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Detection of traumatic brain injury with the picture memory interference test in college students

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DETECTION OF TRAUMATIC BRAIN INJURY WITH THE PICTURE MEMORY INTERFERENCE TEST IN COLLEGE STUDENTS

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ABSTRACT

The purpose of this study was to examine potential effects of head-injury on individuals' performance on the Picture Memory Interference Test (PMIT). This study examined differences in the performance of college-aged students with and without a history of head-injury on the PMIT. Data was drawn from an archival dataset of PMIT completions held at UCLA and analyzed with permission. From the total dataset of 12,227 completions, experimental groups were derived and separated based upon assumed severity of head-injury, based upon self-report data. Following exclusions, the final data sub-set for analysis consisted of 6,897 unique completions of the PMIT. Of these, 412 were assigned to the Mild head-injury group; 61 individuals were assigned to the Moderate-Severe head-injury group. Multiple one-way ANCOVA were conducted to identify difference between group performances. The results of the current study are unclear as to whether or not the PMIT may effectively detect and discriminate college student participants with a history of head-injury from those without, although significant findings were obtained which demonstrated those with a history of mild head-injury obtained higher scores on particular trials of the PMIT.

Introduction

Neuropsychology is the study of brain-behavior relationships within the context of individual functioning. Clinical applications of neuropsychology involve the use of empirically validated assessment measures to determine the expression of brain dysfunction (Lezak, Howieson, Bigler, & Tranel, 2012). Specifically, neuropsychology is interested in determining the functional consequences of neurophysiological insult by measuring an individual's performance through a broad range of cognitive and psychological assessment measures. Comprehensive neuropsychological evaluations are used to evaluate the consequences of localized brain damage, and provide diagnostic clarification in the event of brain damage that cannot be sufficiently evaluated through neuroimaging or neurological evaluations (Lezak et al., 2012).

Neuropsychological evaluations assess cognitive domains including memory, language, visuospatial organization, processing speed, attention and concentration, and executive functions. Of particular importance is the ability of neuropsychological measures to assess the presence of cognitive dysfunction quickly, efficiently, accurately, and in a culturally unbiased format. The detection of cognitive inefficiencies as a result of traumatic brain injury presents a significant challenge for neuropsychologists given the wide array of cognitive, behavioral, social, and vocational difficulties that may result from a history of traumatic brain injury (Catroppa & Anderson, 2011).

Traumatic Brain Injury

Traumatic brain injury (TBI) is a non-specific pathological term that refers to a wide range of physiological damage that occurs on a broad continuum of severity (Iverson & Lange, 2011a). TBI may be separated into the distinguishing groups of penetrating head injury (PHI) and closed head injury (CHI) depending on the pathophysiological characteristics of the injury. PHI refers to TBI in which the brain has been injured due to penetration or partial removal of the skull and protective tissues surrounding the brain. CHI, on the other hand, refers to injury to the brain that results from acceleration-deceleration forces, blunt force trauma, and/or concussive force trauma from an external mechanism (Brenner et al., 2010; Iverson & Lange, 2011a).

Far more attention is paid in the literature to CHI than PHI due to the increased difficulty in determining the exact nature of injury in CHI. PHIs generally are more severe with deficits in function that may be attributed to damage sustained by specific neuroanatomical locations. CHI may result in all grades of injury and range from mild/transient injury with no detectable damage via neuroimaging, to severe edema or intra-cranial hemorrhage (WHO, 2006). CHI is also more commonly encountered in clinical situations (Lezak et al., 2012).

TBI results in both primary and secondary pathophysiological sequelae (Iverson & Lange, 2011a). Primary injury includes axonal shearing injury, hemorrhage, and vascular injury that is an immediate and direct result of the injurious event (Iverson & Lange, 2011a). Secondary injury refers to ischemia, excitotoxicity, “cell death cascades,” (Iverson & Lange, 2011a, p. 667) edema, and traumatic axonal injury also called diffuse axonal injury or microstructural white matter damage that can occur as a delayed or secondary response to the initial injurious event (Smits et al., 2011).

Much in the way PHI garners more attention than CHI, the effects of primary injury have, historically, been the focus of greater attention and more research than secondary injury. This is due to the fact that primary injury is more readily identifiable via traditional methods of medical assessment and neuroimaging such as Computerized Tomography (CT) and Magnetic Resonance Imaging (MRI; Iverson & Lange, 2011a). Primary injury often occurs as an immediate result of the initial injury source and provides clear-cut treatment options that might include surgery and/or anti-inflammatory steroid medications.

Secondary injury, however, is much more subtle and may not be apparent for some time after the initial injury has occurred. Microstructural white matter damage, or traumatic axonal injury as a result of stretching, twisting, or straining may not even be detectable via tradition neuroimaging techniques (Smits et al., 2011). The structure of an axon makes it susceptible to damage resulting from even minor insult. Specifically, the length of the axon structure is comprised of microtubules and neurofilaments that form the structural integrity of the axon (Iverson & Lange, 2011a). Minor physiological insult to the microtubule structures of the axon by way of twisting or stretching allows a shift in the ionic balance within the axon. The resulting alteration of ion balance creates an unstable metabolic change that may eventually lead to deterioration and separation of the axon itself in a process called axotomy (Iverson & Lange, 2011a; Smits et al., 2011). This intracellular damage manifests over time and may manifest pathological effects for days to months (Lezak et al., 2012).

Such injuries, undetected by neuroimaging, affect widespread neural regions due to the interconnectivity of axonal tracts. Smits et al. (2011) found that white matter integrity is disrupted in the splenium of the corpus callosum, the internal capsule, the uncinate fasciculus, and the inferior occipital-frontal fasciculus (Smits et. al., 2011). These brain structures are responsible for communicating and transferring information throughout the brain as well as the fluid completion of advanced cognitive tasks such as memory and recall. The degree of diffuse axonal injury has been found to correlate to the severity of initial injury.

Epidemiology

The World Health Organization's 2006 report on neurological disorders lists traumatic brain injury (TBI) as the "leading cause of death and disability in children and young adults around the world…" (p. 164). Additionally, TBI is credited as the "leading cause of disability in people under 40 years of age" (WHO, 2006, p. 167). Prevalence rates in the United States vary depending upon the source. The World Health Organization estimates that five million persons in the United States are currently living with some form of TBI-related disability (WHO, 2006). According to Lezak et al. (2012), citing Center for Disease Control census data from 2003, there are an estimated 3.17 million individuals in the US with some type of TBI-related long-term disability. Accurate prevalence data are difficult to determine due to the lack of community-based follow up and longitudinal tracking of TBI patients (Tagliaferri, Compagnone, Korsic, Servadei, & Kraus, 2005).

Incidence rates are potentially a more robust measure of TBI epidemiology; however, those rates also vary widely across the literature. Lezak et al. (2012), relies upon data from 2005 to draw incidence rate conclusions of ~150 per 100,000 persons in the United States. Tagliaferri et al. (2005) is widely cited as the preeminent source for worldwide TBI prevalence rates and established an incidence rate of 103 per 100,000 persons in the United States (p. 265). Across the literature, it is agreed upon that roughly 1.4-1.5 million Americans will suffer some form of TBI each year (Iverson & Lange, 2011a; Lezak et al., 2012, Tagliaferri et al., 2005; WHO, 2006).

Of all reported TBI, mild TBI (mTBI) represent by far, the largest single severity class of TBI that is treated by medical care providers. The estimated percentage of total TBI incidents comprised by mTBI varies from 75% to 90% (Iverston & Lange, 2011b; King, 1997; Tagliaferri et al., 2005; WHO, 2006). Large portions of those persons who suffer an mTBI, however, likely never seek medical treatment due to the perceived mildness of their injury or lack of secondary superficial wounds (WHO, 2006). Lezak et al. (2012) estimates that if all those with mTBI were accounted for in the data, the prevalence rate would likely rise to ~500 per 100,000 persons in the population of the United States.

The leading causes of TBI are motor vehicle accidents, falls, and violent impacts (which includes sport-related concussions and TBI associated with warfare; King, 1997: Varnamkhasti & Thomas, 2011). World-wide, motor vehicle accidents (MVA) are the single largest cause of TBI (Tagliaferri et al., 2005; WHO, 2006). In developing countries, MVAs are of particular concern due to the difficulty regulating traffic flow, types of vehicles utilized, use of helmets and seat belts, and minimum vehicle safety standards. One study, for example, found that in Maharashta, India, MVA accounted for 46.8% of all treated TBI (Agrawal et al., 2012). The World Health Organization notes that MVA accounts for no less than 20% of TBI in developed countries, and over 60% of all TBI in Asia (WHO, 2006).

Definition of Severity and Etiology

Traumatic brain injury occurs across a spectrum of severity. The term may be applied to the results of gunshots, motor-vehicle accidents, or other physical trauma that penetrates the skull and causes physical alteration to brain tissue. The same term also applies to low-grade impacts or impactless events that cause pressure changes or rapid acceleration/deceleration to occur within the skull. Depending on the type of injury sustained, the resulting neuropathological and neuropsychological consequences may be expressed quite differently. Severity ratings create a method of objectively defining pathological sequelae and outlining assessment protocols.

Unfortunately, there is currently no universal diagnostic classification system for TBI. The three most common elements used to define TBI severity are the Glasgow Coma Scale (GCS), duration of loss of consciousness (LOC), and duration of posttraumatic amnesia (PTA) (King, 1997; Lezak et al., 2012; WHO 2006). The GCS is a measure of alertness that combines scores across three criteria. The criteria include the injured patient's ability to perform ocular (maximum 4 points), verbal (maximum 5 points), and motor responses (maximum 6 points) upon cueing (CDC, 2003; WHO, 2006). The consensus definition of severity includes cut-off scores across all three elements and is as follows (Iverson & Lange, 2011a):

Table 1.

Classification of TBI Severity

Classification	Duration of LOC	GCS	PTA
Mild	<30 minutes	13-15	<24 hours
Moderate	30 minutes-24 hours	9-12	1-7 days
Severe	>24 hours	3-8	>7 days

Note: "Moderate and severe traumatic brain injury" (p. 667), by G. L. Iverstion and R. T. Lange, in The little black book of neuropsychology; A syndrome-based approach by M. R. Schoenberg and J. G. Scott (Eds), 2011, New York, NY: Springer. Copyright 2011 by Springer Science+Business Media. Adapted with permission.

Further differentiation of severity is based on the presence of bleeding or structural abnormality and is referred to as complicated (with structural abnormality on neuroimaging) or uncomplicated (without abnormality; Iverson & Lange, 2011b).

There is also little agreement within the literature as to the terminology used to describe TBI, particularly mild TBI (mTBI). The terms *minor head injury*, *mild closed head injury*, *mild* *traumatic brain injury*, *mild concussion*, and *concussion* are frequently used interchangeably (Cunningham, Brison, & Picket, 2011). Iverson & Lange (2011b) suggest that *concussion* is often used in reference to mTBIs suffered by athletes or civilians possibly due to the common lay understanding of the term in comparison to *traumatic brain injury*. For the sake of parsimony and clinical clarity, the term TBI will be used throughout this work, with severity specified.

While particular terminology of TBI is not agreed upon throughout the literature, there is agreement as to how and why the brain is susceptible to injury with even minor trauma and why common neuropsychological deficits are seen in TBI. As TBI may be caused by such a wide array of events with impact (or concussive force) assaulting the brain from a multitude of angles and sources, it is important to consider the biomechanical and anatomical factors that explain why common patterns of injury are seen.

According to Lezak et al. (2012), the anatomical regions of the brain most susceptible to injury following TBI are the frontal and temporal lobes, the corpus callosum, and other white matter structures. When the head is struck by, or comes to a sudden stop against an object, the point of impact results in what is referred to as a "*coup*" injury (Lezak et al., 2012, p. 195). As the brain is a free-floating structure within the skull, acceleration forces cause the brain to rebound and impact the skull in the area opposite the initial impact. This rebound effect results in a *"contracoup"* injury (Iverson and Lange, 2011a; Lezak et al., 2012, p. 195). The brain, composed of multiple lobes, does not move as a singular organ and the lobes and lateral hemispheres are forced together and away from each other which results in strain against the white matter structures that transmit information, including the corpus callosum.

The frontal and temporal lobes are also highly vulnerable to damage following TBI. These lobes are more susceptible to injury resulting from acceleration and deceleration forces due to the way the frontal and temporal lobes are situated within the bone structures of skull (Lezak et al., 2012). This predilection for injury may be why frontotemporal dysfunctions (i.e. processing speed, attention and concentration, and memory) present as the hallmark neuropsychological sequelae of TBI (Lezak et al., 2012).

Prognostic Considerations

Prognosis of TBI is correlated with severity (Lezak et al., 2012). Severe TBI is related with the poorest prognostic outcomes and most patients that endure severe TBI never return to independent functional abilities (Lezak et al., 2012). In addition to the deficits in memory, attention, organization and planning, self-control and behavioral inhibition, survivors of severe TBI also frequently experience motor and speech difficulties as well and psychiatric disturbance (Lezak et al., 2012). Long-term outcomes suggest that, in most cases, little if any improvement is seen in cognitive outcomes and social and personality deterioration are common (Lezak et al., 2012).

With regard to moderate TBI, Lezak et al. (2012) notes that this diagnostic group contains those with the most widespread variability in both injury and symptom presentation. What is consistent is that approximately one-third (38%) of moderate TBI patients will make a substantial recovery as determined by the GCS and be able to return to some semblance of their previously enjoyed lifestyle (Lezak et al., 2012). It has been noted for this group that frontal lobe problems (difficulty with initiation, planning, and organization), temporal lobe difficulties, and lack of deficit awareness are the most pronounced and problematic (Iverson & Lange, 2011a; Lezak et al., 2012).

Mild TBI constitutes the single largest classification group of TBI. In the mildest form, mTBI is thought to present with complete symptom resolution within the first week to three-months post-injury (Iverson & Lange, 2011b; Lezak et al. 2012; WHO, 2006). Given the high prevalence of mTBI, as previously noted, the most attention has been focused on this type of injury and clinical outcomes appear to be greatly influenced by factors including LOC, PTA, and whether or not the mTBI was complicated. Although there is still debate about prognostic factors for mTBI, duration of PTA in particular, seems to be correlated with greater symptoms complaints at three and six-month follow-up (Lezak et al., 2012). Despite the widely reported finding that most mTBI patients return to baseline levels of functioning on most neuropsychological measures within the first three months following injury, it is also noted that many patients continue to report cognitive and emotional symptoms for years and, for a small percentage, permanently following a mTBI (Iverson & Lange, 2011b; King & Kirwilliam, 2011; Lezak et al., 2012).

Indeed, a large portion TBI patients report ongoing cognitive and social difficulties long after standard neuropsychological and neuroimaging evaluations show asymptomatic results. Lezak et al. (2012), points out that "patients whose injuries seem mild, as measured by most accepted methods, may have relatively poor outcomes, both cognitively and socially; and conversely, some others who have been classified as moderately to severely injured have enjoyed surprisingly good outcomes" (p. 183). Those symptoms that persist long after the expected prognostic time frame have been termed "Post Concussion Syndrome" and have been subjectively reported to be present for years, or permanently, following even mild TBI (King & Kirwilliam, 2011; Smits et al., 2009).

Long Term Consequences of TBI

Silverberg and Millis (2009) make the distinction between a neuropsychological "deficit" and "impairment," where "impairment" refers to an alteration in ability for the worse and "deficit" refers to a performance that interferes with a patient's functional abilities (p. 195). While this distinction is often thought of as somewhat arbitrary when attempting to distinguish between subtle neurocognitive changes, such differentiation is, phenomenologically, a much more salient factor to consider. Given that most persons who suffer a TBI have not had a complete neuropsychological evaluation prior to their injury, determination of a negative change in performance is either impossible, or based on a test attempting to estimate premorbid function that does not adequately stress the neuroanatomical regions affected by PCS. As such, subtle impairments (i.e., negative alterations from baseline) that may exist as a permanent symptom of TBI may be interpreted as insignificant variation in standard neuropsychological evaluations (Geary, Kraus, Pliskin, & Little, 2010).

Most recovery from TBI that will be achieved occurs within the first year following injury, regardless of severity (Iverson & Lange, 2011a; WHO, 2006). For mTBI, the literature seems to maintain that drastic symptom improvement will be seen within the first three months post-injury, with nearly complete resolution within six months for approximately 90% of mTBI patients (King & Kirwilliam, 2011; WHO 2006). Ongoing follow-up studies and research on those with a past history of TBI has, however, complicated potential outcome determinations.

One such complication of TBI recovery outcome is Post Concussion Syndrome (PCS). PCS consists of a range of cognitive, somatic, and emotional symptoms that include "headaches, dizziness, fatigue, irritability, reduced concentration, sleep disturbance, memory dysfunction, sensitivity to noise or light, double or blurred vision, nausea, anxiety, and depression." (King & Kirwilliam, 2011, p. 463). Of particular relevance to neuropsychological research are the inefficiencies of attention, concentration, and memory reported by those patients with chronic or persistent PCS (Iverson and Lange, 2011c). Smits et al. (2011), suggest that ongoing inefficiencies may be rooted in microstructural white matter damage to axonal tracts that are undetectable by conventional neuroimaging methods such as MRI and CT scans.

Subtle neurocognitive deficits due to microstructural white matter (axonal) damage have a significant effect on selective attention and working memory (Smits et al., 2011). These deficits may not be severe enough to be revealed during initial recovery from TBI and may only reflect subtle inefficiencies on neuropsychological evaluations that generally rely upon performance of 1.5 standard deviations, or more, below the mean of a normative sample to be considered deficient (Silverberg & Millis, 2009). Subtle changes in attention and working memory, however, may be subjectively experienced by a patient as quite severe once they attempt to resume the demanding tasks of everyday life (Smits et al., 2011).

Memory

Memory is a fundamental cognitive function that impacts an individual's ability to engage in everyday life. The role of memory in daily life is pervasive and memory dysfunction is one of the most common complaints for person's who report ongoing difficulties following a TBI. Memory dysfunction may also lead to the patient's belief that that they are incapable of fulfilling employment and familial responsibilities and lead to interpersonal conflict.

Memory is not a singular construct; instead, it is a complex process comprised of multiple stages and numerous brain regions. Memory may be thought of as the end result of the following components: attention, acquisition, encoding, consolidation, organization, and retrieval (Geary et al., 2010; Lezak et al., 2012). Anatomical regions for memory are further separated into systems for explicit (declarative) memory, implicit (procedural memory), visual memory, and verbal memory. This highly complex system is dependent upon the interconnections of sensory input, integration cortices, and the frontal and temporal lobes via axonal fasciculi (Niogi, et al., 2008).

Neuropsychological tests of memory are heavily weighted on the verbal component of memory. Standard memory assessment includes list learning tasks such as the California Verbal Learning Task- II, Hopkins Verbal Learning Task, Rey Auditory Verbal Learning Test, and Repeatable Battery for the Assessment of Neuropsychological Assessment: List Learning as well as memory for verbally presented stories such as Logical Memory I & II on the Wechsler Memory Scale.

Some researchers have questioned the ecological validity of these verbal learning tasks in the detection of memory deficits in chronic PCS or long-term evaluation of TBI symptomology. Most chronic PCS patients report memory deficits in their everyday interactions/activities. Geary et al. (2010) suggest that the structure of list-learning tasks that consist of multiple learning trials is not generalizable to daily activities where people are often presented with information only once. The literature points out that participants with a history of TBI perform much worse than controls on Trial 1 of the CVLT-II, even though after Trial 5 significant differences were not found (Geary et al., 2010). Thus, the memory inefficiencies that constitute long-term effects of TBI may be "exacerbated by the qualities of day-to-day interaction *versus* constitut[ing] a generalized encoding, consolidation, and/or retrieval-based 'memory' deficit." (Geary et al., 2010, p. 513).

Additional neuropsychological measures for non-verbal memory such as the Rey-Osterrith Complex Figure Test and Medical College of Georgia Complex Figure Test are heavily dependent on visuospatial and visuoconstructional graphomotor abilities. As a result, these tests are often sensitive only to hemisphere-specific damage to the temporal lobes (Ariza, et al., 2006). Furthermore, the realistic applications of visual memory in a person's day-to-day functioning have little generalizability with visuoconstructional-based neuropsychological measures. Visual memory is involved in a person's ability to recall where they placed objects, recognize familiar people and places, and their ability to navigate through their world. Visual memory abilities play a vital role in a person's employment or capabilities in the realms of design, architecture, driving, piloting, and operation of consoles and/or computer operating systems (Shum, Harris, O'Gorman, 2000). Thus, the act of recreating a drawing from memory may provide valuable neuropsychological information in situations where damage to specific anatomical brain locations is suspected, but holds little ecological validity to the real-world tasks that utilize the visual memory system.

Furthermore, the memory impairment reported with TBI is non-specific (Ariza et al., 2006) and mediated by the role of the frontal lobes that necessitates the use of an assessment measure not limited by graphomotor functions or crystallized verbal knowledge (McDonald, Bauer, Grande, Gilmore, & Roper, 2001). The assessment of visual memory on a task free of visuospatial and graphomotor visuoconstructional confounds will be the focus of this study. The Picture Memory Interference Test (PMIT) holds promise, theoretically, as a method of detection for TBI due to it's non-reliance upon either verbal or visuoconstructional abilities, and that it does not lend itself to the use of verbal strategies to aid in memory performance.

Research has also shown that visual memory may represent a more "fluid" ability than verbal memory (Busch et al., 2005). As diffuse brain damage, of the type recognized to occur in the course of TBI, has a more pronounced effect on fluid cognitive abilities than those that are considered crystallized, a visual memory test may provide a more accurate method of detection (Busch et al., 2005). Previous research has also suggested that visual memory impairments are long-lasting following moderate to severe TBI (Shum et al., 2000).

Visual Memory

Visual memory may be said to be any memory for information that was obtained via the visual sensory system. In order for sensory information to be perceived as visual information and eventually stored as memory, multiple brain regions are needed in addition to numerous axonal fasciculi facilitating the neuronal communication between them. The system begins at the sensory level with cells that react biochemically when contacted by light. These cells, called photoreceptors, are located in the cellular membrane on the inner posterior surface of the eyes (Martin, 2012). When photoreceptor cells are activated via contact with light, they begin a chain of action potentials that send signals down the optic nerve to various brain regions. The optic nerve projects to the superior colliculus and the lateral geniculate nucleus (LGN) in the thalamus (Martin, 2012). The LGN serves as a relay system to the primary visual cortex in the occipital lobe (Martin, 2012).

From the occipital lobe, visual information travels forward through two primary pathways. One, often referred to as the “where” visual pathway extends dorsally from the occipital lobe to the posterior parietal lobe and provides information regarding location and movement (Martin, 2012). The second, commonly called the “what” visual pathway, extends ventrally to the temporal lobe and provides object recognition, color, and form information (Martin, 2012). Both of these pathways are involved in the formation of visual memory and utilize neocortex in the frontal lobe to accomplish memory encoding (Sneve, Alnaes, Endestad, Greenlee, & Magnussen, 2012).

The influence of the frontal lobes on visual memory performance is increasingly understood within the literature. In fact, it has been demonstrated that maintenance of a visual image within the perceptual system long enough for memory encoding to occur requires consistent activation of the frontal lobes (Busch et al., 2005). It has even been found that frontal lobe damage results in more severe memory encoding and retrieval deficits than temporal lobe damage (McDonald et al., 2001). The complex system for visual perception and visual memory then, places greater strain upon microstructural white matter and axonal fasciculi that ensure communication between various brain regions, than does the linguistic and verbal memory system.

Role of TBI Detection in College Students

College students with subtle cognitive impairments related to a history of TBI may be at greater risk of being inappropriately diagnosed with learning or developmental disorders (Beers, Goldstein, & Katz, 1994). Some research indicates that a history of TBI is associated with poorer grades, greater utilization of special education services, and repeated grades in adolescents (Arnett et al., 2013). Arnett et al. (2013), suggest that executive functions associated with frontal lobe functions are diminished due to a reduction in the integrity of the uncinate fasciculus following a history of TBI. As follows, those with a history of TBI may have a history of academic struggles or neurobehavioral symptom presentation that may have been misidentified prior to entering college. Despite difficulty, research suggests that careful evaluation of attention and memory, especially visual memory, may be particularly useful in the differentiation of college students with bona-fide learning disorders and those with history of TBI (Beers, Goldstein, & Katz, 1994).

College students face particular cognitive challenges, both academically and socially that necessitate increased expenditure of cognitive horsepower. Given the high prevalence of TBI in the general population, the lack of research related to the impact of previously endured TBI in college-students is a significant gap in the literature. Segalowitz & Lawson (1995) sampled 3,666 high-school and college students and revealed a prevalence of 12-15% of the total sample that reported a history of TBI with loss of consciousness. Evaluation of a test to detect performance changes related to TBI in college students also affords the opportunity to provide recommendations to individuals who may be experiencing subjective difficulties but are considered neuropsychologically asymptomatic (Segalowitz & Lawson, 1995).

Despite the prevalence of TBI, and mTBI in particular, there is a limited amount of research on the identification of those college-age individuals with cognitive deficits related to a history of mTBI. Those with cognitive symptoms related to a history of TBI may consider themselves to be less capable than their peers or be misdiagnosed with attentional or learning disorders (Beers et al., 1994). A potential reason for this oversight is a prevailing perspective in the literature that *mild* TBI is an inconsequential injury without lasting neurocognitive sequelae (Beers et al., 1994). The difficulty of detecting significant (>1.5 standard deviations) neuropsychological deficits and lack of pathophysiological correlates on neuroimaging in the evaluation of mTBI has led many care providers to determine that PCS is related to psychological symptoms of anxiety, depression, or psychosocial difficulties rather than bona-fide neurocognitive inefficiencies directly related to TBI. Iverson and Lange (2011c), note "differential diagnoses, co-morbidities, and social-psychological factors that may *cause* or *maintain* self-reported symptoms" (p. 794) must always be considered when evaluating an individual for possible PCS.

This disparity of thought is reflected in the contrary opinions of neuropsychologists and neurosurgeons regarding PCS. A 1988 survey by McMordie, as cited in King 1997, found that only 55% of neurosurgeons believed PCS was attributable to organic causes while 72% of neuropsychologists believed PCS was caused by organic factors (King, 2007). Ettenhofer, Reinhardt, and Barry (2013), suggest that "postconcussive" symptoms may be better conceptualized as "neurobehavioral" (p. 978) symptoms to more accurately describe and clinically illuminate the presentation of patients with a history of TBI.

Some research has demonstrated that particular neurobehavioral symptoms such as anxiety, depression, and frequent alcohol use are associated with greater self-report on post-concussive symptom assessment measures in college students and these findings are more strongly influenced by gender (female) and a history of Attention-Deficit Hyperactivity Disorder and/or Learning Disorders than a history of TBI (Ettenhoffer et al., 2013). The authors of that study, however, suggest that further research is needed to clarify the role of TBI in the development of neurobehavioral symptoms and the identification of symptom clusters that may enhance the specificity of identifying long-term consequences of TBI (Ettenhoffer et al., 2013).

Statement of Purpose and Significance of Study

This study examined the use of a neuropsychological assessment of nonverbal memory in a sample of college students. Specifically, performance on the Picture Memory Interference Test (PMIT) was evaluated to determine the measure's efficacy in detecting potential neurocognitive deficits related to a history of TBI. The PMIT is a computerized test of visual memory. Participants are presented with a series of images they are asked to recall over multiple trials as well as attempt to distinguish based on which trial they were exposed to a particular image. A detailed description of the PMIT will be provided in the Methods section. The data analyzed for this study was drawn from an archival data set from the UCLA Life Sciences Laboratory.

Study hypotheses: that there will be a significant difference in PMIT performance between: (a) those students who report a history of TBI will score significantly lower on the PMIT than students who do not report a history of TBI, and (b) students with a history of moderate to severe TBI will score significantly lower on the PMIT than students with a history of mild TBI (with TBI severity estimated from reported length of LOC).

Methods

Participants

The University of California, Los Angeles (UCLA) Life Sciences Core Laboratories (LS2) is an undergraduate course through which students may become voluntary participants in ongoing research projects. The project, entitled, "Undergraduate Research Initiative (URI) for Life Sciences 2, Students about Cognitive Processing" enrolls between 1500 and 2000 students each year. The initiative, conducted by Gaston Pfluegl, Ph.D., and Enrique Lopez, Psy.D., is a physiology course with a laboratory component. Student information is obtained voluntarily and stored anonymously. The aims of the URI are to provide undergraduate students with a database that allows for their participation and practice in conducting archival research and developing an appreciation for research design. Participants were provided informed consent for research purposes and voluntarily opted to participate in the study (see Appendix B). The original study received approval from UCLA's Institutional Review Board (IRB). Approval was obtained for this study by Pepperdine University's Graduate and Professional Schools IRB (see Appendix C).

Participants who contributed to the available data set completed a self-report questionnaire prior to completion of the PMIT (see Appendix D). The questionnaire included items about participants' age, ethnicity, primary language, gender, history of head injury, and other factors. As an exploratory data set, exclusionary criteria were not established for participation and all students who chose to complete the PMIT contributed data to the archival set. For the current study, participant groups of students were determined based on their self-identification as having sustained a head injury with or without LOC, and duration of LOC. The questionnaire included items differentiating those who reported a history of head injury from those without, and further differentiated those who reported prior head injury by the experience of LOC, and duration of LOC based on "minutes," and "hours and days."

Groups were separated by level of severity that was inferentially estimated by duration of LOC and approximated to the previously noted severity grading guidelines (see Table 1). Thus, the TBI group was separated into two groups: (a) mild and (b) moderate-to-severe. The TBI groups were compared to a control group derived from the remaining sample. The mild and moderate-to-severe groups were also compared to each other to determine if the PMIT is useful in discriminating groups of differing TBI severity.

For this study, the investigator explored the archival data-set obtained from the UCLA URI. The original data set included scores from 12,227 completions of the Memory-Interference Test (MIT). From this data set, repeat completions by the same participants were excluded as well as completions on versions of the MIT utilizing alternative stimuli (e.g. faces, kanji). Completions were also excluded based upon missing data points or failure to complete the PMIT. Following exclusions, the final data sub-set for analysis consisted of 6,897 unique completions of the PMIT. Of these, 412 endorsed a history of head-injury with LOC duration of "minutes" and were assigned to the Mild group; 61 individuals endorsed a history of head-injury with LOC of "hours or days" and were assigned to the Moderate-Severe group. For a full description of the research sample participants, see Table 2.

Table 2.

Characteristics of the Research Sample

Characteristics of the participants	Control (*n*=6424)	Mild (*n*=412)	Moderate-severe (*n*=61)	*p* value
# of male participants (% of total males)	2503 (39%)	226 (55%)	37 (61%)	
# of female participants (% of total females)	3917 (61%)	186 (45%)	24 (39%)	<.001 (Across all groups)
Age (years; mean±SD)	19.6±2.0	20.1±3.8	19.9±1.9	<.001
Language				
English	3425 (53%)	290 (70%)	34 (56%)	
Other	2999 (47%)	123 (30%)	27 (44%)	
ADD/ADHD/Learning disability	63 (1%)	7 (2%)	2 (3%)	

Note: The Mild group was designated as those participants that endorsed a history of head injury without LOC or with LOC duration of "minutes." The Moderate-Severe group was designated by those participants who endorsed a history of head-injury with LOC of "hours or days."

Instrument

Participants in the original study from which archival data will be analyzed were administered the Picture Memory Interference Test (PMIT). The PMIT was originally designed as a cross-culturally valid measure of memory for use in detecting neurocognitive deficits associated with Human Immunodeficiency Virus (HIV) seropositive status (Maj et al., 1991). It was developed in a joint effort by the World Health Organization and UCLA for inclusion in a multi-center battery to assess HIV-related neurocognitive decline in diverse patient populations and was evaluated for its adherence to four criteria: "1) Ability to tap the functional domains that have been claimed to be affected in symptomatic HIV-1 infection, 2) sensitivity to mild degrees of cognitive or motor dysfunction, 3) suitability for large-scale administration, and 4) suitability for use in a cross-cultural context" (Maj et al., 1994, p. 52). Additionally, tests used in the battery must have been determined to possess reliability and validity across diverse patient populations with regards to language, ethnicity, gender, sexuality, and country of origin (Maj et al., 1991). The WHO/UCLA PMIT was developed specifically for inclusion in this battery.

The WHO-UCLA PMIT was developed using a standardized set of culture-fair line-drawings representing various objects that was obtained from Snodgrass (Snodgrass & Vanderwart, 1980). The black and white line drawings were created and evaluated to create a standardized set of images that may be used in research requiring the use of images to be viewed by participants. The pictures were selected on the basis of being (a) unambiguous, (b) derived from well-studied categories, and (c) representative of basic categorization levels (Snodgrass & Vanderwart, 1980). Furthermore, Snodgrass & Vanderwart (1980) researched guidelines for how the pictures should be presented with regard to level of detail, orientation, realism, and typical representations. Participants in their study named each image, rated the agreement between their mental image of the represented concept, and rated the complexity of each picture; allowing for the researchers to identify the most commonly used name for each picture and the most effective way for it to be represented (Snodgrass & Vanderwart, 1980).

The result of this study was 260 monochromatic images, representative of concrete nouns that could be used in studies of semantic, episodic, and visual memory. The guidelines created by Snodgrass & Vanderwart (1980) were also used to determine specific details of presentation such as ensuring that animals are presented in silhouette, objects "whose up-down orientation may vary (e.g. fork chisel) are drawn with the functional end down" (p. 181), and long, thin objects are always presented at a 45° angle.

The images developed by Snodgrass and Vanderwart were utilized in the PMIT and piloted by Maj et al. (1991), to participants in Brazil, Germany, Kenya, Thailand, and the United States. This multi-country evaluation of a neuropsychological assessment measure was, at the time, unprecedented, and the study concluded that the PMIT was both sensitive to neurocognitive deficits in memory functioning, and applicable to those from a wide-range of cultural backgrounds (Maj et al., 1991). Images are presented in Appendix G.

Research uses of the PMIT have addressed nonverbal memory in a wide range of patients and studies interested in diverse pathologies. One such study utilized the PMIT as a measure of nonverbal memory in a sample of gay and bisexual, urban, African-American men who were both HIV-1 seropositive and frequent cocaine users (Durvasula et al., 2000). The PMIT was selected as the primary measure in a study examining alexithymia, emotional stimuli processing, and performance on neuropsychological tests exploring fronto-temporo-limbic circuit activity in patients with a history of panic disorder (Galderisi et al., 2008). Additionally, the PMIT was evaluated to determine if first-language differences existed between native English and Farsi-speaking individuals (Kianmahd, 2012).

To date, the PMIT has never been utilized as a measure of non-verbal memory in patients with a history of TBI.

Administration

The PMIT is currently administered visually, using a computer interface and automated presentation of the stimuli. Instructions for the PMIT are presented in Appendix E. The archival dataset is comprised of the PMIT administered as a stand-alone test, accompanied by an introductory demographic questionnaire, as previously described. The test involves the presentation of four sections referred to as Books 1-4 (Maj et al., 1991). Books 1-3 each consists of 20 unique pictorial items (e.g., fork, airplane) that are presented sequentially. Following the presentation of a Book (the learning phase) there is a recognition phase. More specifically, following the learning phase of Book 1, the participant is presented with 50 items: 20 from Book 1, and 30 novel (distracter) images. The participant then presses a *yes* key when they identify a target item from Book 1, and a *no* key when viewing a distracter. For each subsequent book, the participant keys *yes* or *no* for correct identification of the Book that immediately preceded the recognition trial. The recognition trials become more complex with each trial, as items from the preceding Books are presented in addition to new distracters. The recognition trial following Book 4 differs from the preceding trials as the participant must press a numerical key (i.e. 1, 2, 3, or 4) to identify from which Book each image was derived.

Throughout the recognition trials, subsequent stimuli are revealed following a participant's response. Reaction time is measured and indicates how quickly individual participants responded to each item. A fifth and final trial (Book 5) also measures reaction time independent of memory assessment, and requires the participant to correctly identify 50 common shapes (20 circles and 30 squares).

The original version of the PMIT was administered using 3 x 5 inch notecards, and verbal presentation of the task instructions (Maj et al., 1994). The current version of the PMIT (and the one utilized in the original study from which data was drawn) is done exclusively on the computer and requires participants to read the test instructions prior to beginning the test. Presentation of the stimuli and millisecond timing is accomplished via web-based administration, which may be accessed via any computer system with internet capability.

Procedure

Post-hoc analysis of a subset of existing data collected at UCLA for the URI was examined to determine is participants who report a history of head-injury perform differently on the PMIT than individuals who did not report a history of head injury. Following participants' completion of the PMIT on the computer, data were transferred to an electronically aggregated database. The data are only available to individuals who obtain permission from the URI panel members (i.e. Dr. Lopez & Dr. Pfleugl). Permission for this study was obtained from Drs. Gaston Pfluegl and Enrique Lopez (see Appendix F).

Scores are reflective of True Positive (TP) scores obtained from each recognition trial. There is a maximum TP score of 20 per trial. In addition, data are gathered on True Negative (TN), False Positive (FP), and False Negative (FN) scores for each Book. Due to the investigational nature of the PMIT and its recent adaptation to a computer administration, there are currently no reliability or validity data for True Positive scores. Therefore, scores were analyzed for significant group differences, rather than analyzed based on scores above or below established cut-offs.

Multiple one-way analysis of covariance (MANCOVA) were utilized to examine if there were differences in the participants' PMIT scores between (a) the mTBI and control group, (b) the moderate-to-severe TBI group and control group, and (c) the mTBI and moderate-to-severe TBI group. Covariates of age and gender were factors in the analyses. Differences in performance were analyzed based upon individual performance on Books 1-4 to determine if there were differences between group performances as the difficulty of the task increased. Additional post-hoc analysis was conducted utilizing Tukey multiple comparison of means test, in order to determine significance of differences. The Tukey test was utilized due to the unequal group sizes. Statistical analyses were conducted in collaboration with a statistician utilizing R, an open-source statistical analysis programming language for use in social sciences research.

Results

For all scores of interest (TP, TN, FP, FN), multiple one-way analysis of covariance (MANCOVA) with factor of group (control, mild, or moderate-severe) and covariates (concomitant variables) of age and gender were conducted. All scores, except as otherwise indicated, are representative of the total scores for each criterion (e.g., TP3 indicates the sum of True Positive scores on Book 3). For TP scores, significant between groups differences were found for Books 2, 3, & 4, $F[2,6833] = 8.5$, $p < .001$; $F[2,6832] = 14.9$, $p < .001$; $F[2,6835] = 14.8$, $p < .001$, respectively. Post hoc Tukey pairwise tests showed that only the Mild and Control groups differed significantly ($p < .001$) from each other, with the Mild group achieving higher TP scores (see Table 3). None of the other group pairs demonstrated significant differences.

Table 3**.**

Differences Between Group Means for True Positive Scores on Books 1-4

Group	True Positive 1	True Positive 2	True Positive 3	True Positive 4
Mild-Control	0.17	0.57***	0.86***	1.19***
Mod/Severe - Control	-0.16	0.21	0.16	0.52
Mod/Severe - Mild	-0.34	-0.32	-0.72	-0.67
p	0.099°	0.0002***	3.61e-07***	3.79e-07***

Note: ° *p*<0.1. * *p*<0.05. ** *p*<0.01. *** *p*<0.001.

For True Negative (TN) scores (i.e., those items participants correctly identified as non-target items) significant group differences were found for performance on Book 2 alone, $F[2,6832] = 9.7$, $p < .01$. Post hoc analysis with Tukey pairwise tests showed that only the Mild and Control groups differed significantly ($p < 0.01$) from each other, with the Mild group achieving higher TN2 scores (see Table 4).

Table 4.

Differences Between Group Means for True Negative Scores on Books 1-4

Group	True Negative 1	True Negative 2	True Negative 3	True Negative 4
Mild-Control	0.1	0.43*	0.22	0.36
Mod/Severe-Control	0.13	0.76	0.2	-0.26
Mod/Severe – Mild	0.02	0.33	-0.03	-0.62
P	0.65	0.005**	0.25	-0.204

Note: ° p<0.1. * p<0.05. ** p<0.01. *** p<0.001.

For False Positive scores (i.e., novel or distracter items participants incorrectly identified as target stimuli) a significant group difference was found on Book 2, $F[2,6317] = 9.8$, $p < .05$. Post hoc Tukey pairwise tests found the Mild and Control group differed from each other ($p <$ 0.1), with the Mild group achieving lower FP2 scores (see Table 5).

Table 5.

Differences Between Group Means for False Positive Scores on Books 1-4

Group	False Positive 1	False Positive 2	False Positive 3	False Positive 4
Mild-Control	-0.06	-0.39°	-0.08	-0.09
Mod/Severe - Control	0.05	-0.63	-0.23	0.23
Mod/Severe - Mild	0.1	-0.25	-0.14	0.32
p	0.94	0.025*	-0.74	0.901

Note: ° p<0.1. * p<0.05. ** p<0.01. *** p<0.001.

For False Negative scores (i.e., target items participants incorrectly identified as novel or distracter items) significant differences were found between groups on Book 2, 3, & 4, $F[2,6115] = 6.3$, $p < .05$; $F[2,6273] = 9.28$, $p < .001$; $F[2,6835] = 19.15$, $p < .001$, respectively. Post hoc Tukey pairwise tests found the Mild and Control groups differed from each other (Book 2, $p < .01$; Books 3 & 4, $p < .001$), with the Mild group achieving lower FN scores (see Table 6).

Table 6.

Differences Between Group Means for False Negative Scores on Books 1-4

Group	False Negative 1	False Negative 2	False Negative 3	False Negative 4
Mild-Control	-0.1	-0.39**	-0.68***	-1.21***
Mod/Severe - Control	0.34	-0.01	0.03	-0.55
Mod/Severe - Mild	0.45	0.38	0.7	0.67
P	0.37	0.02*	0.0003***	2.55e-07***

Note: ° *p*<0.1. * *p*<0.05. ** *p*<0.01. *** *p*<0.001.

Analysis of response-time latency between groups on TP scores revealed no significant differences in speed of response to providing correct answers. Only one significant difference was found when response time was analyzed for other scores; FN scores on Book 4 differed significantly between the Moderate-Severe and Mild groups, with the Moderate-Severe group responding more rapidly rejecting target stimuli, $F[2,6834] = 3.86$, $p < .05$. An observed (but not statistically significant) trend was noted with the Mild group responding more slowly to TP and FN items across Books 2, 3, & 4, although on Book 5 (an embedded measure of response time), the Control group responded more rapidly than both the Mild and Moderate-Severe groups.

To evaluate group differences that may be attributable to age, an initial one way ANOVA conducted between experimental groups indicated a significant effect for age, $F[2,6898] = 6.202$, $p < .05$. Additional analysis was conducted on age as a covariate, revealing significant age effects for TP scores on Books 1 – 4, $F[1,6831] = 26.25$, $p < .01$; $F[1,6833] = 11.56$, $p < .001$; $F[1,6832] = 8.76$, $p < .01$; $F[1,6834] = 16.54$, $p < .001$, respectively (see Table 7). The results indicate older participants scored lower (worse) than younger participants. Using ad hoc partial eta squared (partial η^2), analysis indicated the effect size of age was minimal in explaining differences in TP scores.

Table 7**.**

Effects of Age as Concomitant Variable on True Positive (TP) Scores

Group	True Positive 1	True Positive 2	True Positive 3	True Positive 4
Age	p = 2.68e-07**	p = 0.000675***	p = 0.0031**	p = 4.82e-05***
Effect Size	Partial η^2 = .004	Partial η^2 = .002	Partial η^2=.001	Partial η^2 = .002

Note: ° p<0.1. * p<0.05. ** p<0.01. *** p<0.001.

Chi-square analysis of gender revealed the experimental groups differed significantly (p < .001). Gender was then examined as a covariate between the factors of mild and moderate-severe, to determine possible effects of gender on variable performance among those participants with a head injury. Significant effects were found for gender on TP scores for Book 2 performance only, F[1,2686] = 3.641, p < 0.05, with women performing better than men. Using ad hoc partial eta squared (partial η^2), analysis of the effect of gender indicated it was minimal in explaining between group differences, as depicted in Table 7.

Table 8**.**

Effects of Gender as Concomitant Variable on True Positive (TP) Scores

Group	True Positive 1	True Positive 2	True Positive 3	True Positive 4
Gender	p = 0.71	p = 0.03*	p = 0.33	p = 0.06°
Effect Size	η^2 = 0.002	η^2 = 0.016	η^2 = 0.007	η^2 = 0.006

Note: ° p<0.1. * p<0.05. ** p<0.01. *** p<0.001.

Additional Exploratory Analyses

As the PMIT was designed to be a culture-neutral test of visual memory functioning, exploratory analysis was conducted to determine if performance differed when the effects of language were held constant. Therefore, an additional MANCOVA was conducted to identify difference in performance among only those participants who reported English as their first language. Among those participants who reported English as their first language, significant differences in performance were observed on TP scores for Books 1 – 4, $F[2,3712] = 3.94$, $p < .05$; $F[2,3715] = 4.47$, $p < 0.5$; $F[2,3714] = 8.81$, $p < .001$; $F[2,3715] = 8.7$, $p < .001$, respectively; see Table 8. Among English speaking participants, post hoc Tukey pairwise tests indicated the mild and moderate-severe groups differed significantly from each other on Book 1, with the mild group identifying more correct target stimuli. TP scores for Books 2 – 4 indicated the mild group performed better than the control or moderate-severe groups, that is, they correctly responded to more target stimuli. For books 2 – 4, this result is consistent with the observed results for all participants, regardless of reported first language.

Table 9**.**
Differences Between Group Means for TP Scores on Books 1-4 (English).

English-speaking Groups	True Positive 1	True Positive 2	True Positive 3	True Positive 4
Mild-Control	0.18	0.45*	0.77***	1.13***
Mod/Severe-Control	-0.6	-0.26	-0.42	0.03
Mod/Severe - Mild	-.78*	-0.71	-1.12	-1.1
p	0.02*	0.012*	0.0002***	0.00017***

Note: ° p<0.1. * p<0.05. ** p<0.01. *** p<0.001.

Analysis of pre- and/or co-morbid ADHD/Learning Disabilities (ADHD/LD) was also examined between groups. No statistically significant differences were found between the groups; however, a general trend was observed in which rates of ADHD/LD were proportionally greater in the Mild and Moderate-Severe groups (1%, 2%, and 3%, respectively. Although not significant, this finding is consistent with the literature asserting rates of ADHD/LD are higher among those with a history of head-injury.

Discussion

The purpose of this study was to investigate the potential utility of the PMIT in detection and or discrimination of individuals with a history of TBI. With regards to the hypotheses of this study, the results indicate:

1. Hypothesis one: that students who reported a history of TBI would score significantly lower than those students who do not report a history of TBI was unsubstantiated by the results. Contrarily, the results indicated the Mild TBI group scored significant higher on true positive scores (i.e., correct identification of previously presented target stimuli) for Books 2, 3, and 4.
2. Hypothesis two: that students with a history of moderate to severe TBI would score significantly lower on the PMIT than students with a history of mild TBI (with TBI severity estimated from reported length of LOC), was substantiated only among English-speaking students on Book 1. Otherwise, the hypothesis was disconfirmed, with the Moderate-Severe TBI group producing scores not significantly different from the Mild TBI group.

Primary Findings

Results of the analysis of PMIT performance between subjects with a self-reported history of head-injury revealed those with a history of mTBI achieved statistically higher (better) True Positive scores than the Control or Moderate – Severe group on Books 2, 3, & 4. The mTBI group correctly identified more non-target stimuli on Book 2 as incorrect (i.e., True Negative scores) and responded affirmatively to fewer novel or distracter items on Books 2, 3, & 4. No other results indicated statistically significant differences between the groups. These findings are in opposition to the hypotheses of the study, which proposed participants with a history of head-injury would perform worse than individuals without, and the Moderate-Severe group would perform worse than individuals with a reported history of mTBI. Interestingly, the results suggest those individuals with a reported history of mTBI actually demonstrate better performance on the PMIT than the Control group. The results, although statistically significant, were not indicative of potential cut-off scores to utilize in group discrimination, as mean differences between group performance was generally less than one response. For TP4 and FN scores, the differences were just above one (1.19, and -1.21, respectively). The results further indicated age and gender are significant mediating variables in test performance; however, the proportion of variance attributable to these variables was minimal.

Exploratory analysis examined both response-time latency and whether language-of-origin may mediate performance. The analysis of response time yielded only one significant result; participants in the Moderate – Severe group typically responded more rapidly when incorrectly identifying target stimuli as novel or distracter items on Book 4. A general trend was observed across Books 2, 3, & 4 consisting of slower response latency to TP and FN items among the mTBI group. As this trend was observed to change on Book 5 (which only requires shape discrimination and is used as a measure of response time) with the Control group responding more rapidly than either the Mild or Moderate – Severe groups, it may be presumed that the observed slowing of response latency was not due to true differences in processing speed or reaction time. Although not statistically significant, this author proposes the finding on Books 2, 3, & 4 may suggest the mTBI group exhibited greater prudence in responding than the other two groups, i.e., they more carefully considered their answers before responding.

With regards to language-of-origin, for English-speaking participants the results indicated a significant difference in performance on Book 1, with the Moderate – Severe group identifying fewer correct target stimuli than the Mild group (lower TP scores). On Books 2, 3, & 4, significant differences were only observed between the Mild and Control groups, with the Mild group exhibiting better performance, consistent with the findings observed when language was not held constant. This finding suggests that although the PMIT is considered a culture-neutral test of visual memory, certain culture-bound effects, such as language, may influence performance. Specifically, among English-speaking participants, diminished performance among the Moderate – Severe group may be indicative of a cognitive "warming up" process, wherein those participants were slower to orient to the task.

Among the participants, the Mild and Moderate – Severe groups had proportionally higher rates of self-reported ADHD/LD than the Control group. Although this finding was not significantly significant, it does lend credence to the proposition by Beers, Goldstein, & Katz (1994) that individuals with a history of TBI are at an increased risk of being diagnosed, perhaps incorrectly, with ADHD/LD. This is a tentative supposition; however, as the temporal association between diagnosis of ADHD/LD and head-injury is unknown in the sample.

Implications

The results of the current study are unclear as to whether or not the PMIT may effectively detect and discriminate college student participants with a history of mTBI from those without, despite the statistical significance of the findings. As a tool for detection, the PMIT may hold some promise; however, given the general interest in neuropsychological assessment of identifying deficits or impairments, this discriminatory ability may not be clinically efficacious. Furthermore, it is unclear what other mediating cognitive and/or emotional variables may be contributing to the observed differences in performance between the groups.

As ongoing neurocognitive impairment secondary to a history of TBI (specifically mTBI) remains somewhat controversial, the findings of this study seem to support the idea that cognitive impairments secondary to mTBI typically resolve without lingering symptomology. As discussed, however, individual and emotional variables may play a large role in the recovery process. Leventhal's Common Sense Model of injury and illness behavior (CSM; as cited in Snell, Hay-Smith, Surgenor, & Seigert, 2013) proposes that psychological factors may play a substantial role in mediating observed injury outcomes, beyond what may be attributable to physiological injury and recovery. The CSM proposes five specific psychological components, which may affect recovery: "…identity (illness label and associated symptoms), expected consequences, timeline perceptions, perceptions of controllability, and causal attributions" (Snell et al., 2013, p. 335). Iverson and Lange (2011c) discuss the concept of "expectation as etiology" (p. 750) when considering persistent self-reported symptomology, consistent with the CSM component of consequential expectations.

The CSM has been demonstrated to predict reported distress and self-reported functional difficulties, regardless of physical injury outcome, based upon development of coping skills, presence of anxiety and/or depression, and perception of injury (Snell et al., 2013). Surprisingly, the CSM demonstrates individuals with better initial outcomes following TBI (as opposed to poor outcomes directly related to greater severity of injury) typically report increased distress at follow-up. This may be due to poor understanding of TBI among the general population and a tendency to minimize problems associated with initial recovery, leading to a tendency to become self-critical when complete recovery is not immediately obtained. As the sample of the current study was comprised entirely of students at a prestigious and academically demanding university, this author proposes that perception of injury and *identity* may be less injury-linked than in other demographic samples. Namely, by achieving acceptance to UCLA, their identity may be more linked to successful academic performance and high-achievement and less likely to be maladaptively mediated by negative expectancy regarding their history of head-injury.

In addition to being, perhaps, less affected by negative expectancies, the generally high-functioning sample may also be assumed to possess greater cognitive reserve than lower-achieving individuals. Cognitive reserve has been defined as "…one's capacity to adaptively use neural networks to compensate for increasing damage, with indices such as crystallized intelligence and years of education used to reflect this concept" (Satz et al., 2011, p. 122), and is considered a mediator between neurophysiological insult and outcomes. Although intelligence testing was not a factor in the present study, this author proposes the sample of UCLA students in this study is likely to have greater cognitive reserve than the general population.

In considering the demographics of the current study within the context of the CSM and cognitive reserve, the absence of diminished performance among the head-injured groups may be reflective of more positive expectancy, greater adaptive coping skills, and increased cognitive reserve among the current sample. The results indicating improved performance by the mTBI group may be conceptualized within this framework. Considering the CSM predicts those with better initial outcomes will report greater distress upon follow-up, it is likely individuals in the mTBI group experienced initial outcomes better than the Moderate-Severe group, and thereafter began to develop cognitive strategies to cope with any ongoing perceived impairments. The slower response-latency among the Mild group seems to support this conceptualization, suggesting the Mild group may have learned to approach tasks with greater prudence in an attempt to compensate for perceived impairments related to psychological factors. Among such a high-functioning sample, additional cognitive coping strategies may account for the statistically significant increase in performance among the mTBI group.

Within the context of increased rates of ADHD/LD among those individuals with a history of head-injury, it is notable that performance on a visual memory task mediated by frontal-executive functions (i.e. source discrimination and response inhibition) did not demonstrate significant negative performance. This finding may lend credence to the supposition that ADHD/LD may be *over-diagnosed* in those with a history of head injury, perhaps due to transient declines in performance temporally linked to the head-injury event. It should be noted, this author is not suggesting the PMIT may be used to identify ADHD/LD, nor should results of the PMIT be used to discredit an existing ADHD/LD diagnosis, as that would be far beyond the construct validity of the test. Rather, the results demonstrate that despite higher prevalence of ADHD/LD, high functioning individuals with a history of head-injury are able to perform comparably to, and even better than, their non-head injured counterparts on a test of visual memory.

Limitations and Future Directions

The significant results indicating the mTBI group performed better than the Control group on the PMIT should be viewed with caution in light of multiple limitations to this study. There is little ability to generalize the results of this study to other head-injured groups given the unique characterization of the sample: namely, college-age students at a major university. Additionally, although statistical tests were chosen to conservatively accommodate the large discrepancy in experimental group sizes, the potential for confounding variables in the much-larger control group exists (e.g. drug and alcohol use, existence of pre- or co-morbid psychiatric conditions, prevalence of other neurophysiological disorders). These factors may be examined in future investigations as concomitant variables, allowing for a determination of the proportion of variance accounted for by these potential confounds.

Limitations exist when extrapolating the results of this study directly to individuals with a medically-substantiated diagnosis history of head-injury, as determination of severity and group assignments were based upon a presumption of severity derived from LOC only (as PTA and GCS information were not available). The determination of severity used in this study may have artificially inflated the size of the mTBI group and deflated the size of the Moderate-Severe group, as any participant reporting LOC of “minutes” was assigned to the Mild group, with “hours or days” assigned to the Moderate-Severe group. Although the consensus definition of severity designates those with LOC greater than 30 minutes as having “moderate” head-injury, any participant with LOC between 30-60 minutes was assigned to the Mild group (due to lack of data regarding precise number of minutes of LOC), for the purpose of this study.

This study consisted of post-hoc analysis of an existing data set collected at ULCA where any student in the Life Sciences Initiative could complete the questionnaire; data were not directly compiled by this investigator. As all data were derived from self-report of head-injury history, the reliability of the data must be interpreted with caution. Regarding the results, data were analyzed based upon performance for each Book (i.e. trial of the PMIT) in order to distinguish differences in performance as the difficulty of the task progressed. This method did not account for total scores on the PMIT, which may have yielded alternate results. It is recommended that future research into the PMIT identify differences in total scores on the PMIT when examining group differences.

Future research into the PMIT for use with individuals with a history of head-injury may include a more substantive examination of the effects of language, given the results of this study. Although developed to be culture-neutral, verbal representations of presented images may play a role in performance.

Finally, the results of this study, contrary to expectations, yielded better performance among those with a history of mTBI. Although surprising, future research may include a more thorough examination of the psychological factors of the participants. Such an approach may yield contributions to a strengths-based approach to neuropsychological assessment of head-injury and assist in the establishment of accurate, and recovery-oriented psychoeducation regarding recovery outcomes and management of expectations.

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APPENDIX A

Review of the Literature

Author, Year, Title	Research Objectives, Hypothesis	Sample	Instruments, Variables measured	Research Design	Major Findings
Agrawal, A., Galwankar, S., Kapil, V., Coronado, V., Basavaraju, S. V., McGuire, L. C., … Dwivedi, S. (2012). Epidemiology and clinical characteristics of traumatic brain injuries in a rural setting in Maharashtra, India. 2007-2009.	To evaluate and describe clinical and epidemiological characteristics, as well as outcomes, of patients with traumatic brain injury admitted to a rural teaching hospital in India.	Participants were obtained via convenience sampling of patients admitted with head injury between 1/2007 and 12/2009. The total sample included 1,926 patients.	Variables included: Age; Sex; Place of residence; Glasgow Coma Scale (GCS) score; Mechanism of injury; Severity of injury; Length of hospital stay; CT results; Surgical intervention (if applicable); Discharge status; Glasgow Coma Outcome Scale (GOS) score	Quantitative study.	The study found most patients admitted with TBI were male (76.9%) with the most frequent cause being motor vehicle accidents (46.8%). The majority of deaths occurred in the 21-35 year age group. Low GCS score on admission was associated with poor outcomes. 10% of survivors had at least moderate TBI-related disabilities.

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Author, Year, Title	Research Objectives, Hypothesis	Sample	Instruments, Variables measured	Research Design	Major Findings
Ariza, M., Pueyo, R., Junqué, C., Mataró, M., Poca, M. A., Mena, M. P., & Sahuquillo, J. (2006). Differences in visual vs. verbal memory impairments as a result of focal temporal lobe damage in patients with traumatic brain injury	To determine if the type of lesion found in moderate and severe traumatic brain injury (TBI) was related to material-specific memory impairment.	The study utilized 59 patients admitted to a neurotrauma unit. Exclusionary criteria included impairment prohibiting engagement in neuropsych evaluations and focal lesions anywhere other than the temporal lobes. The sample of 80% males (n-47) and 20% female (n=12) consisted of moderate and severe TBI.	Head CT; Warrington's Facial Recognition Test (FRMT); Rey's Complex Figure Test (CFT); Rey's Auditory Verbal Learning Test (AVLT)	Quantitative study.	With regards to memory performance, impaired performance on FRMT was associated with right remporal lobe lesions, left temporal lobe lesions were associated with significantly worse AVLT performance. CFT performance was non-specific as patients with both left and right temporal lesions presented the same impairment. This study supports the concept of specific patterns of deficits due to lesion location.

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Author, Year, Title	Research Objectives, Hypothesis	Sample	Instruments, Variables measured	Research Design	Major Findings
Arnett, A. B., Peterson, R. L., Kirkwood, M. W., Taylor, H. G., Stancin, T., Brown, T. M., & Wade, S. (2013). Behavioral and cognitive predictors of educational outcomes in pediatric traumatic brain injury.	To determine if parent ratings of adolescent behavior associated with executive functions following pediatric TBI would predict long-term functional educational outcomes.	The sample included 132 adolescents between 12-18 years of age hospitalized for moderate-to-severe TBI. Exclusions were made for penetrating head injury. The sample was 65% male.	Glasgow Coma Scale (GCS); Behavior Rating Inventory of Executive Function (BRIEF); California Verbal Learning Test (CVLT); Child Behavior Checklist; School Competency subscale (CBCL).	Quantitative study. Longitudinal design. Participants were assessed at 6 and 12 months post-injury.	Contrary to expectations, the parent-completed BRIEF did not predict future CBCL scores. The CVLT and self-report version of the BRIEF were found to predict initiation of special education services. Initial GCS scores were found to predict both initiation of special education services and poor performance on the CVLT. High SES of patient families were found to correlate with scores on follow-up CBCL scores, but did not diminish initiation of special education services.

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Author, Year, Title	Research Objectives, Hypothesis	Sample	Instruments, Variables measured	Research Design	Major Findings
Beers, S., R., Goldstein, G., & Katz, L. J. (1994). Neuropsychological differences between college students with learning disabilities and those with mild head injury.	It was hypothesized academic achievement tests might erroneously identify students with a history of head injury as having a learning disability (LD), whereas neurocognitive tests might effectively differentiate the two.	385 students were recruited from facilities providing services to students with learning disabilities. Exclusionary criteria included excessive alcohol use and a history of major psychiatric illness. Head injury etiology included falls (36%), sports injuries (24%), car accidents (16%), and other accidents (24%).	Booklet Category Test; California Verbal Learning Test (CVLT); Controlled Oral Word Association Test (COWAT); Grooved Pegboard; Nelson-Denny Reading Test: Comprehension; Rey Complex Figure Test (CFT); Speech-Sounds Perception Test; Tactual Performance Test; Trail Making Test; Wechsler Adult Intelligence Test-Revised; WMS-Revised; WRAT; Woodcock-Johnson Psycho-Educational Battery	Quantitative study.	Comprehensive assessment batteries effectively discriminate between LD and head injury. Tests of language and psychomotor abilities most accurately identified LD. Those with a history of head injury performed more poorly on test of novel problem solving with a timed component than did LD participants.

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Author, Year, Title	Research Objectives, Hypothesis	Sample	Instruments, Variables measured	Research Design	Major Findings
Brenner, L. A., Terrio, H., Homaifar, B. Y., Gutierrez, P. M., Staves, P. J., Harwood, J. E. F., … Warden D. (2010). Neuropsychological test performance in soldiers with blast-related mild TBI.	An exploratory analysis to understand neurocognitive test performance of soldiers with blast-related mild traumatic brain injury (mTBI).	The sample included 45 soldiers with post-blast mTBI. 17 met criteria for PTSD.	Paced Auditory Serial Attention test; Trails A & B; RAVLT; Stroop Color and Word test – Golden; WCST-computerized.	Quantitative study.	A history of mTBI secondary to blast-exposure was not associated with decreased performance on assessment measures. It was noted the small sample size may have mitigated significant findings.

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Author, Year, Title	Research Objectives, Hypothesis	Sample	Instruments, Variables measured	Research Design	Major Findings
Busch, R. M., Booth, J. E., McBride, A., Vanderploeg, R. D., Curtiss, G., & Duchnick, J. J. (2005). Role of executive functioning in verbal and visual memory.	To explore the relationship between executive functioning and performance on more structured and less structured visual and verbal memory tests.	The sample was selected from participants enrolled in the Defense and Veterans Brain Injury Center. The sample was comprised of 193 participants. 105 participants completed follow-up at one-year.	As assessment battery was comprised of select subtests from the WAIS-R, select subtests from the WMS-R, CVLT, VSLT, Controlled Oral Word Association Test, Trails A & B, The Stoop Color Word Test, The Wisconsin Card Sorting Test, and the Boston Naming Test.	Quantitative study.	The results on initial testing did not demonstrate differences in memory performance were not affected by differences in executive functions. On one-year follow up, differences were found on visual memory tests, regardless of the degree of structure, suggesting executive functions played a role in visual memory performance. The authors proposed this is an indication of visual memory being a more fluid ability than verbal memory.

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Author, Year, Title	Research Objectives, Hypothesis	Sample	Instruments, Variables measured	Research Design	Major Findings
Catroppa, C., & Anderson, V. A. (2011). Pediatric traumatic brain injury (TBI): Overview.	N/A	N/A	N/A	N/A	The chapter provides an overview of pediatric traumatic brain injury including prevalence, epidemiology, long-term consequences, and typical patterns of injury and cognitive deficits.

Author, Year, Title	Research Objectives, Hypothesis	Sample	Instruments, Variables measured	Research Design	Major Findings
Cunningham, J., Brison, R. J., & Pickett, W. (2011). Concussive symptoms in emergency department patients diagnosed with minor head injury	To examine the prevalence and nature of concussive symptoms persisting up to one month post presentation to an emergency room.	Participants were recruited from patients presenting to emergency departments with minor head injury. The total sample consisted of 94 individuals, 47% were male. The most common injury etiology was sports related accidents (39%).	Participants completed an interview consisting questions regarding the cause of the injury, head injury history, and were administered the Rivermead Post-Concussion Symptoms Questionnaire (RPQ).	Quantitative study.	The study found 72% reported concussive symptoms, as defined by the RPQ criteria at baseline and 63% meeting criteria at one month follow-up. The primary findings indicated a decline in somatic complaints with persisting cognitive and emotional symptoms. A pattern of persisting somatic complaints was identified. The pattern included headache, dizziness, and fatigue.

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Author, Year, Title	Research Objectives, Hypothesis	Sample	Instruments, Variables measured	Research Design	Major Findings
Durvasula, R. S., Myers, H. F., Satz, P., Miller, E. N., Morgenstern, H., Richardson, M. A., ... Forney, D. (2000). HIV-1, cocaine, and neuropsychological performance in African American men.	The study sought to examine the independent and interactive effects of cocaine and seropositive HIV status on assessment measures with African-American men.	The study was comprised of 237 self-identified gay and bisexual African-American men.	Blood and urine tests were utilized to verify HIV status and the presence of cocaine. Neuropsych testing was conducted using the WHO-UCLA Battery which included the Picture Memory Interference Test.	Quantitative study.	The authors noted no significant findings of interaction effects for the use of cocaine and seropositive HIV status. Level of alcohol consumption was found to be associated with poor performance on measures of reaction time.

Author, Year, Title	Research Objectives, Hypothesis	Sample	Instruments, Variables measured	Research Design	Major Findings
Ettenhofer, M. L., Reinhardt, L. E., & Barry, D. M. (2013). Predictors of neurobehavioral symptoms in a university population: A multivariate approach using a postconcussive symptom questionnaire.	To examine relative importance of neurological and behavioral factors in predicting post-concussive symptoms related to mild traumatic brain injury (TBI).	The sample consisted of 3027 college-aged students.	Participants completed a self-report questionnaire consisting of demographics, current symptoms, history of traumatic brain injury, alcohol use, and psychiatric and/or developmental disorders.	Quantitative study consisting of multivariate analysis.	The authors found that alcohol use, history of depression and/or anxiety, history of learning disability, and gender were most predictive of post-concussive symptoms. History of TBI of mildly significant with overall symptoms, but they noted a small effect size in the analysis. It was proposed that post-concussive symptoms are best viewed as a broad range of neurobehavioral symptoms mediated by factors independent of incidence of TBI.

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Author, Year, Title	Research Objectives, Hypothesis	Sample	Instruments, Variables measured	Research Design	Major Findings
Galderisi, S., Mancuso F., Mucci, A., Garramone, S., Zamboli, R., & Maj, M. (2008). Alexithymia and cognitive dysfunctions in patients with panic disorder.	To determine if symptoms of panic disorder (PD) might be related to dysfunction in fronto-temporo-limbic circuits.	The sample consisted of 32 drug-free participants with PD and 32 healthy controls.	Measures of emotional reactivity were administered in conjunction in a cognitive assessment battery that included the Picture Memory Interference Test.	Quantitative study.	The authors found alexithymia was more frequent in PD participants than in healthy controls. Alexithymia was also related with lower verbal cognitive abilities and greater susceptibility to interference from nonverbal stimuli. The findings were consistent with frontolimbic circuit dysfunction, particularly orbitofrontal and cingulate cortices.

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Author, Year, Title	Research Objectives, Hypothesis	Sample	Instruments, Variables measured	Research Design	Major Findings
Geary, E. K., Kraus, F., Pliskin, N. H., & Little, D. M. (2010). Verbal learning differences in chronic mild traumatic brain injury.	As patients with mild traumatic brain injury (mTBI) often demonstrate asymptomati c performance, it was proposed subjective memory complaints in these patients are due to subtle deficits in initial acquisition of information.	Forty participants were recruited from within the community (23 male, 17 female) who had sustained a head injury at least 6 months prior to participation in the study. A group of 35 healthy controls was matched according to age and estimated premorbid intelligence. To ensure only mTBI was included, participants were excluded if they reported loss of consciousness > 30 minutes or post-traumatic amnesia >24 hours.	The assessment battery included the California Verbal Learning Test-Second Edition (CVLT-II), Beck Depression Inventory-II, the Post-Concussion Syndrome Checklist (PCSC), the Frontal Systems Behavior Rating Scale-Self Version (FrSBE), and two measures of effort: the Test of Memory Malingering and Dot Counting. The study also utilize diffuse tensor imaging (DTI) normalized to the Montreal Neurological Institute template.	Quantitative study.	The primary finding of this study was a relationship between reduced fractional anisotropy in the left superior longitudinal fasciculus and left longitudinal fasciculus with poor performance on Trial 1 of the CVLT-II in the mTBI group. The authors noted significant differences were not found on overall performance when all five initial learning trials were measured. The proposed the inefficiency with single-trial learning may be exacerbated by the quality of day-to-day interactions for these participants and be related to subjective complaints of memory difficulties.

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Author, Year, Title	Research Objectives, Hypothesis	Sample	Instruments, Variables measured	Research Design	Major Findings
Iverson, G. L., & Lange, R. T. (2011a). Moderate and severe traumatic brain injury.	N/A	N/A	N/A	N/A	This book chapter provides an overview of mechanisms of injury for moderate and severe brain injury, epidemiology, recovery expectations, a review of typical neuropathological patterns of injury, and recommendations for neuropsychological assessment of cognitive deficits associated with injury.

Author, Year, Title	Research Objectives, Hypothesis	Sample	Instruments, Variables measured	Research Design	Major Findings
Iverson, G. L., & Lange, R.T. (2011b). Mild traumatic brain injury.	N/A	N/A	N/A	N/A	This book chapter provides an overview of mechanisms of injury for mild brain injury, epidemiology, recovery expectations, a review of typical neuropathological patterns of injury, and recommendations for neuropsychological assessment of cognitive deficits associated with injury. The chapter also includes a review of literature on patterns of cognitive deficits typically associated with mild traumatic brain injury.

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Author, Year, Title	Research Objectives, Hypothesis	Sample	Instruments, Variables measured	Research Design	Major Findings
Iverson, G. L., & Lange, R. T. (2011c). Post-Concussion Syndrome.	N/A	N/A	N/A	N/A	This book chapter reviews the literature regarding post-concussion syndrome and addresses the controversy regarding the status of the diagnosis with regards to etiology of persistent symptoms, addresses inconsistencies with regards to prevalence estimates, addresses the non-specific pattern of symptoms associated with the syndrome, discusses the likely insufficiency of a mild head injury to cause the broad range of symptoms associated with the syndrome, and provides guidance for clinicians to evaluate additional factors that may exacerbate or maintain self-reported symptoms following mild head injury.

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Author, Year, Title	Research Objectives, Hypothesis	Sample	Instruments, Variables measured	Research Design	Major Findings
Kianmahd, S. (2012). *The picture memory interference test with iranian americans: Does first language impact performance*	The Picture Memory Interference Test was designed to be a culturally neutral test of nonverbal memory performance. This study examined whether performance may be influenced by language factors in non-native English speakers.	This study utilized archival data from the Life Sciences initiative at UCLA. 103 first-language Farsi speakers were identified and compared to 103 monolingual English speakers. The study also identified 44 first-language English, Farsi speaking individuals and compared them to a matched group of 44 monolingual English speakers.	The WHO-UCLA Picture Memory Interference Test.	Quantitative study.	The study found significant difference between first-language Farsi speaking participants and their monolingual English-speaking matched counterparts. No significant differences were found between monolingual Enlish-speaking participants and those participants who identified English as their first language who also spoke Farsi The author proposed first-language characteristics may have a greater impact on nonverbal memory performance via internal verbal representations of images, highlighting the need for increased consideration of first-language effects on nonverbal tests of memory.

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Author, Year, Title	Research Objectives, Hypothesis	Sample	Instruments, Variables measured	Research Design	Major Findings
King, N. (1997). Literature review: Mild head injury : Neuropathology, sequelae, measurement and recovery.	N/A	N/A	N/A	Literature review.	This literature review addressed the neuropathology of traumatic brain injury (TBI), cognitive and somatic sequelae, methods of measurement of injury severity and cognitive changes, and course of recovery. The author concluded neuropsychological assessment is critical in assessing recovery from TBI and highlighted the role of psychological factors in treatment and recovery.

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Author, Year, Title	Research Objectives, Hypothesis	Sample	Instruments, Variables measured	Research Design	Major Findings
King, N. S., & Kirwilliam, S. (2011). Permanent post-concussion symptoms after mild head injury.	To examine a wide-range of variables in individuals reporting post-concussion symptoms (PCS) persistently following a mild head injury (MHI).	The sample consisted of 24 respondents to recruitment from a community head injury service. The sample consisted of equal male and female participants with a mean time of post-injury of 6.9 years.	Participants completed self-report questionnaires measuring severity of PCS, quality of life, anxitety/depression symptoms, post-traumatic stress symptoms, and pain levels. They then completed cognitive tests measuring verbal a visuo-spatial memory, executive functioning, processing speed, auditory attention, and effort.	Quantitative study.	The study confirmed PCS might persist on a long-term or near-permanent basis following MHI. Cognitive defficts were found on measures of processing speed and rate of verbal learning. The authors found high rates of anxiety and depression (80% and 63% respectively). It was noted that levels of anxiety accounted for 45.9% of the variance in PCS severity ratings. Higher PCS severity ratings were also corolated with lower quality of life ratings and higher rates of unemployment. The uthors highlight the importance of the psychological and quality of life factors in persistent PCS and encourage a biopsychosocial model for perpetuation of PCS ratings.

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Author, Year, Title	Research Objectives, Hypothesis	Sample	Instruments, Variables measured	Research Design	Major Findings
Lezak, M. D., Howieson, D. B., Bigler, E. D., & Tanel, D. (2012). *Neuropsychological assessment* (5th ed.).	N/A	N/A	N/A	N/A	A foundational textbook for neuropsychological assessment, this book addresses the principles of neuropsychological assessment; reviews how to plan, conduct, and interpret a comprehensive assessment; reviews neuropathological disorders for neuropsychologists; and provides a compendium of assessment tests and techniques used to assess various cognitive domains.

Author, Year, Title	Research Objectives, Hypothesis	Sample	Instruments, Variables measured	Research Design	Major Findings
Maj, M., Janssen, R., Satz, P., Zaudig, M., Starace, F., Boor, D., … Sartorius, N. (1991). The World Health Organizations' cross-cultural study on neuropsychiatric aspects of infection with the Human Immunodeficiency Virus (HIV-1).	To identify the psychiatric, neuropsychological, and neurological abnormalities associated with seropositive HIV-1 status in various geographical and socioeconomic contexts. This article describes the preparation of the study.	For this study, six centers around the world were included in: Bangkok, Thailand; Kinshasa, Zaire; Los Angeles, United States; Munich, Germany; Nairobi, Kenya; and Sao Paulo, Brazil.	A comprehensive battery was proposed consisting of a demographic survey, neurological assessment, physical assessment, cognitive assessment, and laboratory tests.	Research preparation discussion.	This paper noted the inclusion of a neuropsychological assessment battery consisting of new and/or recently (at the time) devised tests designed to minimize language and/or cultural biases. These tests included Color Trails 1 & 2, the WHO-UCLA Auditory Learning Test, and the WHO-UCLA Picture Memory Interference Test.

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Author, Year, Title	Research Objectives, Hypothesis	Sample	Instruments, Variables measured	Research Design	Major Findings
Maj, M., Satz, P., Janssen, R., Zaudig, M., Starace, F., D'Elia, L., … Sartorius, N. (1994). WHO neuropsychiatric AIDS study, cross-sectional phase II.	To examine the neurological and neuropsychological complications of HIV-1 and AIDS infections in geographically and socioeconomically diverse populations. This article examined the neuropsychological and neurological findings.	The sample descriptions were not described in this phase of the article.	The WHO-UCLA neurocognitive assessment battery, which included the Picture Memory Interference Test. Comprehensive neurological examination.	Quantitative study.	Predominant findings included the presence of prominent depressive symptoms in conjunction with subjective cognitive complaints among medically asymptomatic seropositive subjects. Cognitive sequelae were not found to be related to immunological status and/or CD-4 count.

Author, Year, Title	Research Objectives, Hypothesis	Sample	Instruments, Variables measured	Research Design	Major Findings
Martin, J. H. (2012). *Neuroanatomy text and atlas* (4th ed.)	N/A	N/A	N/A	N/A	A reference book detailing functional neuroanatomy and specifying cognitive sequelae associated with neuropathological insult to focal brain regions.

(continued)

Author, Year, Title	Research Objectives, Hypothesis	Sample	Instruments, Variables measured	Research Design	Major Findings
McDonald, C. R., Bauer, R. M., Grande, L., Gilmore, R., & Roper, S. (2001). The role of the frontal lobes in memory: Evidence from unilateral frontal resections for relief of intractable epilepsy.	To explore the relationship between memory deficits associated with frontal lobe dysfunction.	The sample consisted of 53 individuals recruited from patients that had undergone either unilateral frontal (n=13) or temporal (n=40) lobe resection.	Cognitive assessment measures included the California Verbal Learning Test-II (CVLT-II), Visual Reproduction Test I & II (VRT I & II), Logical Memory I & II from the Wechsler Memory Scale-Revised, and the Rey-Osterreith Complex Figure Test (ROCF).	Quantitative study.	Primary findings suggested suggested memory and encoding deficits in the frontal lobe resection patients not seen in patients with temporal lobe resection. Particularly, frontal lobe resection patients were more susceptible to proactive interference. The authors noted surprise that no differences were found between groups in the use of semantic clustering.

(continued)

Author, Year, Title	Research Objectives, Hypothesis	Sample	Instruments, Variables measured	Research Design	Major Findings
Niogi, S. N., Mukherjee, P., Ghajar, J., Johnson, C. E., Kolster, R., Lee, H., … McCandliss, B. D. (2008). Structural dissociation of attentional control and memory in adults with and without mild traumatic brain injury.	This study sought to identify if memory and attentional impairments secondary to traumatic brain injury (TBI) can be associated with differences in axonal white matter changes as measured by diffuse tensor imaging (DTI) in particular regions of interest (ROI).	The study utilized 43 patients prospectively recruited with mild traumatic brain injury (mTBI) as determined by Glasgow Coma Scale (GCS) between 13-15 upon presentation to the emergency department following a head injury.	The California Verbal Learning Test, Second Edition (CVLT-II).	Quantitative study.	The results indicated distinct evidence of associations between microstructural white matter integrity in specific regions of interest and memory and attentional performance. The study concluded that diffusion anisotropy measurements may be used as a quantitative biomarker for neurocognitive impairments secondary to mTBI.

(continued)

Author, Year, Title	Research Objectives, Hypothesis	Sample	Instruments, Variables measured	Research Design	Major Findings
Satz, P., Cole, M. A., Hardy, D. J., & Rassovsky, Y. (2011). Brain and cognitive reserve: Mediator(s) and construct validity, a critique	N/A	N/A	N/A	Theoretical discussion of existing cognitive constructs.	The articles discussed competing constructs of brain reserve and cognitive reserve. The first asserting that brain volume translates to increased neuronal capacity for functional cognitive performance and resilience to injury. The second asserts that specific pre-morbid intellectual factors such as level of education, serve as protective factors and increase resilience to brain injury. The article proposes alternative conceptual models derived from current literature in order to increase the ability to provide empirical support for construct validity.

Author, Year, Title	Research Objectives, Hypothesis	Sample	Instruments, Variables measured	Research Design	Major Findings
Segalowitz, S. J., & Lawson, S. (1995). Subtle symptoms associated with self-reported mild head injury.	To explore the relationship between a history of mild head injury and psychological and educational symptoms.	The sample consisted of 1,345 high school students and 2,321 university students. The sample was adjusted to represent a 50:50 gender ratio with 30-37% of the participants reporting a incidence of head injury.	Participants completed The Handedness and Health Questionnaire, which was modified for the university sample. Head injury descriptions and developmental disability history was ascertained by interview.	Quantitative study.	The findings suggest that mild head injury may be more common than typically thought as 74% of high school students and 81% of university students self-reported head injuries for which they did not go to a hospital. The authors reported head injury history was related to psychological, educational, and health-related complaints.

(continued)

Author, Year, Title	Research Objectives, Hypothesis	Sample	Instruments, Variables measured	Research Design	Major Findings
Smits, M., Houston, G. C., Dippel, D. W. J., Wielopolski, P. A., Vernooij, M. W., Koudstaal, P. J., … van der Lugt, A. (2011). Microstructural brain injury in post-concussion syndrome after minor head injury.	The study sought to correlate severity of post-concussive symptoms (PCS) with measures of micro-structural brain injury derived from diffusivity, fractional anisotropy (FA), and micro-hemorrhages.	Participants were recruited following presentation to an emergency department with blunt head trauma. The participants were 58% male, with a mean age of 26.4 years. Patients were excluded if they had abnormal head CT findings within 24 hours of injury. A healthy control group was obtained from healthy volunteers.	Each participant underwent a general neurological examination and completed the Mini Mental Status Examination (MMSE) PCS severity was determined using the Rivermead Post-concussion Symptoms Questionnaire (RPSQ). Each patient underwent magnetic resonance imaging (MRI) with conventional and diffuse tensor imaging (DTI).	Quantitative study.	The severity of self-reported PCS was correlated with a reduction if white matter integrity as determined by increased diffusivity and reduced anisotropic diffusion, particularly in the inferior fronto-occipital fasciculus, the inferior longitudinal fasciculus, and the superior longitudinal fasciculus. FA was found to be reduced, in association with increased symptom severity, in the internal capsule, corpus callosum, and parietal and frontal subcortical white matter.

(continued)

Author, Year, Title	Research Objectives, Hypothesis	Sample	Instruments, Variables measured	Research Design	Major Findings
Smits, M., Dippel, D. W. J., Houston, G. C., Wielopolski, P. A., Koudstaal, P. J., Hunink, M. G. M., & van der Lugt, A. (2009). Postconcussion syndrome after minor head injury: Brain activation of working memory and attention.	The purpose of the study was to correlate functional magnetic resonance imaging brain activation of working memory and selective attention with post-concussion symptoms (PCS).	21 patents with mild head injury (MHI; as determined by Glasgow Coma Scale between 13-15) were recruited and compared to 12 healthy controls recruited from the patients' friends, peers and/or hospital staff.	T1 and T2 weighted images were obtained from magnetic resonance imaging with activation tasks consisting of finger-taping, n-back task, and stroop task completed while imaging was being taken.	Quantitative study.	A positive correlation was found between severity of PCS and brain activation related to working memory and selective attention. In particular, the dorsolateral and ventrolateral prefrontal cortex. It was noted performance declined in patients with MHI as brain activation increased, suggesting limited cognitive resources for increasingly difficult tasks.

Author, Year, Title	Research Objectives, Hypothesis	Sample	Instruments, Variables measured	Research Design	Major Findings
Snodgrass, J. G., & Vanderwart, M. (1980). A standardized set of 260 pictures: Norms for name agreement, image agreement, familiarity, and visual complexity.	The article presented findings from previous research obtaining normative data on a set of images with potential to be used in nonverbal cognitive research.	N/A	N/A	Quantitative study.	The study sought to provide norms on a set of black and white, monochromatic, line-drawn images as determined by agreement on image name, level of familiarity, agreement on visual complexity, and agreement on image representation. The authors proposed the set of pictures provided a quantified set of pictorial representation that may be used in cognitive explorations of memory and perception.

(continued)

Author, Year, Title	Research Objectives, Hypothesis	Sample	Instruments, Variables measured	Research Design	Major Findings
Snell, D. L., Hay-Smith, E. J. C., Surgenor, L. J., & Siegert, R. J. (2013). Examination of outcome after mild traumatic brain injury: The contribution of injury beliefs and Leventhal's common sense model.	The study sought to examine associations between Leventhal's Common Sense Model (CSM) and outcome after mild traumatic brain injury (mTBI).	The sample consisted of 147 participants recruited within three months of a mTBI and assessed six months later.	Questionnaires include the Illness Perceptions Questionnaire Revised, Brief COPE, Hospital Anxiety and Depression Scale. Outcome measures consisted of the Rivermead Post-Concussion Symptoms Questionnaire and Rivermead head Injury Follow-Up Questionnaire.	Quantitative study.	The primary findings supported the theoretical supposition a descriptive model of mTBI recovery could inform approaches to research and clinical management. Consistent with the CSM, participants who attributed their symptoms to mTBI and expected this to have severe and lasting consequences were more likely to have poor clinical outcomes at six-month follow-up. The authors proposed this may aid in predictive power for identifying those at risk for developing atypical or prolonged mTBI recovering.

Author, Year, Title	Research Objectives, Hypothesis	Sample	Instruments, Variables measured	Research Design	Major Findings
Sneve, M. H., Alnæs, D., Endestad, T., Greenlee, M. W., & Magnussen, S. (2012). Visual short-term memory: Activity supporting encoding and maintenance in retinotopic visual cortex.	To examine the process by which visual information is transformed from transient stimulus-evoked sensory responses to enduring memory representations.	The study consisted of six subjects between the ages of 21-28 (5 male). Al participants were extensively trained on the procedure in order to assure successful completion during Functional magnetic resonance imaging (fMRI) scanning.	Visual stimuli were presented using a Psychophysics Toolbox function and projected to a screen inside the scanner. The fMRI images were T2 weighted and sequentially scanned.	Quantitative study.	The primary findings suggest intermediate visual areas in both the dorsal and ventral visual streams play a role in memory encoding and remain active in the seconds following the disappearance of visual stimulus from view. Additional findings suggest that memory encoding can be functionally dissociated from memory maintenance operations in the inferior frontal junction.

(continued)

Author, Year, Title	Research Objectives, Hypothesis	Sample	Instruments, Variables measured	Research Design	Major Findings
Pfleugl, G. M. U (2008). Introduction to scientific methodology.	N/A	N/A	N/A	N/A	A chapter in a manual for the Life Sciences Division of the UCLA Life Sciences Laboratory responsible for data accumulation utilized for the present study.

Author, Year, Title	Research Objectives, Hypothesis	Sample	Instruments, Variables measured	Research Design	Major Findings
Tagliaferri, F., Compagnone, C., Korsic, M., Servadei, F., & Kraus, J. (2006). A systematic review of brain injury epidemiology in Europe.	To review and compile epidemiological findings from an array of geographical regions around the world.	A Medline search was conducted for TBI-related articles from 1980 to 2003. And consisted of studies from Denmark, Sweden, Finland, Portugal, Germany, Norway, Italy, Spain, Ireland, The U.K., and France.		Systematic literature review.	The authors determined a consensus determination of European epidemiology was not possible due to differences in data reporting and operational definitions of traumatic brain injury.

(continued)

Author, Year, Title	Research Objectives, Hypothesis	Sample	Instruments, Variables measured	Research Design	Major Findings
Varnamkhasti, M., & Thomas, A. (2011). Brain and facial trauma: A neuroradiology perspective.	To summarize the pathology of blunt trauma to the head and face and the various patterns of traumatic brain injury (TBI) and describe the role of computerized tomography (CT) in both the acute setting and follow-up.	N/A	N/A	Systematic literature review.	This literature review covered the primary anatomical features relevant to blunt head and face trauma as they related to TBI, as well as the various methods of neuroradiological assessment utilized in the assessment and ongoing maintenance of treatment.

Author, Year, Title	Research Objectives, Hypothesis	Sample	Instruments, Variables measured	Research Design	Major Findings
World Health Organization. (2006). *Neurological disorders: Public health challenges*.	N/A	N/A	N/A	N/A	This book provides a review of neurological disorders and the drain on public health resources related to treatment and care. The book covers operational definitions, techniques of diagnosis, epidemiology, etiology and risk factors, acute management, rehabilitation, and research.

APPENDIX B

UCLA Informed Consent

University of California, Los Angeles

RESEARCH INFORMATION SHEET

Undergraduate Research Initiative (URI) for Life Sciences 2 Students about Cognitive Processing

You are asked to participate in a research study conducted by Gaston Pfluegl, Ph.D., Director of the Life Sciences Laboratories at UCLA and Enrique López, Psy.D., Clinical Assistant Professor from the Semel Institute for Neuroscience & Human Behavior in the Department of Psychiatry and Biobehavioral Sciences at the University of California at Los Angeles. You were selected as a possible participant in this study because you are enrolled in Life Sciences. Your participation in this research study is voluntary.

PURPOSE OF THE STUDY

The primary purpose of the study is to provide undergraduate students with a database on which they could understand research design. The study will cognitively assess undergraduate students through computerized measures in order to create a research database.

PROCEDURES

If you volunteer to participate in this study, we would ask you to do the following:
In one of the Life Sciences 2 labs, you will have the option to perform a variety of computerized measures that involves cognition.

If you wish to participate, you will only complete one of the computerized tests. Each test takes approximately 15 minutes to complete. In addition, you will fill out a computerized questionnaire at the beginning of the test. You will have the right to not answer any of the questions that you may choose not to answer. This questionnaire will also take approximately 15 minutes to complete. No identifiable information will be asked of you.

Your responses will be sent automatically and electronically to an aggregated database. Your specific scores will not be available to you or anyone. This will provide you and others with the opportunity to conduct research and generate hypothesis.

While you are conducting research hypothesis, we will only provide you with demographic information about a subgroup if that group is larger than 50. This assure your and other's anonymity. In addition, it will assist in conducting good research design with an adequate group size.

POTENTIAL RISKS AND DISCOMFORTS

I understand that the study described above may involve the following risks and/or discomforts: I may get a bit tired or anxious, but I will be encouraged to make breaks to rest should I so desire; however, there are no known physical risks.

Protocol ID:IRB#10-000283 UCLA IRB Approved Approval Date: 4/19/2014 Through: 4/18/2015 Committee: North General IRB

POTENTIAL BENEFITS TO SUBJECTS AND/OR TO SOCIETY

There may be specific benefits which will accrue to you as a result of participation in this study, including knowledge about how research is conducted at all phases of the design. Additionally, this study will provide you and others with the opportunity to conduct research with an available database. The possible benefits to humanity include better ways of evaluating individuals cognitively.

PAYMENT FOR PARTICIPATION
You will not receive monetary compensation for participation in this study.

CONFIDENTIALITY
Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission or as required by law. Confidentiality will be maintained by means of sending your responses automatically and electronically to an aggregated database. No identifiable information will be asked of you (e.g., names, date of birth, identification numbers). Additionally, no untrained individuals will have direct access to the database.

PARTICIPATION AND WITHDRAWAL
You can choose whether to be in this study or not. If you volunteer to be in this study, you may withdraw at any time without consequences of any kind. You are not required to participate in the assessment portion of the study in order to use the database for your lab assignment.

IDENTIFICATION OF INVESTIGATORS
If you have any questions or concerns about the research, please feel free to contact: Gaston Pfluegl, Ph.D., who can be reached at (310) 794-4113; Director of the Life Sciences Core Laboratories, UCLA, 2305 Life Sciences Building, Los Angeles, CA 90095-1606 and/or Enrique Lopez Psy.D., who can be reached at (310) 206-8100 and/or (310) 892-3351; 7600 Westwood Plaza, Suite C8-735, Los Angeles, CA 90024-1759.

RIGHTS OF RESEARCH SUBJECTS
You may withdraw your consent at any time and discontinue participation without penalty. You are not waiving any legal rights because of your participation in this research study. If you have questions regarding your rights as a research subject, contact the Office for Protection of Research Subjects, 102 Kinross Building, UCLA, Box 95169407, Los Angeles, CA 90095-1694, (310) 825-5344 or (310) 825-7122.

APPENDIX C

Pepperdine University IRB Approval Form

PEPPERDINE UNIVERSITY

Graduate & Professional Schools Institutional Review Board

August 13, 2014

Bryce Erich

Protocol #: P0714D03
Project Title: Detection of Traumatic Brain Injury with the Picture Memory Interference Test

Dear Mr. Erich:

Thank you for submitting your application, *Detection of Traumatic Brain Injury with the Picture Memory Interference Test,* for exempt review to Pepperdine University's Graduate and Professional Schools Institutional Review Board (GPS IRB). The IRB appreciates the work you and your faculty advisor, Dr. Woo, have done on the proposal. The IRB has reviewed your submitted IRB application and all ancillary materials. Upon review, the IRB has determined that the above entitled project meets the requirements for exemption under the federal regulations (45 CFR 46 - http://www.nihtraining.com/ohsrsite/guidelines/45cfr46.html) that govern the protections of human subjects. Specifically, section 45 CFR 46.101(b)(2) states:

> (b) Unless otherwise required by Department or Agency heads, research activities in which the only involvement of human subjects will be in one or more of the following categories are exempt from this policy:
>
> **Category (2) of 45 CFR 46.101**, research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless: a) Information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and b) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, or reputation.

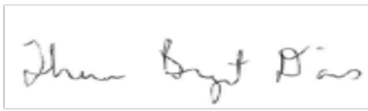
Your research must be conducted according to the proposal that was submitted to the IRB. If changes to the approved protocol occur, a revised protocol must be reviewed and approved by the IRB before implementation. For any proposed changes in your research protocol, please submit a **Request for Modification Form** to the GPS IRB. Because your study falls under exemption, there is no requirement for continuing IRB review of your project. Please be aware that changes to your protocol may prevent the research from qualifying for exemption from 45 CFR 46.101 and require submission of a new IRB application or other materials to the GPS IRB.

A goal of the IRB is to prevent negative occurrences during any research study. However, despite our best intent, unforeseen circumstances or events may arise during the research. If an unexpected situation or adverse event happens during your investigation, please notify the GPS IRB as soon as possible. We will ask for a complete explanation of the event and your response. Other actions also may be required depending on the nature of the event. Details regarding the timeframe in which adverse events must be reported to the GPS IRB and the appropriate form to be used to report this information can be found in the *Pepperdine University Protection of Human Participants in Research: Policies and Procedures Manual* (see link to "policy material" at http://www.pepperdine.edu/irb/graduate/).

Please refer to the protocol number denoted above in all further communication or correspondence related to this approval. Should you have additional questions, please contact Kevin Collins, Manager of the

Institutional Review Board (IRB) at gpsirb@peppderdine.edu. On behalf of the GPS IRB, I wish you success in this scholarly pursuit.

Sincerely,



Thema Bryant-Davis, Ph.D.
Chair, Graduate and Professional Schools IRB

cc: Dr. Lee Kats, Vice Provost for Research and Strategic Initiatives
Mr. Brett Leach, Compliance Attorney
Dr. Stephanie Woo, Faculty Advisor

APPENDIX D

Demographic Questionnaire

Is this your first time performing the URI-UCLA Memory Interference Test? ☐ Y ☐ N

If not, please indicate what trial this is: ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ >5

Age: ☐ 18 ☐ 19 ☐ 20 ☐ 21 ☐ 22 ☐ 23 ☐ 24 ☐ 25 ☐ 26 ☐ 28 ☐ >28

Gender: female ☐ male ☐

Education COMPLETED: ☐ High School ☐ First Year ☐ Sophomore ☐ Junior ☐ Senior

☐ B.S. ☐ M.S. ☐ Ph.D./M.D. ☐ Post-Doc/Residency

Have you been in special education: ☐ Yes ☐ No

Race: ☐ American Indian or Alaska Native ☐ Asian ☐ Black or African American ☐ Native Hawaiian or Pacific Islander ☐ White ☐ Hispanic, Latino or Spanish origin ☐ Interracial ☐ other ☐ undisclosed

Ethnicity:

Country of Birth:

First Language:

Primary Language Use Spoken:

Primary Language Use Written:

Primary Language Use Reading:

Fluent in how many languages: ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ >5

Language Spoken by Mother: by Father:

Handeness: ☐ Right ☐ Left ☐ Ambidextrous
If left, family history of left handeness: ☐ Yes ☐ No

Hand used for test ☐ dominant ☐ Non-Dominant

Ever had loss of consciousness: ☐ No ☐ Yes, if yes duration:

Loss of consciousness incident: ☐ head injury ☐ intoxication ☐ exhaustion ☐ other ☐ N/A

Current Alcohol Use: ☐ No ☐ Yes, if yes frequency:

Current Tobacco Use: ☐ No ☐ Yes, if yes frequency:

Current Caffeine Use: ☐ No ☐ Yes, if yes frequency:

Current Tea Use: ☐ No ☐ Yes, if yes frequency:

Current Soda Use: ☐ No ☐ Yes, if yes frequency:

How many hours ago did you have coffee: ☐0 ☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐>9 ☐N/A

How many hours ago did you have nicotine: ☐0 ☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐>9 ☐N/A

How many hours ago did you have tea: ☐0 ☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐>9 ☐N/A

How many hours ago did you have soda: ☐0 ☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐>9 ☐N/A

How many hours ago did you eat last: ☐0 ☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐>9

How many hours did you sleep last night: ☐0 ☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐>9

How many hours ago did you get up: ☐0 ☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐>9

How do you feel mentally right now: ☐very good ☐ good ☐o.k. ☐ bad ☐ very bad

How do you feel physically right now: ☐very good ☐ good ☐o.k. ☐ bad ☐ very bad

How do you feel emotionally right now: ☐very good ☐ good ☐o.k. ☐ bad ☐ very bad

How spiritual are you: ☐very much ☐ much ☐average ☐ little ☐ not at all ☐ undisclosed

How much are you in love right now: ☐very much ☐ much ☐average ☐ little ☐ not at all ☐ undisclosed

What would be best to describe your pain level right now (10=worst). : ☐0 ☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐10

APPENDIX E

PMIT Computer Instructions

INSTRUCTIONS FOR THE URI UCLA PICTURE MEMORY AND INTERFERENCE TEST

Introduction to Picture Memory Interference Test:

· You are going to see images that you need to remember. You will be shown these images one at a time. The words are things that exist in the real world.

· Please click the line below when you are ready to see and remember the images.

After Presentation of Images:

· Those were the images that you needed to remember. Now we are going to show you some more images. Some of the words will be the ones you just saw, other images will be new. You are to identify which set of images you just saw.

· Press the right arrow key if the image is one you just read or press the left arrow key if the image is new. Make sure you work as quickly as possible. Click on the line below when you are ready to see the images and make your decisions.

End:

· The test has ended. Thank you for your participation. You can return to the home page by clicking on the line below.

____

Choice Reaction Time Test Instructions:

· You are going to see the image of a "square" or the image of a "circle." Press the right arrow key (yes) if the image was a "square" or press the left key (no) if the image was not a "square." Make sure you work as quickly as possible.

· Put your index finger next to both of the arrow keys (right and left). Make sure that you 87 are an equal distance to both arrows (next to the arrow that points down on your keyboard).

· Please click the line below when you are ready to begin.

APPENDIX F

Permission for Use of Data

UNIVERSITY OF CALIFORNIA, LOS ANGELES **UCLA**

BERKELEY • DAVIS • IRVINE • LOS ANGELES • RIVERSIDE • SAN DIEGO • SAN FRANCISCO SANTA BARBARA • SANTA CRUZ

Gaston M.U. Pfluegl, Ph.D.
Academic Coordinator / Lecturer
Director of the
Life Science Core Laboratories

DEPARTMENT OF LIFE SCIENCES CORE EDUCATION
Box 951606
LOS ANGELES CA 90095-1606
Office: (310) 794-4113
e-mail: gaston@lifesci.ucla.edu

May 8th, 2014

Re: Bryce, Erich, MIT-Data

To Whom It May Concern:

I, Dr. Gaston Pfluegl, Ph.D., hereby give Bryce Erich, M.A. full permission to use Picture Memory Interference Test data from the Undergraduate Research Initiative at the University of California, Los Angeles. I understand Bryce will be using the data for clinical dissertation purposes as part of the requirement for the Doctor of Psychology (Psy.D.) program at Pepperdine University. I also give Bryce permission for possible publication purposes at a later date.

Sincerely Yours,

Gaston M.U. Pfluegl, Ph.D.

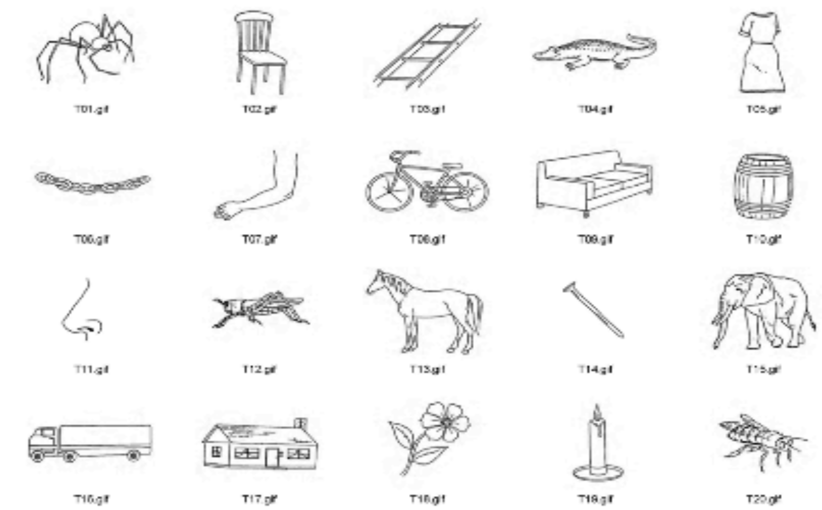
APPENDIX G

PMIT Images (Snodgrass & Vanderwart, 1980)

SHOW PICTURE LIST A

ALL PICTURE LIST A

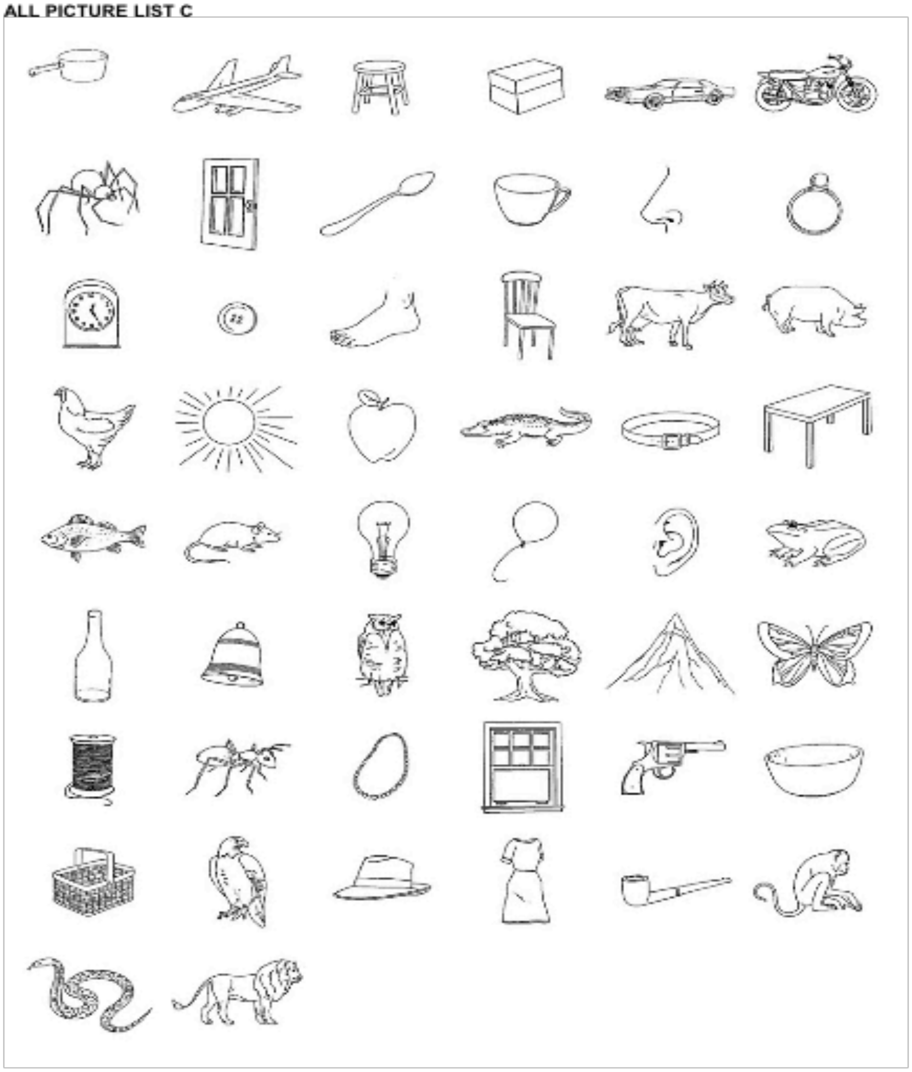
SHOW PICTURE LIST B



ALL PICTURE LIST B

SHOW PICTURE LIST C

ALL PICTURE LIST C



ALL PICTURE LIST D