.38
	After Neuropsychological Testing	.39	.07	< .001*	.26	.52
	Final	.51	.06	< .001*	.39	.64
During Neuropsychological Testing to	After Neuropsychological Testing	.10	.05	.036*	.01	.20
	Final	.23	.04	< .001*	.15	.31
After Neuropsychological Testing to	Final	.12	.04	.008*	.03	.21

Table C112

Means and Standard Deviations for Relaxation Condition for EDA Amplitude across Time

Time	*Mean*	*Standard Deviation*
After Manipulation	.45	.27
During Neuropsychological Testing	.55	.33
After Neuropsychological Testing	.61	.32
Final	.63	.28

Table C113

Repeated Measures Analysis for EDA Amplitude across Time for Relaxation Condition

Source	*df*	*F*	*p*	*ηp2*
		Within Subjects		
Time	3	5.70	.002*	.112
Error	135			

Note. Greenhouse-Geisser correction used.

Table C114

Pairwise Comparisons for Relaxation Condition for EDA Amplitude across Time

Comparison of EDA Amplitude		*Mean Difference*	*Standard Error*	*p*	*95% Confidence Interval*	
					Lower Bound	*Upper Bound*
After Manipulation to	During Neuropsychological Testing	-.10	.04	.009*	-.17	-.03
	After Neuropsychological Testing	-.16	.05	.003*	-.28	-.08
	Final	-.18	.05	.001*	.03	.17
During Neuropsychological Testing to	After Neuropsychological Testing	-.06	.05	.252	-.17	.05
	Final	-.08	.05	.114	-.18	.02
After Neuropsychological Testing to	Final	-.02	.04	.734	-.10	.07

Table C115

Means and Standard Deviations for MHI Groups and Relaxation Condition on Electrodermal Activity Amplitude across Time

Time	*History of MHI*	*Mean*	*Standard Deviation*
After Manipulation	No-MHI	.52	.27
	MHI	.38	.26
During Neuropsychological Testing	No-MHI	.68	.38
	MHI	.42	.22
After Neuropsychological Testing	No-MHI	.74	.34
	MHI	.50	.24
Final	No-MHI	.76	.23
	MHI	.50	.27
Marginal Means	No-MHI	.68	(.04)
	MHI	.45	(.04)
	After Manipulation	.46	(.04)
	During Testing	.56	(.05)
	After Testing	.62	(.04)
	Final	.63	(.04)

Note. Values in parentheses are standard error.

Table C116

Mixed Model Analysis of Variance for Electrodermal Activity Amplitude across Time by MHI History for Relaxation Condition

Source	*df*	*F*	*p*	*ηp2*
		Between Subjects		
MHI	1	14.76	< .001*	.251
Error	44			
		Within Subjects		
Time	3	5.82	.002*	.117
Time x MHI	3	.75	.498	.017
Error	132			

Note. Greenhouse-Geisser correction used.

Table C117

Pairwise Comparisons of EDA Amplitude across Time for Relaxation Condition

Comparison of EDA Amplitude		*Mean Difference*	*Standard Error*	*p*	*95% Confidence Interval*	
					Lower Bound	*Upper Bound*
After Manipulation to	During Neuropsychological Testing	-.10	.04	.007*	-.17	-.03
	After Neuropsychological Testing	-.16	.05	.003*	-.27	-.60
	Final	-.18	.05	.001*	-.28	-.08
During Neuropsychological Testing to	After Neuropsychological Testing	-.06	.06	.261	-.17	.05
	Final	-.08	.05	.118	-.18	.02
After Neuropsychological Testing to	Final	-.02	.04	.726	-.10	.07

Table C118

Means and Standard Deviations for Electrodermal Activity across Time for MHI Groups and Stress Condition

Time	*History of MHI*	*Mean*	*Standard Deviation*
After Manipulation	No-MHI	1.64	.63
	MHI	.77	.33
During Neuropsychological Testing	No-MHI	1.20	.45
	MHI	.59	.29
After Neuropsychological Testing	No-MHI	1.10	.43
	MHI	.48	.25
Final	No-MHI	.90	.38
	MHI	.42	.24
Marginal Means	No-MHI	1.21	(.07)
	MHI	.56	(.06)
	After Manipulation	1.21	(.07)
	During Testing	.90	(.06)
	After Testing	.79	(.05)
	Final	.66	(.05)

Note. Values in parentheses are standard error.

Table C119

Mixed Model Analysis of Variance for Electrodermal Activity Amplitude across Time by MHI History for Stress Condition

Source	*df*	*F*	*p*	*ηp2*
		Between Subjects		
MHI	1	46.91	< .001*	.522
Error	43			
		Within Subjects		
Time	3	43.15	< .001*	.501
Time x MHI	3	5.26	.005*	.109
Error	129			

Note. Greenhouse-Geisser correction used.

Table C120

Pairwise Comparisons of EDA Amplitude across Time for Stress Condition by MHI group

Comparison of EDA Amplitude		*Mean Difference*	*Standard Error*	*p*	*95% Confidence Interval*	
					Lower Bound	*Upper Bound*
After Manipulation to	During Neuropsychological Testing	.31	.04	< .001*	.22	.40
	After Neuropsychological Testing	.41	.07	< .001*	.28	.55
	Final	.55	.06	< .001*	.44	.66
During Neuropsychological Testing to	After Neuropsychological Testing	.10	.05	.044*	.01	.21
	Final	.24	.04	< .001*	.16	.32
After Neuropsychological Testing to	Final	.14	.044	.003*	.05	.22

Table C121

Means and Standard Deviations for EDA Amplitude across Time for No-MHI Group

Time	*Mean*	*Standard Deviation*
After Manipulation	1.03	.73
During Neuropsychological Testing	.92	.48
After Neuropsychological Testing	.90	.42
Final	.83	.31

Table C122

EDA Amplitude across Time for No-MHI Group

Source	*df*	*F*	*P*	*ηp2*
		Within Subjects		
Time	3	2.53	.087	.061
Error	117			

Note. Greenhouse-Geisser correction used.

Table C123

Pairwise Comparisons of EDA Amplitude across Time for No-MHI Group

Comparison of EDA Amplitude		*Mean Difference*	*Standard Error*	*p*	*95% Confidence Interval*	
					Lower Bound	*Upper Bound*
After Manipulation to	During Neuropsychological Testing	.11	.07	.119	-.03	.25
	After Neuropsychological Testing	.12	.09	.187	-.06	.31
	Final	.20	.10	.014*	.01	.40
During Neuropsychological Testing to	After Neuropsychological Testing	.02	.06	.818	-.12	.15
	Final	.09	.06	.116	-.02	.21
After Neuropsychological Testing to	Final	.08	.05	.156	-.03	.18

Table C124

Means and Standard Deviations for EDA Amplitude across Time for MHI Group

Time	*Mean*	*Standard Deviation*
After Manipulation	.59	.35
During Neuropsychological Testing	.51	.27
After Neuropsychological Testing	.49	.24
Final	.45	.25

Table C125

EDA Amplitude across Time for MHI Group

Source	*df*	*F*	*p*	*ηp2*
		Within Subjects		
Time	3	3.05	.052*	.057
Error	150			

Note. Greenhouse-Geisser correction used.

Table C126

Pairwise Comparisons of EDA Amplitude across Time for MHI Group

Comparison of EDA Amplitude		*Mean Difference*	*Standard Error*	*p*	*95% Confidence Interval*	
					Lower Bound	*Upper Bound*
After Manipulation to	During Neuropsychological Testing	.08	.03	.027*	.01	.14
	After Neuropsychological Testing	.10	.05	.068	-.01	.21
	Final	.13	.06	.029*	.02	.25
During Neuropsychological Testing to	After Neuropsychological Testing	.02	.04	.581	-.06	.11
	Final	.06	.04	.186	-.03	.15
After Neuropsychological Testing to	Final	.03	.04	.363	-.04	.11

Table C127

Means and Standard Deviations of Heart Rate across Time by MHI History and Arousal Manipulation Condition

Time	*History of MHI*	*Arousal Condition*	*Mean*	*Standard Deviation*
After Manipulation	No-MHI	Relaxation	69.61	7.15
		Stress	76.30	8.78
	MHI	Relaxation	71.14	8.11
		Stress	70.94	8.31
During Neuropsychological Testing	No-MHI	Relaxation	69.16	8.27
		Stress	75.39	7.00
	MHI	Relaxation	69.71	8.88
		Stress	70.44	10.51
After Neuropsychological Testing	No-MHI	Relaxation	70.14	7.66
		Stress	74.22	8.17
	MHI	Relaxation	69.96	7.64
		Stress	69.35	8.73
Final	No-MHI	Relaxation	69.84	6.78
		Stress	72.08	8.75
	MHI	Relaxation	70.10	9.02
		Stress	68.46	9.64

Table C128

Marginal Means of Heart Rate across Time by MHI History and Arousal Manipulation Condition

Marginal Means			
	No-MHI	72.09	(1.25)
	MHI	70.02	(1.10)
	Relaxation	69.96	(1.16)
	Stress	72.15	(1.20)
	After Manipulation	72.00	(.86)
	During Testing	71.18	(.95)
	After Testing	70.92	(.86)
	Final	70.12	(.92)

Note. Values in parentheses are standard error.

Table C129

Mixed Model Analysis of Variance for Heart Rate across Time by MHI History and Arousal Manipulation Condition

Source	*df*	*F*	*p*	*ηp2*
	Between Subjects			
MHI	1	1.56	.216	.018
Condition	1	1.73	.192	.019
MHI X Condition	1	2.47	.120	.028
Error	87			
	Within Subjects			
Time	3	4.12	.007*	.045
Time x MHI	3	.23	.876	.003
Time x Condition	3	3.75	.012*	.041
Time x MHI x Condition	3	.71	.706	.008
	261			

Table C130

Pairwise Comparisons for Heart Rate across Time

Comparison of Heart Rate		*Mean Difference*	*Standard Error*	*p*	*95% Confidence Interval*	
					Lower Bound	*Upper Bound*
After Manipulation to	During Neuropsychological Testing	.83	.57	.148	-.30	1.95
	After Neuropsychological Testing	1.09	.54	.047*	.02	2.51
	Final	1.88	.56	.001*	.77	2.99
During Neuropsychological Testing to	After Neuropsychological Testing	.26	.55	.637	-.83	1.34
	Final	1.05	.563	.065	-.07	2.17
After Neuropsychological Testing to	Final	.79	.462	.089	-.12	1.71

Table C131

Means and Standard Deviations for Relaxation Condition on Heart Rate across Time

Time	*Mean*	*Standard Deviation*
After Manipulation	70.41	7.62
During Neuropsychological Testing	69.45	8.50
After Neuropsychological Testing	70.04	7.57
Final	69.98	7.94

Table C132

Repeated Measures ANOVA for Heart Rate across Time by Relaxation Condition

Source	*df*	*F*	*p*	*ηp2*
	Within Subjects			
Time	3	.68	.566	.015
Error	135			

Table C133

Means and Standard Deviations for Stress Condition on Heart Rate

Time	*Mean*	*Standard Deviation*
After Manipulation	73.09	8.81
During Neuropsychological Testing	72.42	9.50
After Neuropsychological Testing	71.30	8.76
Final	69.91	9.37

Table C134

Repeated Measures ANOVA for Heart Rate across Time for Stress Condition

Source	*df*	*F*	*p*	*ηp2*
		Within Subjects		
Time	3	5.84	.001*	.117
Error	132			

Table C135

Pairwise Comparisons of Heart Rate across Time for Stress Condition

Comparison of Heart Rate		*Mean Difference*	*Standard Error*	*p*	*95% Confidence Interval*	
					Lower Bound	*Upper Bound*
After Manipulation to	During Neuropsychological Testing	.67	.82	.419	-.98	2.31
	After Neuropsychological Testing	1.79	.75	.021*	.28	3.30
	Final	3.18	.82	< .001*	1.53	4.83
During Neuropsychological Testing to	After Neuropsychological Testing	1.12	.87	.206	-.64	2.88
	Final	2.51	.92	.009*	.67	4.36
After Neuropsychological Testing to	Final	1.39	.69	.051*	-.01	2.78

Table C136

Means and Standard Deviations of Respiration Frequency across Time by MHI History and Arousal Manipulation Condition

Time	*History of MHI*	*Arousal Condition*	*Mean*	*Standard Deviation*
After Manipulation	No-MHI	Relaxation	16.70	4.25
		Stress	20.78	6.13
	MHI	Relaxation	16.85	5.61
		Stress	20.46	6.49
During Neuropsychological Testing	No-MHI	Relaxation	18.95	7.40
		Stress	19.42	4.79
	MHI	Relaxation	15.67	5.94
		Stress	19.52	7.11
After Neuropsychological Testing	No-MHI	Relaxation	19.63	6.18
		Stress	20.56	7.71
	MHI	Relaxation	15.23	5.75
		Stress	19.85	6.26
Final	No-MHI	Relaxation	19.32	5.32
		Stress	18.42	4.68
	MHI	Relaxation	17.75	6.32
		Stress	18.68	5.66

Table C137

Marginal Means of Respiration Frequency across Time by MHI History and Arousal Manipulation Condition

Marginal Means			
	No-MHI	19.22	(.71)
	MHI	18.02	(.62)
	Stress	17.51	(.66)
	Relaxation	19.71	(.68)
	After Manipulation	18.70	(.64)
	During Testing	18.39	(.69)
	After Testing	18.82	(.68)
	Final	18.54	(.59)

Note. Values in parentheses are standard error.

Table C138

Mixed Model Analysis of Variance of Respiration Frequency across Time by MHI History and Arousal Manipulation Condition

Source	*df*	*F*	*p*	*ηp2*
	Between Subjects			
MHI	1	1.68	.198	.019
Condition	1	5.46	.022*	.059
MHI X Condition	1	1.27	.263	.014
Error	87			
	Within Subjects			
Time	3	.13	.923	.001
Time x MHI	3	1.09	.349	.012
Time x Condition	3	2.40	.078	.027
Time x MHI x Condition	3	.84	.460	.010
Error	261			

Note. Greenhouse-Geisser correction used.

Hypothesis 3: Arousal, MHI, and Cognitive Performance

Baseline Cognitive Testing

Table C139

Means and Standard Deviations for Trail Making Test Errors (DKEFS, 2002) for Assigned Arousal Manipulation Condition and MHI History at Baseline

MHI History	Assigned Arousal Manipulation Condition		Marginal Means
	Stress	Relaxation	
MHI	.30 (.67)	.21 (.41)	.25 (*SE* = .06)
No-MHI	.06 (.24)	.09 (.29)	.07 (*SE* = .07)
Marginal Means	.20 (*SE* = .07)	.15 (*SE* = .07)	

Note. Values in parentheses are standard deviation; *SE* = standard error.

Table C140

A 2 (MHI History: MHI, No-MHI) X 2 (Assigned Arousal Manipulation Condition: Stress, Relaxation) ANOVA on Trail Making Test Errors (DKEFS, 2002) at Baseline

Source	*df*	*F*	*p*	*ηp2*
	Between Subjects			
MHI	1	3.38	.069	.037
Condition	1	.07	.788	.001
MHI X Condition	1	.40	.528	.004
Error	87			

Table C141

Mean Trail Making Test (DKEFS, 2002) Time for Completion in seconds by Assigned Arousal Manipulation Condition and MHI History at Baseline

MHI History	Assigned Arousal Manipulation Condition		Marginal Means
	Stress	Relaxation	
MHI	28.65 (7.54)	30.30 (6.34)	29.48 (*SE* = 1.27)
No-MHI	31.19 (10.54)	33.73 (11.59)	32.46 (*SE* = 1.44)
Marginal Means	29.92 (*SE* = 1.38)	32.02 (*SE* = 1.33)	

Note. Values in parentheses are standard deviation; *SE* = standard error.

Table C142

A 2 (MHI History: MHI, No-MHI) X 2 (Assigned Arousal Manipulation Condition: Stress, Relaxation) ANOVA on Trail Making Test Time in seconds (DKEFS, 2002) at Baseline

Source	*df*	*F*	*p*	*ηp2*
	Between Subjects			
MHI	1	2.43	.123	.027
Condition	1	1.20	.277	.013
MHI X Condition	1	.05	.818	.001
Error	87			

Table C143

Means and Standard Deviations by Assigned Arousal Manipulation Condition and MHI History on Number of Correct Symbols for Digit Symbol-Copy Test (WAIS-III, 1997) at Baseline

MHI History	Assigned Arousal Manipulation Condition		Marginal Means
	Stress	Relaxation	
MHI	86.52 (15.62)	83.58 (13.18)	85.05 (*SE* = 2.04)
No-MHI	89.78 (12.95)	91.86 (15.75)	90.82 (*SE* = 2.31)
Marginal Means	88.15 (*SE* = 2.21)	87.72 (*SE* = 2.15)	

Note. Values in parentheses are standard deviation; *SE* = standard error.

Table C144

A 2 (MHI History: MHI, No-MHI) X 2 (Assigned Arousal Manipulation Condition: Stress, Relaxation) ANOVA on Number of Correct Symbols Produced for Digit Symbol-Copy Test (WAIS-III, 1997)

Source	*df*	*F*	*p*	*ηp2*
	Between Subjects			
MHI	1	3.50	.065	.038
Condition	1	.02	.891	.001
MHI X Condition	1	.66	.418	.007
Error	87			

Table C145

Means and Standard Deviations by Assigned Arousal Manipulation Condition and MHI History for Time (in seconds) to Complete the Colour-Word Interference Task—Switching (DKEFS, 2002) at Baseline

MHI History	Assigned Arousal Manipulation Condition		Marginal Means
	Stress	Relaxation	
MHI	53.09 (10.11)	53.02 (10.60)	53.05 (*SE* = 1.30)
No-MHI	49.99 (7.38)	47.61 (7.91)	48.80 (*SE* = 1.47)
Marginal Means	51.54 (*SE* = 1.41)	50.32 (*SE* = 1.37)	

Note. Values in parentheses are standard deviation; *SE* = standard error.

Table C146

A 2 (MHI History: MHI, No-MHI) X 2 (Assigned Arousal Manipulation Condition: Stress, Relaxation) ANOVA on Time (in seconds) to Complete Colour-Word Interference Task—Switching (DKEFS, 2002) at Baseline

Source	*df*	*F*	*p*	*ηp2*
		Between Subjects		
MHI	1	4.67	.033*	.051
Condition	1	.39	.535	.004
MHI X Condition	1	.34	.559	.004
Error	87			

Table C147

Means and Standard Deviations by Assigned Arousal Manipulation Condition and MHI History on Timing of Colour-Word Interference Task—Colour Naming (DKEFS, 2002) at Baseline

MHI History	Assigned Arousal Manipulation Condition		Marginal Means
	Stress	Relaxation	
MHI	27.01 (4.82)	26.11 (3.94)	26.59 (4.41)
No-MHI	25.31 (3.40)	24.76 (3.87)	25.01 (3.63)
Marginal Means	26.16 (*SE* = .63)	25.44 (*SE* = .61)	

Note. Values in parentheses are standard deviation; *SE* = standard error.

Table C148

A 2 (MHI History: MHI, No-MHI) X 2 (Assigned Arousal Manipulation Condition: Stress, Relaxation) ANOVA on Timing of Colour-Word Interference Task—Colour Naming (DKEFS, 2002) at Baseline

Source	*df*	*F*	*p*	*ηp2*
		Between Subjects		
MHI	1	3.06	.084	.034
Condition	1	.68	.411	.008
MHI X Condition	1	.04	.836	.001
Error	87			

Table C149

Means and Standard Deviations by Assigned Arousal Manipulation Condition and MHI History for Time to Complete Colour-Word Interference Task—Word Reading (DKEFS, 2002) at Baseline

MHI History	Assigned Arousal Manipulation Condition		Marginal Means
	Stress	Relaxation	
MHI	20.76 (3.54)	19.53 (2.21)	20.14 (*SE* = .41)
No-MHI	19.43 (2.79)	18.10 (2.84)	18.77 (*SE* = .46)
Marginal Means	20.09 (*SE* = .44)	18.82 (*SE* = .43)	

Note. Values in parentheses are standard deviation; *SE* = standard error.

Table C150

A 2 (MHI History: MHI, No-MHI) X 2 (Assigned Arousal Manipulation Condition: Stress, Relaxation) ANOVA on Time to Complete Colour-Word Interference Task—Word Reading (DKEFS, 2002) at Baseline

Source	*df*	*F*	*p*	*ηp2*
	Between Subjects			
MHI	1	4.94	.029*	.054
Condition	1	4.26	.042*	.047
MHI X Condition	1	.01	.933	.001
Error	87			

Table C151

Means and Standard Deviations by Assigned Arousal Manipulation Condition and MHI History for Time to Complete Colour-Word Interference Task—Inhibition (DKEFS, 2002) at Baseline

MHI History	Assigned Arousal Manipulation Condition		Marginal Means
	Stress	Relaxation	
MHI	45.73 (9.00)	44.90 (7.52)	45.32 (*SE* = 1.13)
No-MHI	43.85 (7.54)	42.56 (7.62)	43.20 (*SE* = 1.27)
Marginal Means	44.79 (*SE* = 1.22)	43.73 (*SE* = 1.18)	

Note. Values in parentheses are standard deviation; *SE* = standard error.

Table C152

A 2 (MHI History: MHI, No-MHI) X 2 (Assigned Arousal Manipulation Condition: Stress, Relaxation) ANOVA on Time to Complete Colour-Word Interference Task—Inhibition (DKEFS, 2002) at Baseline

Source	*df*	*F*	*p*	*ηp2*
	Between Subjects			
MHI	1	1.55	.217	.017
Condition	1	.39	.534	.004
MHI X Condition	1	.02	.892	.001
Error	87			

Cognitive Performance as a function of Arousal Manipulation Condition and MHI History

Pre-and-Post-Manipulation Comparisons of Cognitive Performance

Table C153

Means and Standard Deviations of Number of Symbols Correctly Completed on Digit Symbol-Copy (WAIS-III, 1997) by MHI History and Arousal Manipulation Condition

Time	*History of MHI*	*Arousal Condition*	*Mean*	*Standard Deviation*
Pre-manipulation	No-MHI	Relaxation	91.86	15.75
		Stress	89.78	12.95
	MHI	Relaxation	83.58	13.18
		Stress	86.52	15.62
Post-manipulation	No-MHI	Relaxation	100.50	16.68
		Stress	99.94	14.81
	MHI	Relaxation	89.96	16.70
		Stress	94.26	16.59

Table C154

Marginal Means of Number of Symbols Correctly Completed on Digit Symbol-Copy (WAIS-III, 1997) by MHI History and Arousal Manipulation Condition

		Marginal Mean	Standard Error
Marginal Means	MHI	88.58	2.09
	No-MHI	95.52	2.37
	Stress	92.63	2.27
	Relaxation	91.48	2.20
	Pre-manipulation	87.94	1.54
	Post-manipulation	96.17	1.73

Table C155

Mixed Model Analysis of Variance for Digit Symbol-Copy (WAIS-III, 1997) Performance by MHI History and Arousal Manipulation Condition across Repeated Testing

Source	*df*	*F*	*p*	*ηp2*
	Between Subjects			
MHI	1	4.81	.031*	.052
Condition	1	.13	.717	.002
MHI X Condition	1	.61	.437	.007
Error	87			
	Within Subjects			
Time	1	94.52	< .000*	.521
Time x MHI	1	1.92	.170	.022
Time x Condition	1	.73	.395	.008
Time x MHI x Condition	1	.01	.961	.001
Error	87			

Table C156

Means and Standard Deviations of Trail Making Test (DKEFS, 2002) Time to Completion (in seconds) by MHI History and Arousal Manipulation Condition across Repeated Testing

Time	*History of MHI*	*Arousal Condition*	*Mean*	*Standard Deviation*
Pre-manipulation	No-MHI	Relaxation	33.73	11.59
		Stress	31.19	10.54
	MHI	Relaxation	30.30	6.34
		Stress	28.65	7.54
Post-manipulation	No-MHI	Relaxation	32.36	9.76
		Stress	32.84	11.99
	MHI	Relaxation	28.64	9.06
		Stress	28.04	7.89
		Marginal Mean	Standard Error	
Marginal Means	MHI	28.91	1.20	
	No-MHI	32.53	1.36	
	Stress	31.18	1.30	
	Relaxation	31.26	1.26	
	Pre-manipulation	30.97	.96	
	Post-manipulation	30.47	.99	

Table C157

Mixed Model Analysis of Variance for Trail Making Test Performance (DKEFS, 2002) across Repeated Testing by MHI History and Arousal Manipulation Condition

Source	*df*	*F*	*p*	*ηp2*
	Between Subjects			
MHI	1	4.02	.048*	.044
Condition	1	.36	.552	.004
MHI X Condition	1	.01	.978	.001
Error	87			
	Within Subjects			
Time	1	.48	.492	.005
Time x MHI	1	.78	.379	.009
Time x Condition	1	1.98	.163	.022
Time x MHI x Condition	1	.47	.497	.005
Error	87			

Table C158

Means and Standard Deviations of Trail Making Test Errors (DKEFS, 2002) by MHI History and Arousal Manipulation Condition

Time	*History of MHI*	*Arousal Condition*	*Mean*	*Standard Deviation*
Pre-manipulation	No-MHI	Relaxation	.09	.29
		Stress	.06	.24
	MHI	Relaxation	.21	.41
		Stress	.30	.67
Post-manipulation	No-MHI	Relaxation	.23	.43
		Stress	.17	.38
	MHI	Relaxation	.29	.62
		Stress	.22	.51

Table C159

Means and Standard Deviations of Trail Making Test Errors (DKEFS, 2002) by MHI History and Arousal Manipulation Condition

		Marginal Mean	Standard Error
Marginal Means	MHI	.26	.06
	No-MHI	.14	.06
	Stress	.19	.06
	Relaxation	.21	.06
	Pre-manipulation	.16	.05
	Post-manipulation	.23	.05

Table C160

Mixed Model Analysis of Variance for Trail Making Test Errors (DKEFS, 2002) across Repeated Testing by MHI History and Arousal Manipulation Condition

Source	*df*	*F*	*p*	*ηp2*
	Between Subjects			
MHI	1	2.10	.151	.024
Condition	1	.06	.815	.001
MHI X Condition	1	.12	.729	.001
Error	87			
	Within Subjects			
Time	1	1.14	.289	.013
Time x MHI	1	.98	.325	.011
Time x Condition	1	.58	.450	.007
Time x MHI x Condition	1	.30	.584	.003
Error	87			

Table C161

Means and Standard Deviations of Colour-Word Naming Interference Task—Switching (DKEFS, 2002) by MHI History and Arousal Manipulation Condition across Repeated Testing

Time	*History of MHI*	*Arousal Condition*	*Mean*	*Standard Deviation*
Pre-manipulation	No-MHI	Relaxation	47.61	7.91
		Stress	50.00	7.38
	MHI	Relaxation	53.02	10.60
		Stress	53.09	10.11
Post-manipulation	No-MHI	Relaxation	43.62	8.53
		Stress	43.91	5.82
	MHI	Relaxation	48.13	10.79
		Stress	46.58	7.43
		Marginal Mean	Standard Error	
Marginal Means	MHI	50.20	1.16	
	No-MHI	46.29	1.32	
	Stress	38.40	1.26	
	Relaxation	48.09	1.22	
	Pre-manipulation	50.93	.98	
	Post-manipulation	45.56	.90	

Table C162

Mixed Model Analysis of Variance for Colour-Word Naming Interference Task—Switching (DKEFS, 2002) across Repeated Testing by MHI History and Arousal Manipulation Condition

Source	*df*	*F*	*p*	*ηp2*
	Between Subjects			
MHI	1	4.98	.028*	.054
Condition	1	.03	.864	.001
MHI X Condition	1	.35	.556	.004
Error	87			
	Within Subjects			
Time	1	63.85	< .001*	.423
Time x MHI	1	.24	.625	.003
Time x Condition	1	1.89	.173	.021
Time x MHI x Condition	1	.03	.863	.001
Error	87			

Table C163

Means and Standard Deviations of Colour-Word Naming Interference Task—Colour Naming (DKEFS, 2002) by MHI History and Arousal Manipulation Condition

Time	*History of MHI*	*Arousal Condition*	*Mean*	*Standard Deviation*
Pre-manipulation	No-MHI	Relaxation	24.77	3.87
		Stress	25.31	3.40
	MHI	Relaxation	26.11	3.94
		Stress	27.01	4.82
Post-manipulation				
	No-MHI	Relaxation	22.68	2.66
		Stress	23.97	3.13
	MHI	Relaxation	24.81	3.95
		Stress	24.85	4.34
		Marginal Mean	Standard Error	
Marginal Means	MHI	25.70	.51	
	No-MHI	24.18	.58	
	Stress	25.28	.55	
	Relaxation	24.60	.54	
	Pre-manipulation	25.80	.44	
	Post-manipulation	24.08	.39	

Table C164

Mixed Model Analysis of Variance for Colour-Word Naming Interference Task—Colour Naming (DKEFS, 2002) across Repeated Testing by MHI History and Arousal Manipulation Condition

Source	*df*	*F*	*p*	*ηp2*
	Between Subjects			
MHI	1	3.90	.052*	.043
Condition	1	.81	.371	.009
MHI X Condition	1	.08	.774	.001
Error	87			
	Within Subjects			
Time	1	33.10	< .001*	.276
Time x MHI	1	.01	.979	.001
Time x Condition	1	.01	.923	.001
Time x MHI x Condition	1	1.82	.181	.020
Error	87			

Table C165

Means and Standard Deviations of Colour-Word Naming Interference Task—Word Reading (DKEFS, 2002) by MHI History and Arousal Manipulation Condition

Time	*History of MHI*	*Arousal Condition*	*Mean*	*Standard Deviation*
Pre-manipulation	No-MHI	Relaxation	18.10	2.85
		Stress	19.43	2.79
	MHI	Relaxation	19.53	2.21
		Stress	20.76	3.54
Post-manipulation				
	No-MHI	Relaxation	17.90	2.67
		Stress	19.55	2.48
	MHI	Relaxation	19.43	2.60
		Stress	20.03	3.32
		Marginal Mean	Standard Error	
Marginal Means	MHI	19.94	.38	
	No-MHI	18.75	.43	
	Stress	19.94	.41	
	Relaxation	18.74	.40	
	Pre-manipulation	19.46	.31	
	Post-manipulation	19.23	.30	

Table C166

Mixed Model Analysis of Variance for Colour-Word Naming Interference Task—Word Reading (DKEFS, 2002) across Repeated Testing by MHI History and Arousal Manipulation Condition

Source	*df*	*F*	*p*	*ηp2*
	Between Subjects			
MHI	1	4.37	.040*	.048
Condition	1	4.47	.037*	.049
MHI X Condition	1	.26	.610	.003
Error	87			
	Within Subjects			
Time	1	1.15	.287	.013
Time x MHI	1	.73	.395	.008
Time x Condition	1	.11	.741	.001
Time x MHI x Condition	1	1.24	.268	.014
Error	87			

Table C167

Means and Standard Deviations of Colour-Word Naming Interference Task—Inhibition (DKEFS, 2002) by MHI History and Arousal Manipulation Condition

	History of MHI	*Arousal Condition*	*Mean*	*Standard Deviation*
Pre-manipulation				
	No-MHI	Relaxation	42.56	7.62
		Stress	43.85	7.54
	MHI	Relaxation	44.90	7.52
		Stress	45.73	8.90
Post-manipulation				
	No-MHI	Relaxation	38.68	7.16
		Stress	39.23	5.93
	MHI	Relaxation	41.56	8.71
		Stress	42.11	7.63
		Marginal Mean	Standard Error	
Marginal Means	MHI	43.58	1.03	
	No-MHI	41.08	1.17	
	Stress	42.73	1.12	
	Relaxation	41.92	1.08	
	Pre-manipulation	44.26	.85	
	Post-manipulation	40.39	.80	

Table C168

Mixed Model Analysis of Variance for Colour-Word Naming Interference Task—Inhibition (DKEFS, 2002) across Repeated Testing by MHI History and Arousal Manipulation Condition

Source	*df*	*F*	*p*	*ηp2*
	Between Subjects			
MHI	1	2.57	.113	.029
Condition	1	.27	.606	.003
MHI X Condition	1	.01	.941	.001
Error	87			
	Within Subjects			
Time	1	51.33	< .001*	.371
Time x MHI	1	.50	.482	.006
Time x Condition	1	.23	.636	.003
Time x MHI x Condition	1	.05	.829	.001
Error	87			

Post-manipulation Cognitive Performance

Table C169

Means and Standard Deviations by Arousal Manipulation Condition and MHI History on Time for Completion of Forwards Mental Control Tasks (WAIS-III, 1997)

MHI History	Arousal Manipulation Condition		Marginal Means
	Stress	Relaxation	
MHI	18.13 (5.42)	16.25 (3.36)	17.19 (*SE* = .56)
No-MHI	17.03 (2.48)	16.71 (3.50)	16.87 (*SE* = .63)
Marginal Means	17.58 (*SE* = .61)	16.48 (*SE* = .59)	

Note. Values in parentheses are standard deviation; *SE* = standard error.

Table C170

A 2 (MHI History: MHI, No-MHI) X 2 (Arousal Manipulation Condition: Stress, Relaxation) ANOVA on Timing for Completion of Forwards Mental Control Tasks (WAIS-III, 1997)

Source	*df*	*F*	*p*	*ηp2*
	Between Subjects			
MHI	1	.14	.708	.002
Condition	1	1.70	.196	.019
MHI X Condition	1	.84	.361	.010
Error	87			

Table C171

Means and Standard Deviations by Arousal Manipulation Condition and MHI History on Time for Completion of Backwards Mental Control Tasks (WAIS-III, 1997)

MHI History	Arousal Manipulation Condition		Marginal Means
	Stress	Relaxation	
MHI	23.78 (10.04)	23.44 (7.63)	23.61 (*SE* = 1.12)
No-MHI	24.49 (7.46)	20.36 (5.68)	22.43 (*SE* = 1.27)
Marginal Means	24.14 (*SE* = 1.22)	21.90 (*SE* = 1.18)	

Note. Values in parentheses are standard deviation; *SE* = standard error.

Table C172

A 2 (MHI History: MHI, No-MHI) X 2 (Arousal Manipulation Condition: Stress, Relaxation) ANOVA on Timing for Completion of Backwards Mental Control Tasks (WAIS-III, 1997)

Source	*df*	*F*	*p*	*ηp2*
		Between Subjects		
MHI	1	.49	.486	.006
Condition	1	1.74	.190	.020
MHI X Condition	1	1.25	.267	.014
Error	87			

Table C173

Means and Standard Deviations by Arousal Manipulation Condition and MHI History on Time for Completion of Switching Mental Control Task (WAIS-III, 1997)

MHI History	Arousal Manipulation Condition		Marginal Means
	Stress	Relaxation	
MHI	17.49 (7.17)	21.85 (10.10)	19.67 (*SE* = 1.10)
No-MHI	19.19 (4.91)	17.65 (7.68)	18.42 (*SE* = 1.24)
Marginal Means	18.34 (*SE* = 1.19)	19.75 (*SE* = 1.16)	

Note. Values in parentheses are standard deviations; *SE* = standard error.

Table C174

A 2 (MHI History: MHI, No-MHI) X 2 (Arousal Manipulation Condition: Stress, Relaxation) ANOVA on Timing for Completion of Switching Mental Control Task (WAIS-III, 1997)

Source	*df*	*F*	*p*	*ηp2*
	Between Subjects			
MHI	1	.56	.455	.006
Condition	1	.73	.396	.008
MHI X Condition	1	3.17	.079	.035
Error	87			

Table C175

Means and Standard Deviations of Trail Making Test Switching (DKEFS, 2002) Time for Completion by MHI History and Arousal Manipulation Condition across Time

Variable	*History of MHI*	*Arousal Condition*	*Mean*	*Standard Deviation*
Switching Time	No-MHI	Relaxation	68.54	26.91
		Stress	65.15	25.03
	MHI	Relaxation	58.18	20.68
		Stress	62.02	19.89
Marginal Means		Marginal Mean	Standard Error	
	MHI	60.10	3.22	
	No-MHI	66.84	3.65	
	Stress	63.36	3.40	
	Relaxation	63.58	3.50	

Table C176

Analysis of Variance for Trail Making Test Switching (DKEFS, 2002) Time for Completion by MHI History and Arousal Manipulation Condition

Source	*df*	*F*	*p*	*ηp2*
	Between Subjects			
MHI	1	1.92	.170	.022
Condition	1	.01	.963	.001
MHI X Condition	1	.55	.460	.006
Error	87			

Table C177

Means and Standard Deviations of Trail Making Test Switching Errors (DKEFS, 2002) by MHI History and Arousal Manipulation Condition after Manipulation

Variable	*History of MHI*	*Arousal Condition*	*Mean*	*Standard Deviation*
Switching Errors	No-MHI	Relaxation	1.14	1.64
		Stress	.56	.98
	MHI	Relaxation	.33	.70
		Stress	.67	1.30
Marginal Means		Marginal Mean	Standard Error	
	MHI	.85	.19	
	No-MHI	.50	.17	
	Stress	.61	.19	
	Relaxation	.74	.18	

Table C178

Analysis of Variance for Trail Making Test Switching Errors (DKEFS, 2002) by MHI History and Arousal Manipulation Condition after Manipulation

Source	*df*	*F*	*p*	*ηp2*
	Between Subjects			
MHI	1	1.81	.183	.020
Condition	1	.23	.632	.003
MHI X Condition	1	3.15	.097	.035
Error	87			

Table C179

Means and Standard Deviations of Narrative Memory (WMS-III, 1997) Performance by MHI History and Arousal Manipulation Condition across Repeated Testing

Time	*History of MHI*	*Arousal Condition*	*Mean*	*Standard Deviation*
Immediate Recall	No-MHI	Relaxation	12.91	3.10
		Stress	13.11	4.61
	MHI	Relaxation	14.67	4.26
		Stress	15.33	3.68
Delayed Recall	No-MHI	Relaxation	11.77	3.34
		Stress	11.78	4.64
	MHI	Relaxation	13.21	4.17
		Stress	14.07	3.14
Marginal Means		Marginal Mean	Standard Error	
	MHI	14.32	.52	
	No-MHI	12.39	.59	
	Stress	13.57	.56	
	Relaxation	13.14	.55	
	Immediate	14.05	.42	
	Delayed	12.71	.40	

Table C180

Mixed Model Analysis of Variance for Narrative Memory (WMS-III, 1997) Performance by MHI History and Arousal Manipulation Condition across Repeated Testing

Source	*df*	*F*	*p*	*ηp2*
	Between Subjects			
MHI	1	6.02	.016*	.065
Condition	1	.31	.581	.004
MHI X Condition	1	.18	.674	.002
Error	87			
	Within Subjects			
Time	1	32.59	< .001*	.272
Time x MHI	1	.07	.786	.001
Time x Condition	1	.01	.998	.001
Time x MHI x Condition	1	.19	.664	.002
Error	87			

Table C181

Means and Standard Deviations of Narrative Thematic Memory (WMS-III, 1997) Performance by MHI History and Arousal Manipulation Condition across Repeated Testing

Time	*History of MHI*	*Arousal Condition*	*Mean*	*Standard Deviation*
Immediate Recall	No-MHI	Relaxation	4.77	1.38
		Stress	5.17	1.65
	MHI	Relaxation	5.33	1.46
		Stress	5.81	1.21
Delayed Recall	No-MHI	Relaxation	4.50	1.34
		Stress	4.94	1.73
	MHI	Relaxation	5.08	1.38
		Stress	5.85	1.06
Marginal Means		Marginal Mean	Standard Error	
	MHI	5.52	.19	
	No-MHI	4.85	.21	
	Stress	5.44	.21	
	Relaxation	4.92	.20	
	Immediate	5.27	.15	
	Delayed	5.10	.14	

Table C182

Mixed Model Analysis of Variance for Narrative Thematic Memory (WMS-III, 1997) Performance by MHI History and Arousal Manipulation Condition across Repeated Testing

Source	*df*	*F*	*p*	*ηp2*
	Between Subjects			
MHI	1	5.58	.020*	.060
Condition	1	3.34	.071	.037
MHI X Condition	1	.13	.720	.001
Error	87			
	Within Subjects			
Time	1	6.23	.014*	.067
Time x MHI	1	.99	.323	.011
Time x Condition	1	1.42	.237	.016
Time x MHI x Condition	1	.70	.407	.008
Error	87			

Table C183

Means and Standard Deviations of Visuospatial Memory (Memory for Design; NEPSY, 2007) Performance by MHI History and Arousal Manipulation Condition across Repeated Testing

Time	*History of MHI*	*Arousal Condition*	*Mean*	*Standard Deviation*
Immediate Recall	No-MHI	Relaxation	32.91	8.44
		Stress	33.17	4.45
	MHI	Relaxation	33.96	6.86
		Stress	31.89	6.68
Delayed Recall	No-MHI	Relaxation	31.41	6.93
		Stress	30.94	6.20
	MHI	Relaxation	32.04	5.65
		Stress	30.00	6.25
Marginal Means		Marginal Mean	Standard Error	
	MHI	31.97	.86	
	No-MHI	32.10	.97	
	Stress	31.50	.93	
	Relaxation	32.58	.90	
	Immediate	32.98	.73	
	Delayed	31.10	.66	

Table C184

Mixed Model Analysis of Variance for Visuospatial Memory (NEPSY, 2007) Performance by MHI History and Arousal Manipulation Condition across Repeated Testing

Source	*df*	*F*	*p*	*ηp2*
		Between Subjects		
MHI	1	.01	.917	.001
Condition	1	.70	.406	.008
MHI X Condition	1	.57	.452	.007
Error	87			
		Within Subjects		
Time	1	13.48	< .001*	.134
Time x MHI	1	.01	.968	.001
Time x Condition	1	.12	.736	.001
Time x MHI x Condition	1	.13	.715	.002
Error	87			

Table C185

Means and Standard Deviations by Arousal Manipulation Condition and MHI History on Number of Moves to Complete Tower of Hanoi Task (DKEFS, 2002)

MHI History	Arousal Manipulation Condition		Marginal Means
	Stress	Relaxation	
MHI	129.52 (25.87)	137.42 (26.25)	133.47 (*SE* = 4.08)
No-MHI	145.89 (24.11)	138.36 (37.98)	142.13 (*SE* = 4.62)
Marginal Means	137.70 (*SE* = 4.42)	137.89 (*SE* = 4.29)	

Note. Values in parentheses are standard deviations; *SE* = standard error.

Table C186

A 2 (MHI History: MHI, No-MHI) X 2 (Arousal Manipulation Condition: Stress, Relaxation) ANOVA on Number of Moves to Complete Tower of Hanoi Task (DKEFS, 2002)

Source	*df*	*F*	*p*	*ηp2*
	Between Subjects			
MHI	1	1.98	.163	.022
Condition	1	.01	.976	.001
MHI X Condition	1	1.57	.214	.018
Error	87			

Table C187

Means and Standard Deviations by Arousal Manipulation Condition and MHI History for Total Amount of Errors on Tower of Hanoi Task (DKEFS, 2002)

MHI History	Arousal Manipulation Condition		Marginal Means
	Stress	Relaxation	
MHI	.67 (1.47)	.71 (1.00)	.69 (*SE* = .17)
No-MHI	.72 (1.27)	.41 (.96)	.57 (*SE* = .19)
Marginal Means	.69 (*SE* = .18)	.56 (*SE* = .18)	

Note. Values in parentheses are standard deviations; *SE* = standard error.

Table C188

A 2 (MHI History: MHI, No-MHI) X 2 (Arousal Manipulation Condition: Stress, Relaxation) ANOVA for Total Amount of Errors on Tower of Hanoi Task (DKEFS, 2002)

Source	*df*	*F*	*p*	*ηp2*
		Between Subjects		
MHI	1	.23	.634	.003
Condition	1	.28	.596	.003
MHI X Condition	1	.48	.488	.006
Error	87			

Table C189

Means and Standard Deviations by Arousal Manipulation Condition and MHI History for Total Completion Time for Tower of Hanoi Task (DKEFS, 2002)

MHI History	Arousal Manipulation Condition		Marginal Means
	Stress	Relaxation	
MHI	408.49 (123.34)	399.18 (114.34)	403.84 (*SE* = 19.99)
No-MHI	487.08 (167.10)	443.47 (168.51)	465.28 (*SE* = 22.65)
Marginal Means	447.79 (*SE* = 21.68)	421.33 (*SE* = 21.03)	

Note. Values in parentheses are standard deviation; *SE* = standard error.

Table C190

A 2 (MHI History: MHI, No-MHI) X 2 (Arousal Manipulation Condition: Stress, Relaxation) ANOVA for Total Completion Time for Tower of Hanoi Task (DKEFS, 2002)

Source	*df*	*F*	*p*	*ηp2*
		Between Subjects		
MHI	1	4.14	.045*	.045
Condition	1	.77	.384	.009
MHI X Condition	1	.32	.572	.004
Error	87			

Table C191

Means and Standard Deviations by Arousal Manipulation Condition and MHI History for Total Score on Tower of Hanoi Task (DKEFS, 2002)

MHI History	Arousal Manipulation Condition		Marginal Means
	Stress	Relaxation	
MHI	18.33 (3.10)	17.50 (3.45)	17.92 (*SE* = .43)
No-MHI	17.28 (2.19)	18.55 (3.19)	17.91 (*SE* = .49)
Marginal Means	17.81 (*SE* = .47)	18.02 (*SE* = .45)	

Note. Values in parentheses are standard deviations; *SE* = standard error.

Table C192

A 2 (MHI History: MHI, No-MHI) X 2 (Arousal Manipulation Condition: Stress, Relaxation) ANOVA for Total Score on Tower of Hanoi Task (DKEFS, 2002)

Source	*df*	*F*	*p*	*ηp2*
	Between Subjects			
MHI	1	.01	.994	.001
Condition	1	.11	.739	.001
MHI X Condition	1	2.61	.110	.029
Error	87			

Table C193

Means and Standard Deviations for Pictorial Analogies Total Score (CTONI, 1996) by MHI History and Arousal Manipulation Condition

MHI History	Arousal Manipulation Condition		Marginal Means
	Stress	Relaxation	
MHI	15.26 (4.39)	15.21 (4.40)	15.23 (*SE* = .62)
No-MHI	11.78 (5.45)	14.36 (3.86)	13.07 (*SE* = .72)
Marginal Means	13.52 (*SE* = .69)	14.79 (*SE* = .67)	

Note. Values in parentheses are standard deviations; *SE* = standard error.

Table C194

Analysis of Variance for Pictorial Analogies Total Score (CTONI, 1996) by MHI History and Arousal Manipulation Condition

Source	*df*	*F*	*p*	*ηp2*
	Between Subjects			
MHI	1	5.13	.026*	.056
Condition	1	1.76	.188	.020
MHI X Condition	1	1.91	.171	.021
Error	87			

Table C195

Means and Standard Deviations for Picture Arrangement Total Score (WAIS-III, 1997) by MHI History and Arousal Manipulation Condition

MHI History	Arousal Manipulation Condition		Marginal Means
	Stress	Relaxation	
MHI	15.30 (2.66)	14.83 (2.44)	15.07 (*SE* = .43)
No-MHI	14.17 (3.97)	14.09 (3.22)	14.13 (*SE* = .48)
Marginal Means	14.73 (*SE* = .46)	14.46 (*SE* = .45)	

Note. Values in parentheses are standard deviations; *SE* = standard error.

Table C196

Analysis of Variance for Picture Arrangement Total Score (WAIS-III, 1997) by MHI History and Arousal Manipulation Condition

Source	*df*	*F*	*p*	*ηp2*
	Between Subjects			
MHI	1	2.10	.151	.024
Condition	1	.17	.678	.002
MHI X Condition	1	.09	.765	.001
Error	87			

Table C197

Means and Standard Deviations for Picture Arrangement Time for Completion (WAIS-III, 1997) by MHI History and Arousal Manipulation Condition

MHI History	Arousal Manipulation Condition		Marginal Means
	Stress	Relaxation	
MHI	227.68 (70.87)	228.10 (58.82)	227.89 (*SE* = 9.68)
No-MHI	237.49 (47.12)	234.69 (72.56)	236.09 (*SE* = 10.96)
Marginal Means	232.59 (*SE* = 10.50)	231.40 (*SE* = 10.18)	

Note. Values in parentheses are standard deviations; *SE* = standard error.

Table C198

Analysis of Variance for Picture Arrangement Time for Completion (WAIS-III, 1997) by MHI History and Arousal Manipulation Condition

Source	*df*	*F*	*p*	*ηp2*
	Between Subjects			
MHI	1	.31	.576	.004
Condition	1	.01	.935	.001
MHI X Condition	1	.01	.913	.001
Error	87			

Hypothesis 4: Post-concussive symptom reports between MHI groups

Table C199

Independent t-tests for Post-concussive Symptom Checklist (PCSC) Reports between MHI Groups

Measure	*MHI History*	*Mean*	*Standard Deviation*	*t*	*df*	*p*
PCSC Total Score						
	MHI	69.27	17.22			
	No-MHI	61.15	16.24			
				2.29	89	.024*
Frequency Total Score						
	MHI	21.22	5.69			
	No-MHI	19.33	4.91			
				1.67	89	.098
Intensity Total Score						
	MHI	22.31	5.65			
	No-MHI	19.20	5.62			
				2.62	89	.010*
Duration Total Score						
	MHI	25.74	6.81			
	No-MHI	22.62	6.32			
				2.24	89	.028*

Table C200

Mann Whitney U Analyses for Post-Concussive Symptom Reports and MHI History

Symptom		*Group*	*Mean Rank*	*U*	*p*
Concentration Difficulties	Frequency	MHI	51.26	751.50	.026*
		No-MHI	39.29		
	Intensity	MHI	51.44	742.50	.022*
		No-MHI	39.06		
	Duration	MHI	51.01	764.50	.034*
		No-MHI	39.61		
Irritability	Frequency	MHI	47.32	952.50	.541
		No-MHI	44.31		
	Intensity	MHI	49.61	836.00	.117
		No-MHI	41.40		
	Duration	MHI	50.40	795.50	.059
		No-MHI	40.39		

Table C201

Mann Whitney U Analyses for Post-Concussive Symptom Reports and MHI History

Symptom		*Group*	*Mean Rank*	*U*	*p*
Judgment Problems	Frequency	MHI	48.25	905.00	.308
		No-MHI	43.12		
	Intensity	MHI	49.88	822.00	.079
		No-MHI	41.05		
	Duration	MHI	48.40	897.50	.292
		No-MHI	42.94		
Headaches	Frequency	MHI	47.50	943.50	.520
		No-MHI	44.09		
	Intensity	MHI	51.60	734.50	.017*
		No-MHI	38.86		
	Duration	MHI	49.08	863.00	.183
		No-MHI	42.08		
		No-MHI	45.79		

Table C202

Mann Whitney U Analyses for Post-Concussive Symptom Reports and MHI History

Symptom		*Group*	*Mean Rank*	*U*	*p*
Visual Disturbances	Frequency	MHI	49.66	833.50	.050*
		No-MHI	41.34		
	Intensity	MHI	48.99	867.50	.092
		No-MHI	42.19		
	Duration	MHI	49.46	843.50	.060
		No-MHI	41.59		
Aggravated by Noise	Frequency	MHI	47.59	939.00	.486
		No-MHI	43.98		
	Intensity	MHI	49.89	821.50	.097
		No-MHI	41.04		
	Duration	MHI	50.88	771.00	.037*
		No-MHI	39.78		

Table C203

Mann Whitney U Analyses for Post-Concussive Symptom Reports and MHI History

Symptom		*Group*	*Mean Rank*	*U*	*p*
Dizziness	Frequency	MHI	48.71	882.00	.182
		No-MHI	42.55		
	Intensity	MHI	48.59	888.00	.195
		No-MHI	42.70		
	Duration	MHI	48.57	889.00	.208
		No-MHI	42.72		
Anxiety	Frequency	MHI	47.37	950.00	.549
		No-MHI	44.25		
	Intensity	MHI	49.71	831.00	.115
		No-MHI	41.28		
	Duration	MHI	47.08	965.00	.648
		No-MHI	44.62		

Table C204

Mann Whitney U Analyses for Post-Concussive Symptom Reports and MHI History

Symptom		*Group*	*Mean Rank*	*U*	*p*
Fatigue	Frequency	MHI	46.27	1006.00	.907
		No-MHI	45.65		
	Intensity	MHI	48.80	877.00	.233
		No-MHI	42.42		
	Duration	MHI	47.99	918.50	.396
		No-MHI	43.46		

Table C205

Hierarchical Multiple Regression Analysis of Post-concussive Symptom Checklist Total Score Regressed on Years Since Injury on Step 1, with Severity of Injury on Step 2 (N=91)

Step	Variable	*B*	*SE B*	*df*	*F*	*p*
1.	Years Since Injury	.07	.03	1, 89	.43	.515
2.	Severity of Injury	.15	.97	2, 88	1.21	.304

Note. Overall $R^2 = .03$; $R^2 = .01$ *for Step 1;* $\Delta R^2 = .01$ *for Step 2.*

Post-Hoc Analysis of Hypothesis 1: Decreased Arousal at Baseline for Students with MHI

Table C206

Means and Standard Deviations for Self-reported Arousal State across MHI History Severity and Assigned Arousal Manipulation Condition at Baseline

Assigned Arousal Manipulation Condition	*MHI History Severity*			*Marginal Means*
	No-MHI	MHI Altered State of Consciousness	MHI with Loss of Consciousness	
Relaxation	3.45 (1.50)	3.00 (1.50)	2.50 (1.64)	2.99 (*SE* = .27)
Stress	3.89 (1.60)	3.00 (1.60)	2.75 (1.49)	3.21 (*SE* = .25)
Marginal Means	3.67 (*SE* = .25)	3.00 (*SE* = .26)	2.63 (*SE* = .42)	

Note. Values in parentheses are standard deviation; *SE* = standard error.

Table C207

3 (MHI History Severity: No-MHI, MHI with Altered State of Consciousness, MHI with Loss of Consciousness) X 2 (Assigned Arousal Manipulation Condition: Stress, Relaxation) Analysis of Variance on Self-reported Arousal State at Baseline

Source	*df*	*F*	*p*	*ηp2*
	Between Subjects			
MHI History Severity	2	3.06	.052	.067
Condition	1	.39	.534	.005
MHI History Severity X Condition	2	.19	.829	.004
Error	85			

Table C208

Means and Standard Deviation for One-Way ANOVAs on Life Stressors for MHI Severity Groups

Measure	*Mean*	*Standard Deviation*	*F*	*df*	*p*	*ηp2*
Frequency of Life Stressors						
No-MHI	2.73	1.88				
MHI with Altered State	3.76	1.86				
MHI with LOC	3.29	2.05				
			2.84	2, 88	.064	.061
Total Score for Life Stressors Scale						
No-MHI	91.50	72.77				
MHI with Altered State	138.24	80.74				
MHI with LOC	116.93	79.39				
			3.54	2, 88	.033*	.074

Table C209

Means and Standard Deviations for One-Way ANOVAs for Ratings of Day-to-Day Life Stress and Overall Life Satisfaction for MHI Severity Groups

Measure	*Mean*	*Standard Deviation*	*F*	*df*	*p*	*ηp2*
Rating of Day-to-Day Life Stress						
No-MHI	5.45	1.80				
MHI with Altered State	4.92	2.02				
MHI with LOC	4.86	2.12				
			.90	2, 88	.410	.020
Overall Satisfaction with Life						
No-MHI	7.22	1.17				
MHI with Altered State	7.57	1.17				
MHI with LOC	7.79	.98				
			1.58	2, 88	.211	.035

Table C210

Means and Standard Deviations for MHI History Severity for Baseline Electrodermal Activity Amplitude

MHI History Severity	*Mean*	*Standard Deviation*
No-MHI	1.26	.54
MHI with Altered State of Consciousness	.71	.54
MHI with Loss of Consciousness	.63	.35

Table C211

One-way ANOVA for MHI History Severity (No-MHI, MHI with Altered State of Consciousness, MHI with Loss of Consciousness) for Electrodermal Activity Amplitude at Baseline

Source	*df*	*F*	*p*	*ηp2*
	Between Subjects			
MHI History Severity	2	14.03	< .001*	.242
Error	88			

Table C212

Means and Standard Deviations for MHI History Severity for Baseline Electrodermal Activity Frequency

MHI History Severity	*Mean*	*Standard Deviation*
No-MHI	9.08	3.15
MHI with Altered State of Consciousness	5.68	2.44
MHI with Loss of Consciousness	6.11	3.19

Table C213

One-way ANOVA for MHI History Severity (No-MHI, MHI with Altered State of Consciousness, MHI with Loss of Consciousness) for Electrodermal Activity Frequency at Baseline

Source	*df*	*F*	*p*	*ηp2*
	Between Subjects			
MHI History Severity	2	14.56	< .001*	.249
Error	88			

Table C214

Means and Standard Deviations for MHI History Severity for Baseline Heart Rate Frequency

MHI History Severity	*Mean*	*Standard Deviation*
No-MHI	73.59	7.53
MHI with Altered State of Consciousness	74.11	9.36
MHI with Loss of Consciousness	68.64	9.78

Table C215

One-way ANOVA for MHI History Severity (No-MHI, MHI with Altered State of Consciousness, MHI with Loss of Consciousness) for Heart Rate Frequency at Baseline

Source	*df*	*F*	*p*	*ηp2*
	Between Subjects			
MHI History Severity	2	2.16	.121	.047
Error	88			

Table C216

Means and Standard Deviations for MHI History Severity for Baseline Respiration Frequency

MHI History Severity	*Mean*	*Standard Deviation*
No-MHI	15.65	5.94
MHI with Altered State of Consciousness	16.44	3.79
MHI with Loss of Consciousness	16.14	3.59

Table C217

One-way ANOVA for MHI History Severity (No-MHI, MHI with Altered State of Consciousness, MHI with Loss of Consciousness) for Respiration Frequency at Baseline

Source	*df*	*F*	*p*	*ηp2*
	Between Subjects			
MHI History Severity	2	.26	.773	.006
Error	88			

Post-hoc Analysis of Hypothesis 2: Responsivity to Arousal Manipulation between MHI Groups

Responsivity to Arousal Manipulation as a function of MHI History Severity

Table C218

Means, Standard Deviations, and Marginal Means for Self-reported Arousal State by MHI History Severity and Arousal Manipulation Condition across Time

		Stress	Relaxation
Pre-manipulation	No-MHI	3.89 (1.60)	3.45 (1.50)
	MHI with Altered State of Consciousness	3.00 (1.60)	3.00 (1.50)
	MHI with Loss of Consciousness	2.75 (1.49)	2.50 (1.64)
Post-manipulation	No-MHI	6.28 (1.93)	1.77 (.92)
	MHI with Altered State of Consciousness	5.79 (2.04)	1.78 (.94)
	MHI with Loss of Consciousness	6.13 (.99)	1.33 (.52)
			Standard Error
Marginal Means	No-MHI	3.85	.19
	MHI with Altered State of Consciousness	3.39	.20
	MHI with Loss of Consciousness	3.18	.33
	Stress	4.64	.20
	Relaxation	2.31	.21
	Pre-manipulation	3.10	.18
	Post-manipulation	3.85	.17

Note. Values in parentheses are standard deviation.

Table C219

3 (MHI History Severity: No-MHI, MHI with Altered State of Consciousness, MHI with Loss of Consciousness) X 2 (Arousal Manipulation Condition: Stress, Relaxation) X 2 (Time: Pre-manipulation, Post-manipulation) for Self-reported Arousal State

Source	*df*	*F*	*p*	*ηp2*
		Between Subjects		
MHI Severity	2	2.13	.125	.048
Condition	1	65.62	< .001*	.436
MHI Severity X Condition	2	.42	.659	.010
Error	85			
		Within Subjects		
Time	1	13.01	.001*	.133
Time X MHI Severity	2	1.13	.328	.026
Time X Condition	1	103.22	< .001*	.548
Time X MHI Severity X Condition	2	.12	.887	.003
Error	85			

Note. Greenhouse-Geisser correction used.

Table C220

Means, Standard Deviations, and Marginal Means for Electrodermal Activity Amplitude by MHI History Severity and Arousal Manipulation Condition across Time

		Stress	Relaxation
Pre-manipulation	No-MHI	1.32 (.43)	1.21 (.62)
	MHI with Altered State of Consciousness	.72 (.56)	.70 (.52)
	MHI with Loss of Consciousness	.68 (.35)	.57 (.38)
Post-manipulation	No-MHI	1.64 (.63)	.53 (.27)
	MHI with Altered State of Consciousness	.81 (.26)	.38 (.28)
	MHI with Loss of Consciousness	.68 (.46)	.40 (.24)
			Standard Error
Marginal Means	No-MHI	1.18	.06
	MHI with Altered State of Consciousness	.65	.06
	MHI with Loss of Consciousness	.58	.09
	Stress	.98	.06
	Relaxation	.63	.06
	Pre-manipulation	.87	.06
	Post-manipulation	.74	.05

Note. Values in parentheses are standard deviation.

Table C221

3 (MHI History Severity: No-MHI, MHI with Altered State of Consciousness, MHI with Loss of Consciousness) X 2 (Arousal Manipulation Condition: Stress, Relaxation) X 2 (Time: Pre-manipulation, Post-manipulation) for Electrodermal Activity Amplitude

Source	*df*	*F*	*p*	*ηp2*
		Between Subjects		
MHI Severity	2	27.38	< .001*	.819
Condition	1	17.47	< .001*	.171
MHI Severity X Condition	2	3.66	.030*	.079
Error	85			
		Within Subjects		
Time	1	3.27	.074	.037
Time X MHI Severity	2	.19	.829	.004
Time X Condition	1	14.40	< .001*	.145
Time X MHI Severity X Condition	2	3.61	.031*	.078
Error	85			

Note. Greenhouse-Geisser correction used.

Table C222

Means, Standard Deviations, and Marginal Means for Heart Rate Frequency by MHI History Severity and Arousal Manipulation Condition across Time

		Stress	Relaxation
Pre-manipulation	No-MHI	74.69 (8.38)	72.68 (6.83)
	MHI with Altered State of Consciousness	73.71 (10.44)	74.53 (8.34)
	MHI with Loss of Consciousness	66.44 (11.91)	71.58 (5.64)
Post-manipulation	No-MHI	76.31 (8.78)	69.61 (7.15)
	MHI with Altered State of Consciousness	73.21 (6.54)	71.28 (8.58)
	MHI with Loss of Consciousness	65.56 (9.98)	70.78 (7.20)
			Standard Error
Marginal Means	No-MHI	73.32	1.20
	MHI with Altered State of Consciousness	73.18	1.24
	MHI with Loss of Consciousness	68.58	2.03
	Stress	71.65	1.21
	Relaxation	71.74	1.30
	Pre-manipulation	72.27	1.03
	Post-manipulation	71.12	.94

Note. Values in parentheses are standard deviation.

Table C223

3 (MHI History Severity: No-MHI, MHI with Altered State of Consciousness, MHI with Loss of Consciousness) X 2 (Arousal Manipulation Condition: Stress, Relaxation) X 2 (Time: Pre-manipulation, Post-manipulation) for Heart Rate Frequency

Source	*df*	*F*	*p*	*ηp2*
		Between Subjects		
MHI Severity	2	2.25	.112	.050
Condition	1	.01	.962	.001
MHI Severity X Condition	2	2.13	.125	.048
Error	85			
		Within Subjects		
Time	1	1.83	.180	.021
Time X MHI Severity	2	.26	.771	.006
Time X Condition	1	2.09	.152	.024
Time X MHI Severity X Condition	2	.57	.567	.013
Error	85			

Table C224

Means, Standard Deviations, and Marginal Means for Electrodermal Activity Frequency by MHI History Severity and Arousal Manipulation Condition across Time

		Stress	Relaxation
Pre-manipulation	No-MHI	8.50 (2.92)	9.55 (3.31)
	MHI with Altered State of Consciousness	5.93 (2.10)	5.42 (2.79)
	MHI with Loss of Consciousness	6.19 (2.28)	6.00 (4.38)
Post-manipulation	No-MHI	14.42 (4.64)	12.39 (5.61)
	MHI with Altered State of Consciousness	12.16 (4.12)	10.03 (6.23)
	MHI with Loss of Consciousness	10.56 (3.23)	10.42 (4.33)
			Standard Error
Marginal Means	No-MHI	11.21	.48
	MHI with Altered State of Consciousness	8.38	.50
	MHI with Loss of Consciousness	8.29	.82
	Stress	9.63	.49
	Relaxation	8.97	.52
	Pre-manipulation	6.93	.34
	Post-manipulation	11.66	.59

Table C225

3 (MHI History Severity: No-MHI, MHI with Altered State of Consciousness, MHI with Loss of Consciousness) X 2 (Arousal Manipulation Condition: Stress, Relaxation) X 2 (Time: Pre-manipulation, Post-manipulation) for Electrodermal Activity Frequency

Source	*df*	*F*	*p*	*ηp2*
		Between Subjects		
MHI Severity	2	9.83	< .001*	.188
Condition	1	.85	.358	.010
MHI Severity X Condition	2	.26	.769	.006
Error	85			
		Within Subjects		
Time	1	52.08	< .001*	.380
Time X MHI Severity	2	.38	.686	.009
Time X Condition	1	1.40	.241	.016
Time X MHI Severity X Condition	2	.44	.646	.010
Error	85			

Table C226

Means, Standard Deviations, and Marginal Means for Respiration Frequency by MHI History Severity and Arousal Manipulation Condition across Time

		Stress	Relaxation
Pre-manipulation	No-MHI	14.86 (6.13)	16.30 (5.84)
	MHI with Altered State of Consciousness	16.17 (4.47)	16.72 (3.03)
	MHI with Loss of Consciousness	16.50 (4.10)	15.67 (3.08)
Post-manipulation	No-MHI	20.78 (6.13)	16.70 (4.25)
	MHI with Altered State of Consciousness	19.92 (6.45)	16.08 (5.63)
	MHI with Loss of Consciousness	21.75 (6.84)	19.17 (9.55)
			Standard Error
Marginal Means	No-MHI	17.16	.73
	MHI with Altered State of Consciousness	17.22	.75
	MHI with Loss of Consciousness	18.27	1.23
	Stress	18.33	.74
	Relaxation	16.77	.79
	Pre-manipulation	16.04	.58
	Post-manipulation	19.07	.71

Table C227

3 (MHI History Severity: No-MHI, MHI with Altered State of Consciousness, MHI with Loss of Consciousness) X 2 (Arousal Manipulation Condition: Stress, Relaxation) X 2 (Time: Pre-manipulation, Post-manipulation) for Respiration Frequency

Source	*df*	*F*	*p*	*ηp2*
		Between Subjects		
MHI Severity	2	.33	.722	.008
Condition	1	2.09	.152	.024
MHI Severity X Condition	2	.02	.984	.001
Error	85			
		Within Subjects		
Time	1	17.72	< .001*	.172
Time X MHI Severity	2	1.28	.284	.029
Time X Condition	1	7.27	.008*	.079
Time X MHI Severity X Condition	2	.48	.618	.011
Error	85			

Note. Greenhouse-Geisser correction used.

Table C228

Means, Standard Deviations, and Marginal Means for State Anxiety by Arousal Manipulation Condition and MHI History Severity

MHI History Severity	*Condition*		*Marginal Means*
	Stress	Relaxation	
No-MHI	37.17 (10.67)	33.55 (7.39)	35.36 (*SE* = 1.31)
MHI with Altered State of Consciousness	33.26 (8.94)	32.17 (6.39)	32.72 (*SE* = 1.36)
MHI with Loss of Consciousness	35.88 (8.20)	26.33 (4.89)	31.10 (*SE* = 2.23)
Marginal Means	35.44 (*SE* = 1.33)	30.68 (*SE* = 1.43)	

Table C229

3 (MHI History Severity: No-MHI, MHI with Altered State of Consciousness, MHI with Loss of Consciousness) X 2 (Arousal Manipulation Condition: Stress, Relaxation) for State Anxiety

Source	*df*	*F*	*p*	*ηp2*
	Between Subjects			
MHI History Severity	2	1.73	.183	.039
Condition	1	5.94	.017*	.065
MHI History Severity X Condition	2	1.31	.276	.030
Error	85			

Post-hoc Analysis of Response to Arousal Manipulation across time as a function of MHI History Severity

Table C230

Means and Standard Deviations for MHI History Severity and Arousal Manipulation Condition on Self-reported Arousal State across Time

Time	*MHI History Severity*	*Arousal Condition*	*Mean*	*Time*	*MHI History Severity*	*Arousal Condition*	*Mean*
After manipulation	No-MHI	Relaxation	1.77 (.92)	*After Neuropsychological Testing*	No-MHI	Relaxation	3.59 (1.62)
		Stress	6.28 (1.93)			Stress	4.22 (1.06)
	MHI with altered state of consciousness	Relaxation	1.78 (.94)		MHI with altered state of consciousness	Relaxation	3.17 (1.15)
		Stress	5.79 (2.04)			Stress	3.05 (1.27)
	MHI with loss of consciousness	Relaxation	1.33 (.52)		MHI with loss of consciousness	Relaxation	2.00 (.89)
		Stress	6.13 (.99)			Stress	3.05 (1.27)
During Neuropsychological Testing	No-MHI	Relaxation	2.81 (1.33)	*Final*	No-MHI	Relaxation	3.14 (1.32)
		Stress	4.94 (1.70)			Stress	3.28 (.96)
	MHI with altered state of consciousness	Relaxation	3.22 (1.35)		MHI with altered state of consciousness	Relaxation	2.72 (1.07)
		Stress	3.63 (1.42)			Stress	2.68 (1.20)
	MHI with loss of consciousness	Relaxation	2.00 (.63)		MHI with loss of consciousness	Relaxation	2.33 (1.51)
		Stress	4.63 (1.92)			Stress	2.88 (.99)

Note. Values in parentheses are standard deviation.

Table C231

Marginal Means for MHI History Severity and Arousal Manipulation Condition on Self-reported Arousal State across Time

	Marginal Means
No-MHI	3.76 (.18)
MHI with altered state of consciousness	3.26 (.18)
MHI with loss of consciousness	3.21 (.30)
Relaxation	2.45 (.19)
Stress	4.32 (.18)
After Manipulation	3.85 (.17)
During Neuropsychological Testing	3.54 (.17)
After Neuropsychological Testing	3.40 (.16)
Final	2.84 (.14)

Note. Values in parentheses are standard error.

Table C232

Mixed Model Analysis of Variance for Self-reported Arousal across Time by MHI History Severity and Arousal Manipulation Condition

Source	*df*	*F*	*p*	*ηp2*
		Between Subjects		
MHI History Severity	2	2.34	.103	.052
Condition	1	48.29	< .001*	.362
MHI History Severity X Condition	2	2.61	.080	.058
Error	85			
		Within Subjects		
Time	3	15.11	<. 001*	.151
Time x MHI History Severity	6	.64	.667	.015
Time x Condition	3	71.87	< .001*	.458
Time x MHI History Severity x Condition	6	2.25	.051*	.050
Error	255			

Note. Greenhouse-Geisser correction used.

Table C233

Pairwise Comparisons of Self-reported Arousal State across Time

Comparison of Self-Report of Arousal State		*Mean Difference*	*Standard Error*	*p*	*95% Confidence Interval*	
					Lower Bound	*Upper Bound*
After manipulation to	During Neuropsychological Testing	.31	.15	.049*	.01	.61
	After Neuropsychological Testing	.45	.18	.015*	.09	.80
	Final	1.01	.18	< .001*	.66	1.36
During Neuropsychological Testing to	After Neuropsychological Testing	-.14	.12	.267	-.11	.39
	Final	.70	.16	< .001*	.39	1.01
After Neuropsychological Testing to	Final	.56	.12	< .001*	.32	.81

Table C234

Means and Standard Deviations of Self-reported Arousal State across Time for Relaxation Condition

Time	*Mean*	*Standard Deviation*
After manipulation	1.72	.89
During Neuropsychological Testing	2.87	1.31
After Neuropsychological Testing	3.22	1.44
Final	2.87	1.26

Table C235

Repeated Measures Analysis for Self-reported Arousal State across Time for Relaxation Condition

Source	*df*	*F*	*p*	*ηp2*
		Within Subjects		
Time	3	31.31	< .001	.410
Error	135			

Note. Greenhouse-Geisser correction used.

Table C236

Pairwise Comparisons for Self-reported Arousal State across Time for Relaxation Condition

Comparison of Self-Report of Arousal State		*Mean Difference*	*Standard Error*	*p*	*95% Confidence Interval*	
					Lower Bound	*Upper Bound*
After manipulation to	During Neuropsychological Testing	-1.15	.15	< .001*	-1.46	-.85
	After Neuropsychological Testing	-1.50	.18	< .001*	-1.86	-1.14
	Final	-1.15	.16	< .001*	-1.48	-.83
During Neuropsychological Testing to	After Neuropsychological Testing	-.35	.16	.034*	.023	.67
	Final	.01	.20	1.00	-.40	.40
After Neuropsychological Testing to	Final	.35	.14	.017*	.07	.63

Table C237

Means and Standard Deviations for Stress Condition on Self-reported Arousal State across Time

Time	*Mean*	*Standard Deviation*
After manipulation	6.04	1.83
During Neuropsychological Testing	4.33	1.71
After Neuropsychological Testing	3.76	1.49
Final	2.96	1.09

Table C238

Repeated Measures Analysis for Self-reported Arousal across Time for Stress Condition

Source	*df*	*F*	*p*	*ηp2*
		Within Subjects		
Time	3	69.91	< .001*	.614
Error	132			

Note. Greenhouse-Geisser correction used.

Table C239

Pairwise Comparisons for Stress Condition for Self-reported Arousal State across Time

Comparison of Self-Report of Arousal State		*Mean Difference*	*Standard Error*	*p*	*95% Confidence Interval*	
					Lower Bound	*Upper Bound*
After manipulation to	During Neuropsychological Testing	1.71	.23	< .001*	1.25	2.18
	After Neuropsychological Testing	2.29	.27	< .001	1.74	2.84
	Final	3.09	.27	< .001*	2.55	3.62
During Neuropsychological Testing to	After Neuropsychological Testing	.58	.16	.001*	.25	.90
	Final	1.38	.20	< .001	.97	1.78
After Neuropsychological Testing to	Final	.80	.18	< .001	.45	1.15

Table C240

Means and Standard Deviations of Self-reported Arousal State across Time for No-MHI Group

Time		*Mean*	*Standard Deviation*
After manipulation	Relaxation	1.77	.92
	Stress	6.28	1.93
During Neuropsychological Testing	Relaxation	2.82	1.33
	Stress	4.94	1.70
After Neuropsychological Testing	Relaxation	3.59	1.62
	Stress	4.22	1.06
Final	Relaxation	3.14	1.32
	Stress	3.28	.96

Table C241

Repeated Measures Analysis for Self-reported Arousal State across Time for No-MHI Group

Source	*df*	*F*	*p*	*ηp2*
		Between Subjects		
Condition	1	26.23	< .001*	.408
Error	38			
		Within Subjects		
Time	3	6.35	.001*	.143
Time X Condition	3	44.39	< .001*	
Error	114			

Table C242

Pairwise Comparisons for Self-reported Arousal State across Time for No-MHI Group

Comparison of Self-Report of Arousal State		*Mean Difference*	*Standard Error*	*p*	*95% Confidence Interval*	
					Lower Bound	*Upper Bound*
After manipulation to	During Neuropsychological Testing	.14	.20	.472	-.26	.55
	After Neuropsychological Testing	.12	.24	.62	-.37	.60
	Final	.82	.24	.001*	.34	1.29
During Neuropsychological Testing to	After Neuropsychological Testing	-.03	.19	.892	-.40	.35
	Final	.67	.21	.003*	.25	1.10
After Neuropsychological Testing to	Final	.70	.17	< .001*	.35	1.05

Table C243

Means and Standard Deviations of Self-reported Arousal State across Time for MHI-with-altered-state-of-consciousness Group

Time		*Mean*	*Standard Deviation*
After manipulation	Relaxation	1.78	.94
	Stress	5.79	2.04
During Neuropsychological Testing	Relaxation	3.22	1.35
	Stress	3.63	1.42
After Neuropsychological Testing	Relaxation	3.17	1.15
	Stress	3.05	1.27
Final	Relaxation	2.72	1.07
	Stress	2.68	1.20

Table C244

Repeated Measures Analysis for Self-reported Arousal State across Time for MHI-with-altered-state-of-consciousness Group

Source	*df*	*F*	*p*	*ηp2*
	Between Subjects			
Condition	1	9.12	.005*	.207
Error	35			
	Within Subjects			
Time	3	8.79	< .001*	.201
Time X Condition	3	40.60	< .001*	.537
Error	105			

Note. Greenhouse-Geisser correction used.

Table C245

Pairwise Comparisons for Self-reported Arousal State across Time for MHI-with-altered-state-of-consciousness Group

Comparison of Self-Report of Arousal State		*Mean Difference*	*Standard Error*	*p*	*95% Confidence Interval*	
					Lower Bound	*Upper Bound*
After manipulation to	During Neuropsychological Testing	.36	.23	.126	-.11	.82
	After Neuropsychological Testing	.67	.26	.015*	.14	1.21
	Final	1.02	.28	< .001*	.51	1.65
During Neuropsychological Testing to	After Neuropsychological Testing	.32	.17	.071	-.03	.66
	Final	.72	.21	.001*	.30	1.14
After Neuropsychological Testing to	Final	.41	.13	.004*	-.68	-.14

Table C246

Means and Standard Deviations of Self-reported Arousal State across Time for MHI-with-loss-of-consciousness Group

Time		*Mean*	*Standard Deviation*
After manipulation	Relaxation	1.33	.52
	Stress	6.13	.99
During Neuropsychological Testing	Relaxation	2.00	.63
	Stress	4.63	1.92
After Neuropsychological Testing	Relaxation	2.00	.89
	Stress	4.38	2.20
Final	Relaxation	2.33	1.51
	Stress	2.88	.99

Table C247

Repeated Measures Analysis for Self-reported Arousal State across Time for MHI-with-loss-of-consciousness Group

Source	*df*	*F*	*p*	*ηp2*
	Between Subjects			
Condition	1	16.31	.002*	.576
Error	12			
	Within Subjects			
Time	3	4.29	.011*	.263
Time X Condition	3	15.06	< .001*	.557
Error	36			

Note. Greenhouse-Geisser correction used.

Table C248

Pairwise Comparisons for Self-reported Arousal State across Time for MHI-with-loss-of-consciousness Group

Comparison of Self-Report of Arousal State		*Mean Difference*	*Standard Error*	*p*	*95% Confidence Interval*	
					Lower Bound	*Upper Bound*
After manipulation to	During Neuropsychological Testing	.42	.33	.223	-.29	1.12
	After Neuropsychological Testing	.54	.36	.154	-.23	1.32
	Final	1.13	.21	< .001*	.66	1.59
During Neuropsychological Testing to	After Neuropsychological Testing	.13	.18	.507	-.27	.52
	Final	.71	.39	.093	-.14	1.56
After Neuropsychological Testing to	Final	.58	.38	.147	-.24	1.40

Table C249

Means and Standard Deviations for MHI History Severity and Arousal Manipulation Condition on Electrodermal Activity Frequency across Time

Time	*MHI History Severity*	*Arousal Condition*	*Mean*		*Arousal Condition*	*Mean*
After manipulation	No-MHI	Relaxation	12.39 (5.61)	*After Neuropsychological Testing* No-MHI	Relaxation	10.77 (3.32)
		Stress	14.12 (4.64)		Stress	12.28 (4.73)
	MHI with altered state of consciousness	Relaxation	10.03 (6.23)	MHI with altered state of consciousness	Relaxation	9.56 (3.68)
		Stress	12.16 (4.12)		Stress	8.92 (3.54)
	MHI with loss of consciousness	Relaxation	10.42 (4.33)	MHI with loss of consciousness	Relaxation	7.67 (4.79)
		Stress	10.56 (3.23)		Stress	8.81 (2.42)
During Neuropsychological Testing	No-MHI	Relaxation	9.39 (2.37)	*Final* No-MHI	Relaxation	10.77 (3.90)
		Stress	13.06 (3.01)		Stress	10.36 (2.50)
	MHI with altered state of consciousness	Relaxation	8.53 (3.26)	MHI with altered state of consciousness	Relaxation	8.08 (3.81)
		Stress	9.18 (3.01)		Stress	8.42 (3.07)
	MHI with loss of consciousness	Relaxation	9.75 (3.91)	MHI with loss of consciousness	Relaxation	7.00 (4.11)
		Stress	8.69 (3.14)		Stress	7.50 (1.83)

Note. Values in parentheses are standard deviation.

Table C250

Marginal Means for MHI History Severity and Arousal Manipulation Condition on Electrodermal Activity Frequency across Time

	Marginal Means	
No-MHI	11.68	(.42)
MHI with altered state of consciousness	9.36	(.43)
MHI with loss of consciousness	8.80	(.71)
Relaxation	9.53	(.45)
Stress	10.36	(.42)
After Manipulation	11.66	(.59)
During Neuropsychological Testing	9.77	(.35)
After Neuropsychological Testing	9.67	(.45)
Final	8.69	(.39)

Note. Values in parentheses are standard error.

Table C251

Mixed Model Analysis of Variance for Electrodermal Activity Frequency across Time by MHI History Severity and Arousal Manipulation Condition

Source	*df*	*F*	*p*	*ηp2*
		Between Subjects		
MHI History Severity	2	10.19	< .001*	.193
Condition	1	1.84	.179	.021
MHI History Severity X Condition	2	.62	.542	.014
Error	85			
		Within Subjects		
Time	3	10.19	< .001*	.107
Time x MHI History Severity	6	.21	.962	.005
Time x Condition	3	.51	.650	.006
Time x MHI History Severity x Condition	6	1.20	.308	.028
Error	255			

Note. Greenhouse-Geisser correction used.

Table C252

Pairwise Comparisons of Electrodermal Activity Frequency across Time

Comparison of Electrodermal Activity Frequency		*Mean Difference*	*Standard Error*	*p*	*95% Confidence Interval*	
					Lower Bound	*Upper Bound*
After manipulation to	During Neuropsychological Testing	1.90	.62	.003*	.66	3.13
	After Neuropsychological Testing	1.99	.62	.002*	.77	3.22
	Final	2.97	.62	< .001*	1.74	4.20
During Neuropsychological Testing to	After Neuropsychological Testing	.10	.51	.848	-.91	1.10
	Final	1.08	.45	.018*	.19	1.96
After Neuropsychological Testing to	Final	.98	.47	.039*	.05	1.91

Table C253

Multiple Comparisons of Electrodermal Activity Frequency between MHI History Severity Groups

MHI History Severity		*Mean Difference*	*Standard Error*	*p*	*95% Confidence Interval*	
					Lower Bound	*Upper Bound*
No-MHI	MHI with altered state of consciousness	2.23	.60	< .001*	1.04	3.41
	MHI with loss of consciousness	2.78	.81	.001*	1.17	4.39
MHI with altered state of consciousness	MHI with loss of consciousness	.56	.82	.499	-1.07	2.18

Table C254

Means and Standard Deviations for MHI History Severity and Arousal Manipulation Condition on Electrodermal Activity Amplitude across Time

Time	*MHI History Severity*	*Arousal Condition*	*Mean*	*Time*	*MHI History Severity*	*Arousal Condition*	*Mean*
After manipulation	No-MHI	Relaxation	.53 (.27)	*After Neuropsychological Testing*	No-MHI	Relaxation	.74 (.34)
		Stress	1.64 (.63)			Stress	1.11 (.43)
	MHI with altered state of consciousness	Relaxation	.38 (.28)		MHI with altered state of consciousness	Relaxation	.51 (.28)
		Stress	.81 (.26)			Stress	.50 (.20)
	MHI with loss of consciousness	Relaxation	.40 (.24)		MHI with loss of consciousness	Relaxation	.47 (.08)
		Stress	.68 (.46)			Stress	.43 (.35)
During Neuropsychological Testing	No-MHI	Relaxation	.69 (.38)	*Final*	No-MHI	Relaxation	.77 (.23)
		Stress	1.20 (.45)			Stress	.90 (.38)
	MHI with altered state of consciousness	Relaxation	.43 (.24)		MHI with altered state of consciousness	Relaxation	.50 (.30)
		Stress	.61 (.23)			Stress	.46 (.26)
	MHI with loss of consciousness	Relaxation	.42 (.16)		MHI with loss of consciousness	Relaxation	.49 (.17)
		Stress	.54 (.40)			Stress	.30 (.15)

Note. Values in parentheses are standard deviation.

Table C255

Marginal Means for MHI History Severity and Arousal Manipulation Condition on Electrodermal Activity Amplitude across Time

	Marginal Means	
No-MHI	.95	(.04)
MHI with altered state of consciousness	.53	(.04)
MHI with loss of consciousness	.47	(.07)
Relaxation	.53	(.05)
Stress	.77	(.04)
After Manipulation	.74	(.05)
During Neuropsychological Testing	.65	(.04)
After Neuropsychological Testing	.63	(.04)
Final	.57	(.03)

Note. Values in parentheses are standard error.

Table C256

Mixed Model Analysis of Variance for Electrodermal Activity Amplitude across Time by MHI History Severity and Arousal Manipulation Condition

Source	*df*	*F*	*p*	*ηp2*
		Between Subjects		
MHI History Severity	2	30.94	< .001*	.421
Condition	1	14.98	< .001*	.150
MHI History Severity X Condition	2	7.18	.001*	.145
Error	85			
		Within Subjects		
Time	3	6.54	.001*	.071
Time x MHI History Severity	6	.63	.707	.015
Time x Condition	3	25.12	< .001*	.228
Time x MHI History Severity x Condition	6	2.57	.020*	.057
Error	255			

Note. Greenhouse-Geisser correction used.

Table C257

Pairwise Comparisons of Electrodermal Activity Amplitude across Time

Comparison of Electrodermal Activity Amplitude		*Mean Difference*	*Standard Error*	*p*	*95% Confidence Interval*	
					Lower Bound	*Upper Bound*
After manipulation to	During Neuropsychological Testing	.09	.03	.005*	.03	.15
	After Neuropsychological Testing	.11	.05	.016*	.02	.21
	Final	.17	.04	< .001*	.09	.225
During Neuropsychological Testing to	After Neuropsychological Testing	.02	.04	.597	-.06	.11
	Final	.08	.04	.031*	.01	.15
After Neuropsychological Testing to	Final	.06	.03	.113	-.01	.12

Table C258

Multiple Comparisons of Electrodermal Activity Amplitude between MHI History Severity Groups

MHI History Severity		*Mean Difference*	*Standard Error*	*p*	*95% Confidence Interval*	
					Lower Bound	*Upper Bound*
No-MHI	MHI with altered state of consciousness	.39	.06	< .001*	.27	.51
	MHI with loss of consciousness	.45	.08	< .001*	.29	.61
MHI with altered state of consciousness	MHI with loss of consciousness	.06	.08	.495	-.11	.22

Table C259

Means and Standard Deviations of EDA Amplitude across Time for Relaxation Condition

Time	*Mean*	*Standard Deviation*
After manipulation	.45	.27
During Neuropsychological Testing	.55	.33
After Neuropsychological Testing	.61	.32
Final	.63	.28

Table C260

Repeated Measures Analysis for EDA Amplitude across Time for Relaxation Condition

Source	*df*	*F*	*p*	*ηp2*
		Within Subjects		
Time	3	5.70	.002*	.112
Error	135			

Note. Greenhouse-Geisser correction used.

Table C261

Pairwise Comparisons for EDA Amplitude across Time for Relaxation Condition

Comparison of EDA Amplitude		*Mean Difference*	*Standard Error*	*p*	*95% Confidence Interval*	
					Lower Bound	*Upper Bound*
After manipulation to	During Neuropsychological Testing	-.10	.04	.009*	-.17	-.03
	After Neuropsychological Testing	-.16	.05	.003*	-.27	-.06
	Final	-.18	.05	.001*	-.28	-.08
During Neuropsychological Testing to	After Neuropsychological Testing	-.06	.05	.252	-.17	.05
	Final	-.058	.05	.114	-.18	.02
After Neuropsychological Testing to	Final	-.02	.04	.734	-.10	.07

Table C262

Means and Standard Deviations for Stress Condition on EDA Amplitude across Time

Time	*Mean*	*Standard Deviation*
After manipulation	1.12	.63
During Neuropsychological Testing	.84	.47
After Neuropsychological Testing	.73	.45
Final	.61	.38

Table C263

Repeated Measures Analysis for EDA Amplitude across Time for Stress Condition

Source	*df*	*F*	*p*	*ηp2*
		Within Subjects		
Time	3	35.59	< .001*	.447
Error	132			

Note. Greenhouse-Geisser correction used.

Table C264

Pairwise Comparisons for Stress Condition for EDA Amplitude across Time

Comparison of EDA Amplitude		*Mean Difference*	*Standard Error*	*p*	*95% Confidence Interval*	
					Lower Bound	*Upper Bound*
After manipulation to	During Neuropsychological Testing	.28	.05	< .001*	.19	.38
	After Neuropsychological Testing	.39	.07	< .001*	.26	.52
	Final	.51	.06	< .001*	.39	.64
During Neuropsychological Testing to	After Neuropsychological Testing	.11	.05	.036*	.01	.20
	Final	.23	.04	< .001*	.15	.31
After Neuropsychological Testing to	Final	.12	.04	.008*	.03	.21

Table C265

Means and Standard Deviations of EDA Amplitude across Time for No-MHI Group

Time		*Mean*	*Standard Deviation*
After manipulation	Relaxation	.53	.27
	Stress	1.64	.63
During Neuropsychological Testing	Relaxation	.69	.38
	Stress	1.20	.45
After Neuropsychological Testing	Relaxation	.74	.34
	Stress	1.11	.43
Final	Relaxation	.77	.23
	Stress	.90	.38

Table C266

Repeated Measures Analysis for EDA Amplitude across Time for No-MHI Group

Source	*df*	*F*	*p*	*ηp2*
		Between Subjects		
Condition	1	26.22	< .001*	.408
Error	38			
		Within Subjects		
Time	3	6.46	.001*	.145
Time X Condition	3	26.46	< .001	.410
Error	114			

Note. Greenhouse-Geisser correction used.

Table C267

Pairwise Comparisons for EDA Amplitude across Time for No-MHI Group

Comparison of EDA Amplitude		*Mean Difference*	*Standard Error*	*p*	*95% Confidence Interval*	
					Lower Bound	*Upper Bound*
After manipulation to	During Neuropsychological Testing	.14	.05	.009*	.04	.24
	After Neuropsychological Testing	.16	.07	.031*	.02	.31
	Final	.25	.06	< .001*	.14	.36
During Neuropsychological Testing to	After Neuropsychological Testing	.02	.07	.730	-.11	.15
	Final	.11	.05	.029*	.01	.21
After Neuropsychological Testing to	Final	.09	.05	.087	-.14	.19

Table C268

Means and Standard Deviations of EDA Amplitude across Time for MHI-with-altered-state-of-consciousness Group

Time		*Mean*	*Standard Deviation*
After manipulation	Relaxation	.38	.28
	Stress	.81	.26
During Neuropsychological Testing	Relaxation	.43	.24
	Stress	.61	.23
After Neuropsychological Testing	Relaxation	.51	.28
	Stress	.50	.20
Final	Relaxation	.50	.30
	Stress	.46	.26

Table C269

Repeated Measures Analysis for EDA Amplitude across Time for MHI-with-altered-state-of-consciousness Group

Source	*df*	*F*	*p*	*ηp2*
	Between Subjects			
Condition	1	5.02	.031*	.126
Error	35			
	Within Subjects			
Time	3	2.13	.122	.057
Time X Condition	3	10.94	< .001*	.149
Error	105			

Note. Greenhouse-Geisser correction used.

Table C270

Pairwise Comparisons for EDA Amplitude across Time for MHI-with-altered-state-of-consciousness Group

Comparison of EDA Amplitude		*Mean Difference*	*Standard Error*	*p*	*95% Confidence Interval*	
					Lower Bound	*Upper Bound*
After manipulation to	During Neuropsychological Testing	.07	.04	.046*	.01	.14
	After Neuropsychological Testing	.09	.05	.085	-.01	.19
	Final	.11	.06	.07	-.01	.23
During Neuropsychological Testing to	After Neuropsychological Testing	.02	.04	.696	-.07	.10
	Final	.04	.05	.444	-.06	.14
After Neuropsychological Testing to	Final	.02	.04	.581	-.06	.10

Table C271

Means and Standard Deviations of EDA Amplitude across Time for MHI-with-loss-of-consciousness Group

Time		*Mean*	*Standard Deviation*
After manipulation	Relaxation	.40	.24
	Stress	.68	.46
During Neuropsychological Testing	Relaxation	.42	.16
	Stress	.54	.40
After Neuropsychological Testing	Relaxation	.47	.08
	Stress	.43	.35
Final	Relaxation	.49	.17
	Stress	.30	.15

Table C272

Repeated Measures Analysis for EDA Amplitude across Time for MHI-with-loss-of-consciousness Group

Source	*df*	*F*	*p*	*ηp2*
	Between Subjects			
Condition	1	.17	.690	.167
Error	12			
	Within Subjects			
Time	3	.83	.451	.065
Time X Condition	3	2.25	.126	.158
Error	36			

Note. Greenhouse-Geisser correction used.

Table C273

Pairwise Comparisons for EDA Amplitude across Time for MHI-with-loss-of-consciousness Group

Comparison of EDA Amplitude		*Mean Difference*	*Standard Error*	*p*	*95% Confidence Interval*	
					Lower Bound	*Upper Bound*
After manipulation to	During Neuropsychological Testing	.06	.06	.305	-.07	.19
	After Neuropsychological Testing	.09	.11	.416	-.15	.33
	Final	.15	.10	.164	-.07	.36
During Neuropsychological Testing to	After Neuropsychological Testing	.03	.12	.815	-.23	.29
	Final	.08	.08	.294	-.08	.25
After Neuropsychological Testing to	Final	.06	.09	.569	-.45	.26

Table C274

Means and Standard Deviations for MHI History Severity and Arousal Manipulation Condition on Heart Rate Frequency across Time

Time	*MHI History Severity*	*Arousal Condition*	*Mean*	*Time*	*MHI History Severity*	*Arousal Condition*	*Mean*
After manipulation	No-MHI	Relaxation	69.61 (7.15)	*After Neuropsychological Testing*	No-MHI	Relaxation	70.14 (7.66)
		Stress	76.31 (8.78)			Stress	74.22 (8.17)
	MHI with altered state of consciousness	Relaxation	71.28 (8.58)		MHI with altered state of consciousness	Relaxation	70.69 (7.66)
		Stress	73.21 (6.54)			Stress	71.11 (8.12)
	MHI with loss of consciousness	Relaxation	70.75 (7.20)		MHI with loss of consciousness	Relaxation	67.75 (7.83)
		Stress	65.56 (9.98)			Stress	65.19 (9.25)
During Neuropsychological Testing	No-MHI	Relaxation	69.16 (8.27)	*Final*	No-MHI	Relaxation	69.84 (6.78)
		Stress	75.39 (7.00)			Stress	72.08 (8.75)
	MHI with altered state of consciousness	Relaxation	70.94 (9.14)		MHI with altered state of consciousness	Relaxation	71.25 (9.04)
		Stress	72.76 (9.56)			Stress	70.16 (9.04)
	MHI with loss of consciousness	Relaxation	66.00 (7.52)		MHI with loss of consciousness	Relaxation	66.67 (8.80)
		Stress	64.94 (11.24)			Stress	64.44 (10.43)

Note. Values in parentheses are standard deviation.

Table C275

Marginal Means for MHI History Severity and Arousal Manipulation Condition on Heart Rate Frequency across Time

	Marginal Means	
No-MHI	72.09	(1.23)
MHI with altered state of consciousness	71.43	(1.27)
MHI with loss of consciousness	66.41	(2.09)
Relaxation	69.51	(1.33)
Stress	70.45	(1.24)
After Manipulation	71.12	(.94)
During Neuropsychological Testing	69.87	(1.03)
After Neuropsychological Testing	69.85	(.95)
Final	69.07	(1.01)

Note. Values in parentheses are standard error.

Table C276

Mixed Model Analysis of Variance for Heart Rate Frequency across Time by MHI History Severity and Arousal Manipulation Condition

Source	*df*	*F*	*p*	*ηp2*
		Between Subjects		
MHI History Severity	2	2.87	.062	.063
Condition	1	.27	.607	.003
MHI History Severity X Condition	2	1.43	.246	.032
Error	85			
		Within Subjects		
Time	3	3.98	.009*	.045
Time x MHI History Severity	6	.51	.799	.012
Time x Condition	3	1.73	.161	.020
Time x MHI History Severity x Condition	6	.98	.441	.022
Error	255			

Table C277

Pairwise Comparisons of Heart Rate Frequency across Time

Comparison of Electrodermal Activity Frequency		*Mean Difference*	*Standard Error*	*p*	*95% Confidence Interval*	
					Lower Bound	*Upper Bound*
After manipulation to	During Neuropsychological Testing	1.25	.63	.048*	.01	2.50
	After Neuropsychological Testing	1.27	.60	.037*	.08	2.46
	Final	2.05	.62	.001*	.82	3.27
During Neuropsychological Testing to	After Neuropsychological Testing	.02	.61	.979	-1.19	1.23
	Final	.79	.63	.212	-.46	2.05
After Neuropsychological Testing to	Final	.78	.52	.138	-.25	1.81

Table C278

Multiple Comparisons of Heart Rate Frequency between MHI History Severity Groups

MHI History Severity		*Mean Difference*	*Standard Error*	*p*	*95% Confidence Interval*	
					Lower Bound	*Upper Bound*
No-MHI	MHI with altered state of consciousness	.67	1.77	.706	-2.84	4.18
	MHI with loss of consciousness	5.68	2.42	.021*	.87	10.50
MHI with altered state of consciousness	MHI with loss of consciousness	5.01	2.44	.043*	.16	9.87

Table C279

Means and Standard Deviations for MHI History Severity and Arousal Manipulation Condition on Respiration Frequency across Time

Time	*MHI History Severity*	*Arousal Condition*	*Mean*	*Time*	*MHI History Severity*	*Arousal Condition*	*Mean*
After manipulation	No-MHI	Relaxation	16.70 (4.25)	*After Neuropsychological Testing*	No-MHI	Relaxation	19.64 (6.18)
		Stress	20.78 (6.13)			Stress	20.56 (7.72)
	MHI with altered state of consciousness	Relaxation	16.08 (5.63)		MHI with altered state of consciousness	Relaxation	14.44 (6.08)
		Stress	19.92 (6.45)			Stress	19.39 (5.56)
	MHI with loss of consciousness	Relaxation	19.17 (9.55)		MHI with loss of consciousness	Relaxation	17.58 (4.15)
		Stress	21.75 (6.84)			Stress	20.94 (8.00)
During Neuropsychological Testing	No-MHI	Relaxation	18.95 (7.40)	*Final*	No-MHI	Relaxation	19.32 (5.32)
		Stress	19.42 (4.79)			Stress	18.42 (4.68)
	MHI with altered state of consciousness	Relaxation	15.33 (5.59)		MHI with altered state of consciousness	Relaxation	16.89 (6.85)
		Stress	20.03 (8.00)			Stress	18.63 (6.34)
	MHI with loss of consciousness	Relaxation	16.67 (7.36)		MHI with loss of consciousness	Relaxation	20.33 (3.67)
		Stress	18.31 (4.58)			Stress	18.58 (5.24)

Note. Values in parentheses are standard deviation.

Table C280

Marginal Means for MHI History Severity and Arousal Manipulation Condition on Respiration Frequency across Time

	Marginal Means	
No-MHI	19.22	(.71)
MHI with altered state of consciousness	17.59	(.73)
MHI with loss of consciousness	19.20	(1.20)
Relaxation	17.59	(.77)
Stress	19.75	(.72)
After Manipulation	19.07	(.71)
During Neuropsychological Testing	18.12	(.77)
After Neuropsychological Testing	18.76	(.76)
Final	18.73	(.66)

Note. Values in parentheses are standard error.

Table C281

Mixed Model Analysis of Variance for Respiration Frequency across Time by MHI History Severity and Arousal Manipulation Condition

Source	*df*	*F*	*p*	*ηp2*
		Between Subjects		
MHI History Severity	2	1.46	.238	.033
Condition	1	4.22	.043*	.047
MHI History Severity X Condition	2	.92	.401	.021
Error	85			
		Within Subjects		
Time	3	.47	.679	.005
Time x MHI History Severity	6	.85	.522	.020
Time x Condition	3	2.04	.118	.023
Time x MHI History Severity x Condition	6	.48	.825	.011
Error	255			

Note. Greenhouse-Geisser correction used.

Post-hoc Analysis of Intelligence Capacity as a function of MHI History Severity

Table C282

Mean WAIS-III (1997) Scaled Vocabulary Score by Assigned Arousal Manipulation Condition and MHI History Severity

MHI History Severity	Assigned Arousal Manipulation Condition		Marginal Means
	Stress	Relaxation	
No-MHI	12.17 (1.89)	13.73 (2.55)	12.95 (*SE* = .38)
MHI with altered state of consciousness	13.21 (2.92)	13.89 (2.37)	13.55 (*SE* = .39)
MHI with loss of consciousness	13.75 (1.28)	13.83 (1.94)	13.79 (*SE* = .64)
Marginal Means	13.04 (*SE* = .38)	13.82 (*SE* = .41)	

Note. Values in parentheses are standard deviation; *SE* = standard error.

Table C283

A 3 (MHI History Severity: No-MHI, MHI with altered state of consciousness, MHI with loss of consciousness) X 2 (Assigned Arousal Manipulation Condition: Stress, Relaxation) ANOVA on WAIS-III (1997) Vocabulary Scaled Scores

Source	*df*	*F*	*p*	*ηp2*
		Between Subjects		
MHI History Severity	2	.94	.395	.022
Condition	1	1.92	.169	.022
MHI History Severity X Condition	2	.62	.541	.014
Error	85			

Table C284

Mean WAIS-III (1997) Scaled Block Design Score by Assigned Arousal Manipulation Condition and MHI History Severity

MHI History Severity	Assigned Arousal Manipulation Condition		Marginal Means
	Stress	Relaxation	
No-MHI	11.67 (2.59)	12.09 (2.84)	11.88 (*SE* = .44)
MHI with altered state of consciousness	11.95 (3.21)	12.44 (2.09)	12.20 (*SE* = .45)
MHI with loss of consciousness	10.50 (2.39)	13.00 (3.41)	11.75 (*SE* = .74)
Marginal Means	11.37 (*SE* = .44)	12.51 (*SE* = .47)	

Note. Values in parentheses are standard deviation; *SE* = standard error.

Table C285

A 3 (MHI History Severity: No-MHI, MHI with altered state of consciousness, MHI with loss of consciousness) X 2 (Assigned Arousal Manipulation Condition: Stress, Relaxation) ANOVA on WAIS-III (1997) Block Design Scaled Scores

Source	*df*	*F*	*p*	*ηp2*
		Between Subjects		
MHI History Severity	2	.19	.828	.004
Condition	1	3.10	.082	.035
MHI History Severity X Condition	2	.80	.451	.019
Error	85			

Post-hoc Examination of Hypothesis 3: Arousal, MHI, and Cognitive Performance

Baseline Cognitive Testing

Table C286

Means and Standard Deviations for MHI History Severity for Time (in seconds) to Complete the Colour-Word Interference Task—Switching (DKEFS, 2002) at Baseline

MHI History	Mean	Standard Deviation	Standard Error
No-MHI	48.69	7.67	1.46
MHI with altered state of consciousness	52.79	9.43	1.52
MHI with loss of consciousness	53.76	12.50	2.47

Note. Values in parentheses are standard deviation.

Table C287

One-way ANOVA of MHI History Severity (No-MHI, MHI with altered state of consciousness, MHI with loss of consciousness MHI, No-MHI) on Time (in seconds) to Complete Colour-Word Interference Task—Switching (DKEFS, 2002) at Baseline

Source	*df*	*F*	*p*	*ηp2*
		Between Subjects		
MHI History Severity	2	2.56	.083	.055
Error	88			

Table C288

Multiple Comparisons of Time for Completion for Colour-Word Naming Interference Task—Switching between MHI History Severity Group at Baseline

MHI History Severity		*Mean Difference*	*Standard Error*	*p*	*95% Confidence Interval*	
					Lower Bound	*Upper Bound*
No-MHI	MHI with altered state of consciousness	-4.10	2.11	.055	-8.30	.08
	MHI with loss of consciousness	-5.07	2.87	.081	-10.78	.64
MHI with altered state of consciousness	MHI with loss of consciousness	-.97	2.90	.739	-6.74	4.80

Table C289

Means and Standard Deviations for MHI History Severity Group on Timing of Colour-Word Interference Task—Colour Naming (DKEFS, 2002) at Baseline

MHI History	Mean	Standard Deviation	Standard Error
No-MHI	25.00	3.63	.64
MHI with altered state of consciousness	26.33	4.62	.67
MHI with loss of consciousness	27.28	3.86	1.09

Note. Values in parentheses are standard deviation.

Table C290

One-way ANOVA for MHI History Severity (No-MHI, MHI with altered state of consciousness, MHI with loss of consciousness) on Timing of Colour-Word Interference Task—Colour Naming (DKEFS, 2002) at Baseline

Source	*df*	*F*	*p*	*ηp2*
	Between Subjects			
MHI History Severity	2	1.94	.150	.042
Error	88			

Table C291

Means and Standard Deviations by Assigned Arousal Manipulation Condition and MHI History for Time to Complete Colour-Word Interference Task—Word Reading (DKEFS, 2002) at Baseline

MHI History	Mean	Standard Deviation	Standard Error
No-MHI	18.70	2.87	.47
MHI with altered state of consciousness	20.31	3.23	.49
MHI with loss of consciousness	19.82	2.44	.79

Note. Values in parentheses are standard deviation.

Table C292

One-way ANOVA for MHI History Severity (No-MHI, MHI with altered state of consciousness, MHI with loss of consciousness) on Time to Complete Colour-Word Interference Task—Word Reading (DKEFS, 2002) at Baseline

Source	*df*	*F*	*p*	*ηp2*
		Between Subjects		
MHI History Severity	2	2.92	.059	.062
Error	88			

Table C293

Multiple Comparisons of Time for Completion for Colour-Word Naming Interference Task—Word Reading between MHI History Severity Group at Baseline

MHI History Severity		*Mean Difference*	*Standard Error*	*p*	*95% Confidence Interval*	
					Lower Bound	*Upper Bound*
No-MHI	MHI with altered state of consciousness	-1.61	.68	.019*	-2.96	-.27
	MHI with loss of consciousness	-1.12	.92	.227	-2.95	.71
MHI with altered state of consciousness	MHI with loss of consciousness	.49	.93	.598	-1.36	2.34

Table C294

Means and Standard Deviations for MHI History Severity Group for Time to Complete Colour-Word Interference Task—Inhibition (DKEFS, 2002) at Baseline

MHI History Severity	Mean	Standard Deviation	Standard Error
No-MHI	43.14	7.52	1.26
MHI with altered state of consciousness	44.82	8.15	1.31
MHI with loss of consciousness	46.72	8.70	2.13

Note. Values in parentheses are standard deviation.

Table C295

One-way ANOVA for MHI History Severity Group on Time to Complete Colour-Word Interference Task—Inhibition (DKEFS, 2002) at Baseline

Source	*df*	*F*	*p*	*ηp2*
		Between Subjects		
MHI	2	1.15	.323	.025
Error	88			

Post-hoc Investigation of Cognitive Performance as a function of Arousal Manipulation Condition and MHI History Severity

Post-hoc Analysis of Pre-and-Post-Manipulation Comparisons of Cognitive Performance

Table C296

Means and Standard Deviations of Number of Symbols Correctly Completed on Digit Symbol-Copy (WAIS-III, 1997) by MHI History Severity and Arousal Manipulation Condition

Time	*MHI History Severity*	*Arousal Condition*	*Mean*	*Standard Deviation*
Pre-manipulation	No-MHI	Relaxation	91.86	15.75
		Stress	89.78	12.95
	MHI with altered state of consciousness	Relaxation	85.00	11.12
		Stress	84.84	17.23
	MHI with loss of consciousness	Relaxation	79.33	18.69
		Stress	90.50	10.82
Post-manipulation	No-MHI	Relaxation	100.50	16.68
		Stress	99.94	14.81
	MHI with altered state of consciousness	Relaxation	91.78	14.81
		Stress	92.32	18.94
	MHI with loss of consciousness	Relaxation	84.50	22.15
		Stress	98.88	8.08

Table C297

Marginal Means of Number of Symbols Correctly Completed on Digit Symbol-Copy (WAIS-III, 1997) by MHI History Severity and Arousal Manipulation Condition

		Marginal Mean	Standard Error
Marginal Means	No-MHI	95.52	2.38
	MHI with altered state of consciousness	88.48	2.46
	MHI with loss of consciousness	88.30	4.04
	Stress	92.71	2.41
	Relaxation	88.83	2.58
	Pre-manipulation	86.89	1.72
	Post-manipulation	94.65	1.93

Table C298

Mixed Model ANOVA for Digit Symbol-Copy (WAIS-III, 1997) Performance by MHI History Severity and Arousal Manipulation Condition across Repeated Testing

Source	*df*	*F*	*p*	*ηp2*
	Between Subjects			
MHI History Severity	2	2.50	.088	.056
Condition	1	1.21	.274	.014
MHI X Condition	2	1.19	.310	.027
Error	85			
	Within Subjects			
Time	1	66.58	< .001*	.439
Time x MHI History Severity	2	.97	.383	.022
Time x Condition	1	.91	.344	.011
Time x MHI History Severity x Condition	2	.12	.885	.003
Error	85			

Table C299

Multiple Comparisons of Number of Symbols Produced on the Digit Symbol-Copy Task (WAIS-III, 1997) for MHI History Severity Group

MHI History Severity		*Mean Difference*	*Standard Error*	*p*	*95% Confidence Interval*	
					Lower Bound	*Upper Bound*
No-MHI	MHI with altered state of consciousness	7.04	3.42	.043*	.24	13.83
	MHI with loss of consciousness	7.22	4.68	.127	-2.09	16.53
MHI with altered state of consciousness	MHI with loss of consciousness	.18	4.73	.969	-9.21	9.56

Table C300

Means and Standard Deviations of Colour-Word Naming Interference Task—Switching (DKEFS, 2002) by MHI History Severity and Arousal Manipulation Condition across Repeated Testing

Time	*MHI History Severity*	*Arousal Condition*	*Mean*	*Standard Deviation*
Pre-manipulation	No-MHI	Relaxation	47.61	7.91
		Stress	49.99	7.38
	MHI with altered state of consciousness	Relaxation	53.26	10.74
		Stress	52.34	8.27
	MHI with loss of consciousness	Relaxation	52.30	11.12
		Stress	54.85	14.10
Post-manipulation	No-MHI	Relaxation	43.62	8.53
		Stress	43.92	5.82
	MHI with altered state of consciousness	Relaxation	47.98	10.45
		Stress	47.12	6.88
	MHI with loss of consciousness	Relaxation	48.58	12.81
		Stress	45.32	8.99

Table C301

Marginal Means Colour-Word Naming Interference Task—Switching (DKEFS, 2002) by MHI History Severity and Arousal Manipulation Condition

		Marginal Mean	Standard Error
Marginal Means	No-MHI	46.29	1.33
	MHI with altered state of consciousness	50.17	1.38
	MHI with loss of consciousness	50.26	2.26
	Stress	48.92	1.35
	Relaxation	48.89	1.44
	Pre-manipulation	51.73	1.10
	Post-manipulation	46.09	1.01

Table C302

Mixed Model Analysis of Variance for Colour-Word Naming Interference Task—Switching (DKEFS, 2002) across Repeated Testing by MHI History and Arousal Manipulation Condition

Source	*df*	*F*	*p*	*ηp2*
	Between Subjects			
MHI History Severity	2	2.42	.095	.054
Condition	1	.01	.986	.001
MHI History Severity X Condition	2	.18	.839	.004
Error	85			
	Within Subjects			
Time	1	57.50	< .001*	.403
Time x MHI History Severity	2	.33	.718	.008
Time x Condition	1	3.09	.082	.035
Time x MHI History Severity x Condition	2	1.10	.336	.025
Error	85			

Table C303

Multiple Comparisons of Colour-Word Naming Interference Task—Switching (DKEFS, 2002) for MHI History Severity Group

MHI History Severity		*Mean Difference*	*Standard Error*	*p*	*95% Confidence Interval*	
					Lower Bound	*Upper Bound*
No-MHI	MHI with altered state of consciousness	-3.89	1.92	.046*	-7.70	-.08
	MHI with loss of consciousness	-3.98	2.63	.134	-9.20	1.25
MHI with altered state of consciousness	MHI with loss of consciousness	-.09	2.65	.974	-5.36	5.18

Table C304

Means and Standard Deviations of Colour-Word Naming Interference Task—Colour Naming (DKEFS, 2002) by MHI History Severity and Arousal Manipulation Condition across Repeated Testing

Time	*MHI History Severity*	*Arousal Condition*	*Mean*	*Standard Deviation*
Pre-manipulation	No-MHI	Relaxation	24.77	3.87
		Stress	25.31	3.40
	MHI with altered state of consciousness	Relaxation	26.06	4.28
		Stress	26.58	5.03
	MHI with loss of consciousness	Relaxation	26.27	3.02
		Stress	28.03	4.43
Post-manipulation	No-MHI	Relaxation	22.68	2.66
		Stress	23.97	3.13
	MHI with altered state of consciousness	Relaxation	24.72	4.03
		Stress	25.13	4.52
	MHI with loss of consciousness	Relaxation	25.10	4.03
		Stress	24.19	4.08

Table C305

Marginal Means Colour-Word Naming Interference Task—Colour Naming (DKEFS, 2002) by MHI History Severity and Arousal Manipulation Condition

		Marginal Mean	Standard Error
Marginal Means	No-MHI	24.18	.58
	MHI with altered state of consciousness	25.62	.60
	MHI with loss of consciousness	25.90	.99
	Stress	25.54	.59
	Relaxation	24.93	.63
	Pre-manipulation	26.17	.49
	Post-manipulation	24.30	.44

Table C306

Mixed Model Analysis of Variance for Colour-Word Naming Interference Task—Colour Naming (DKEFS, 2002) across Repeated Testing by MHI History and Arousal Manipulation Condition

Source	*df*	*F*	*p*	*ηp2*
	Between Subjects			
MHI History Severity	2	1.93	.151	.043
Condition	1	.49	.488	.006
MHI History Severity X Condition	2	.04	.958	.001
Error	85			
	Within Subjects			
Time	1	32.39	< .001*	.276
Time x MHI History Severity	2	.79	.456	.018
Time x Condition	1	1.07	.305	.012
Time x MHI History Severity x Condition	2	1.92	.153	.043
Error	85			

Table C307

Means and Standard Deviations of Colour-Word Naming Interference Task—Word Reading (DKEFS, 2002) by MHI History Severity and Arousal Manipulation Condition across Repeated Testing

Time	*MHI History Severity*	*Arousal Condition*	*Mean*	*Standard Deviation*
Pre-manipulation	No-MHI	Relaxation	18.10	2.85
		Stress	19.43	2.79
	MHI with altered state of consciousness	Relaxation	19.54	2.35
		Stress	21.04	3.81
	MHI with loss of consciousness	Relaxation	19.48	1.90
		Stress	20.08	2.88
Post-manipulation	No-MHI	Relaxation	17.89	2.67
		Stress	19.55	2.48
	MHI with altered state of consciousness	Relaxation	19.51	2.53
		Stress	20.39	3.48
	MHI with loss of consciousness	Relaxation	19.19	3.05
		Stress	19.17	2.95

Table C308

Marginal Means Colour-Word Naming Interference Task—Word Reading (DKEFS, 2002) by MHI History Severity and Arousal Manipulation Condition

		Marginal Mean	Standard Error
Marginal Means	No-MHI	18.75	.43
	MHI with altered state of consciousness	20.12	.45
	MHI with loss of consciousness	19.48	.73
	Stress	19.95	.44
	Relaxation	18.95	.47
	Pre-manipulation	19.61	.35
	Post-manipulation	19.28	.34

Table C309

Mixed Model Analysis of Variance for Colour-Word Naming Interference Task—Word Reading (DKEFS, 2002) across Repeated Testing by MHI History and Arousal Manipulation Condition

Source	*df*	*F*	*p*	*ηp2*
	Between Subjects			
MHI History Severity	2	2.48	.090	.055
Condition	1	2.42	.124	.028
MHI History Severity X Condition	2	.25	.778	.006
Error	85			
	Within Subjects			
Time	1	1.86	.176	.021
Time x MHI History Severity	2	.43	.656	.010
Time x Condition	1	.38	.542	.004
Time x MHI History Severity x Condition	2	.59	.555	.014
Error	85			

Table C310

Multiple Comparisons of Colour-Word Naming Interference Task—Word Reading (DKEFS, 2002) for MHI History Severity Group

MHI History Severity		*Mean Difference*	*Standard Error*	*p*	*95% Confidence Interval*	
					Lower Bound	*Upper Bound*
No-MHI	MHI with altered state of consciousness	-1.38	.62	.029*	-2.61	-.15
	MHI with loss of consciousness	-.74	.85	.388	-2.42	.95
MHI with altered state of consciousness	MHI with loss of consciousness	.64	.85	.456	-1.06	2.34

Table C311

Means and Standard Deviations of Colour-Word Naming Interference Task—Inhibition (DKEFS, 2002) by MHI History Severity and Arousal Manipulation Condition across Repeated Testing

Time	*MHI History Severity*	*Arousal Condition*	*Mean*	*Standard Deviation*
Pre-manipulation	No-MHI	Relaxation	42.56	7.62
		Stress	43.85	7.54
	MHI with altered state of consciousness	Relaxation	44.32	7.54
		Stress	45.30	8.87
	MHI with loss of consciousness	Relaxation	46.64	7.86
		Stress	46.78	9.82
Post-manipulation	No-MHI	Relaxation	38.68	7.16
		Stress	39.23	5.93
	MHI with altered state of consciousness	Relaxation	40.14	8.06
		Stress	41.32	7.15
	MHI with loss of consciousness	Relaxation	45.80	9.97
		Stress	44.00	8.88

Table C312

Marginal Means Colour-Word Naming Interference Task—Inhibition (DKEFS, 2002) by MHI History Severity and Arousal Manipulation Condition

		Marginal Mean	Standard Error
Marginal Means	No-MHI	41.08	1.17
	MHI with altered state of consciousness	42.77	1.21
	MHI with loss of consciousness	45.80	1.99
	Stress	43.41	1.18
	Relaxation	43.02	1.27
	Pre-manipulation	44.91	.95
	Post-manipulation	41.53	.88

Table C313

Mixed Model Analysis of Variance for Colour-Word Naming Interference Task—Inhibition (DKEFS, 2002) across Repeated Testing by MHI History and Arousal Manipulation Condition

Source	*df*	*F*	*p*	*ηp2*
	Between Subjects			
MHI History Severity	2	2.15	.123	.048
Condition	1	.05	.825	.001
MHI History Severity X Condition	2	.09	.913	.002
Error	85			
	Within Subjects			
Time	1	31.74	< .001*	.272
Time x MHI History Severity	2	1.26	.288	.029
Time x Condition	1	.48	.492	.006
Time x MHI History Severity x Condition	2	.24	.791	.005
Error	85			

Table C314

Multiple Comparisons of Colour-Word Naming Interference Task—Inhibition (DKEFS, 2002) for MHI History Severity Group

MHI History Severity		*Mean Difference*	*Standard Error*	*p*	*95% Confidence Interval*	
					Lower Bound	*Upper Bound*
No-MHI	MHI with altered state of consciousness	-1.69	1.68	.318	-5.04	1.66
	MHI with loss of consciousness	-4.73	2.31	.043*	-9.31	-.14
MHI with altered state of consciousness	MHI with loss of consciousness	-3.04	2.33	.195	-7.66	1.59

Post-hoc Analysis of Hypothesis 4: Post-concussive symptom reports between MHI History Severity groups

Table C315

Means and Standard Deviations for MHI History Severity for Total Score on Post-concussion Symptom Checklist (PCSC)

MHI History Severity	*Mean*	*Standard Deviation*
No-MHI	61.15	16.24
MHI with Altered State of Consciousness	70.86	18.83
MHI with Loss of Consciousness	65.07	11.53

Table C316

One-way ANOVA for MHI History Severity (No-MHI, MHI with Altered State of Consciousness, MHI with Loss of Consciousness) for Total Score on PCSC

Source	*df*	*F*	*p*	*ηp2*
	Between Subjects			
MHI History Severity	2	3.23	.044*	.068
Error	88			

Table C317

Pairwise Comparisons for MHI History Severity Groups for Total PCSC Score

Comparison of Total PCSC Score		*Mean Difference*	*Standard Error*	*p*	*95% Confidence Interval*	
					Lower Bound	*Upper Bound*
No-MHI	MHI with altered state of consciousness	-9.71	3.83	.013*	-17.32	-2.11
	MHI with loss of consciousness	-3.92	5.21	.454	-14.28	6.43
MHI with altered state of consciousness	MHI with loss of consciousness	5.79	5.27	.274	-4.67	16.26

Table C318

Means and Standard Deviations for MHI History Severity for Total Frequency Score on Post-concussion Symptom Checklist (PCSC)

MHI History Severity	*Mean*	*Standard Deviation*
No-MHI	19.33	4.91
MHI with Altered State of Consciousness	21.70	6.28
MHI with Loss of Consciousness	19.93	3.56

Table C319

One-way ANOVA for MHI History Severity (No-MHI, MHI with Altered State of Consciousness, MHI with Loss of Consciousness) for Total Frequency Score on PCSC

Source	*df*	*F*	*p*	*ηp2*
	Between Subjects			
MHI History Severity	2	1.95	.148	.043
Error	88			

Table C320

Means and Standard Deviations for MHI History Severity for Total Intensity Score on Post-concussion Symptom Checklist (PCSC)

MHI History Severity	*Mean*	*Standard Deviation*
No-MHI	19.20	5.62
MHI with Altered State of Consciousness	22.70	6.25
MHI with Loss of Consciousness	21.29	3.60

Table C321

One-way ANOVA for MHI History Severity (No-MHI, MHI with Altered State of Consciousness, MHI with Loss of Consciousness) for Total Intensity Score on PCSC

Source	*df*	*F*	*p*	*ηp2*
	Between Subjects			
MHI History Severity	2	3.72	.028*	.078
Error	88			

Table C322

Pairwise Comparisons for MHI History Severity Groups for Total PCSC Intensity Score

Comparison of Total PCSC Intensity Score		*Mean Difference*	*Standard Error*	*p*	*95% Confidence Interval*	
					Lower Bound	*Upper Bound*
No-MHI	MHI with altered state of consciousness	-3.50	1.29	.008*	-6.06	-.94
	MHI with loss of consciousness	-2.09	1.75	.238	-5.57	1.40
MHI with altered state of consciousness	MHI with loss of consciousness	1.42	1.77	.426	-2.11	4.94

Table C323

Means and Standard Deviations for MHI History Severity for Total Duration Score on Post-concussion Symptom Checklist (PCSC)

MHI History Severity	*Mean*	*Standard Deviation*
No-MHI	22.63	6.32
MHI with Altered State of Consciousness	26.46	7.25
MHI with Loss of Consciousness	23.86	5.27

Table C324

One-way ANOVA for MHI History Severity (No-MHI, MHI with Altered State of Consciousness, MHI with Loss of Consciousness) for Total Duration Score on PCSC

Source	*df*	*F*	*p*	*ηp2*
	Between Subjects			
MHI History Severity	2	3.32	.041*	.070
Error	88			

Table C325

Pairwise Comparisons for MHI History Severity Groups for Total PCSC Duration Score

Comparison of Total PCSC Duration Score		*Mean Difference*	*Standard Error*	*p*	*95% Confidence Interval*	
					Lower Bound	*Upper Bound*
No-MHI	MHI with altered state of consciousness	-3.83	1.50	.012*	-6.82	-.85
	MHI with loss of consciousness	-1.23	2.04	.548	-5.29	2.83
MHI with altered state of consciousness	MHI with loss of consciousness	2.60	2.06	.211	-1.50	6.70