DISTINGUISHING IMPAIRMENTS IN SPEED OF INFORMATION PROCESSING BETWEEN TRAUMATIC BRAIN INJURY AND CHRONIC PAIN

By

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Abstract

Speed of information processing deficits are hallmark symptoms of, and a primary consideration, in the differential diagnosis of mild traumatic brain injury (MTBI). Chronic pain is a common comorbid symptom following trauma-induced brain injury and can impact information processing speed thereby creating a potential confound in a differential diagnosis. Examining Chronic Pain, MTBI, Severe Traumatic Brain Injury (STBI), and a Healthy Control group, the Computerized Tests of Information Processing (CTIP) were used to assess processing speed. CTIP results were contrasted with traditional paper and pencil neuropsychological (NP) tests (Digit Span, Digit Symbol, Trails A & B) across groups. The Chronic Pain group performed significantly worse than the MTBI and Control groups on the CTIP with no significant differences between the Chronic Pain and Control group on any traditional NP test. Notably, there were no significant differences in scores on the CTIP or traditional NP tests between the Chronic Pain and the STBI groups. Discriminant analyses indicated the Semantic test was the strongest predictor of group membership among CTIP tasks, correctly predicting 41% of the present sample and estimating 34% correct prediction in a new sample. Digit Span was the strongest predictor when the CTIP and traditional NP tests were examined together with the model correctly predicting 47.5% in the present sample and estimating 35% correct prediction in a new sample. In regression analyses, depressive symptoms predicted Semantic CTIP scores; fatigue, and a measure of the current affective quality of pain, predicted Digit Span scores; and cumulative effects of multiple symptoms predicted most CTIP and traditional NP scores. These results provide additional evidence that individuals with Chronic Pain experience notable impairments in information processing.
speed with the potential to confound NP test results for potentially brain injured patients. Implications, limitations and future recommendations are discussed.
Acknowledgements

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<thead>
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<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>CTIP</td>
<td>Computerized Tests of Information Processing</td>
</tr>
<tr>
<td>CES-D</td>
<td>Center for Epidemiological Studies Depression Scale</td>
</tr>
<tr>
<td>ESFS</td>
<td>Empirical Sleepiness and Fatigue Scales</td>
</tr>
<tr>
<td>MTBI</td>
<td>Mild Traumatic Brain Injury</td>
</tr>
<tr>
<td>NP</td>
<td>Neuropsychological</td>
</tr>
<tr>
<td>PCD</td>
<td>Postconcussional Disorder</td>
</tr>
<tr>
<td>PCS</td>
<td>Postconcussional Syndrome</td>
</tr>
<tr>
<td>RT</td>
<td>Reaction Time</td>
</tr>
<tr>
<td>STAI</td>
<td>State Trait Anxiety Inventory</td>
</tr>
<tr>
<td>STBI</td>
<td>Severe Traumatic Brain Injury</td>
</tr>
<tr>
<td>TBI</td>
<td>Traumatic Brain Injury</td>
</tr>
<tr>
<td>TMT - A &amp; B</td>
<td>Trail-Making Test - A &amp; B</td>
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Chapter 1: General Introduction

Traumatic brain injury (TBI) results in wide-ranging impairments from subtle inconveniences to severe life-altering issues, even death. Recognition of the significance of even subtle consequences of these injuries and potential long-term effects is growing (Faul et al., 2010; Laker, 2011). Accurate diagnoses are imperative and while a severe traumatic brain injury (STBI) is readily diagnosable, a mild traumatic brain injury (MTBI) can be more difficult to identify. A neuropsychological (NP) evaluation is required to determine the extent of cognitive impairment of any TBI and may be necessary to diagnose an MTBI. Potential confounds must be considered within a NP assessment and chronic pain is known to produce particular cognitive deficits similar to those resulting from an MTBI (Nicholson & Martelli, 2006; Nicholson, Martelli, & Zasler, 2001a). Thus, the primary aim of the present research is to examine the potential impact of chronic pain, a common comorbid symptom with MTBI, on test scores obtained in a neuropsychological evaluation. TBI, chronic pain and neuropsychological testing are discussed in greater detail below, followed by specific research objectives.

Traumatic Brain Injury

Awareness of TBI has skyrocketed due, in part, to the negative outcomes reported by high profile athletes after incurring multiple concussions (Khurana & Kaye, 2012; Stern et al., 2011), and the mental health issues associated with military combat injuries (Cifu et al., 2009; Halbauer et al. 2009; Laker, 2011). Although inconsistencies regarding long-term consequences of even mild repetitive brain trauma have been
reported (Cifu et al., 2009; McCrory et al., 2009), evidence suggests a link between repeated MTBI and debilitating conditions like chronic traumatic encephalopathy. Chronic traumatic encephalopathy is a neurodegenerative disease that results in a progressive decline in cognitive functioning, development of depression and possible suicidal behaviour, aggression, poor impulse control, parkinsonism and dementia (Khurana & Kaye, 2012; Stern et al., 2011). Therefore, diagnosing, treating, and developing prevention strategies for all forms of brain injury is well warranted.

Conservative estimates indicate approximately 50,000 Canadians sustain a TBI each year. The leading causes of these accidents are: falls (42%), being struck by or against an object (31%), and motor vehicle accidents (12%). Estimates are based on emergency department visits and hospitalizations and these figures do not include TBIs treated in outpatient settings. Further, TBIs are suspected to be underreported and prevalence rates may therefore be underestimated (Colantonio et al., 2010).

Brain injuries are routinely categorized as mild, moderate or severe according to specific criteria outlined below. Accurate reports of MTBIs, however, are difficult to obtain. These injuries can be difficult to diagnose due to confounding symptoms, incidence reports are inconsistent due to varying definitions, and the injuries are frequently under-reported. After extensive review by the World Health Organization the incidence of MTBI was estimated to be 100-300 cases per 100,000 residents based on records of victims receiving hospital care. A significant number of people with MTBIs, however, never receive treatment at a hospital and as such the true population-based
incidence was estimated to be above 600 cases per 100,000 residents (Cassidy et al., 2004).

MTBI research and public awareness have coincided with international efforts to develop a consistent definition and agreed upon diagnostic criteria, treatments, return to work and return to sports (play) decisions, and prevention strategies. An in-depth evidence-based Clinical Practical Guideline for the Management of Concussion/ Mild Traumatic Brain Injury was released in 2009 by The Department of Veterans Affairs and The Department of Defense in the United States providing more clarity and consistency regarding the diagnosis and management of brain injuries (Cifu et al., 2009). New Canadian clinical practice guidelines for assessing and treating persistent symptoms following MTBI were released in 2012 after extensive review initiated by the Ontario Neurotrauma Foundation (Marshall, Bayley, McCullagh, Velikonja & Berrigan, 2012). An international effort produced a position statement also clarifying the definition and criteria for diagnosis of TBI (Menon et al., 2010). TBI was defined as “an alteration in brain function, or other evidence of brain pathology, caused by an external force.” An alteration in brain function is defined as one of several clinical signs: any loss or decreased level of consciousness; any retrograde or posttraumatic amnesia; any neurologic deficit; or any alteration in mental state at the time of the injury (confusion, disorientation, slowed thinking, etc.). Other evidence of brain pathology may include visual, imaging, or laboratory confirmation. Finally, the last criteria in the definition of TBI, caused by an external force, may include the head striking or being struck by an
object, an acceleration/deceleration movement without direct external trauma to the head (e.g., whiplash), a foreign body penetrating the brain, forces generated from events such as a blast or explosion, or other force yet to be defined (Menon et al.).

Traumatic brain injury severity is categorized as mild, moderate, or severe based on the length of Loss of Consciousness, Alteration of Consciousness, Posttraumatic Amnesia, or score on the Glasgow Coma Scale at the time of injury (see Table 1.1). Loss of Consciousness refers to any period of loss or decreased level of consciousness; Alteration of Consciousness refers to any alteration in mental state including confusion, disorientation, slowed thinking, etc.; and Posttraumatic Amnesia refers to any loss of memory for events immediately before or after the injury. The Glasgow Coma Scale is comprised of a series of evaluations of basic cognitive functions such as eye opening, verbal, and motor responses. Scores are assigned for each action according to patient responses, resulting in a total score ranging from 3-15 (see Table 1.2). If criteria for TBI severity are met in more than one category, the higher severity level is applied (Cifu et al., 2009).
### Table 1.1

**Classification of Traumatic Brain Injury Severity**

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structural imaging</td>
<td>Normal</td>
<td>Normal or abnormal</td>
<td>Normal or abnormal</td>
</tr>
<tr>
<td>Loss of Consciousness</td>
<td>0–30 min</td>
<td>&gt; 30 min and &lt; 24 hrs</td>
<td>&gt; 24 hrs</td>
</tr>
<tr>
<td>Alteration of Consciousness /mental state</td>
<td>a moment up to 24 hrs</td>
<td>&gt; 24 hours. Severity based on other criteria</td>
<td></td>
</tr>
<tr>
<td>Post-traumatic Amnesia</td>
<td>0–1 day</td>
<td>&gt; 1 and &lt; 7 days</td>
<td>&gt; 7 days</td>
</tr>
<tr>
<td>Glasgow Coma Scale (best available score in first 24 hours)</td>
<td>13-15</td>
<td>9-12</td>
<td>&lt; 9</td>
</tr>
</tbody>
</table>

### Table 1.2

**The Glasgow Coma Scale Response Chart**

<table>
<thead>
<tr>
<th>Examiners Test</th>
<th>Patient’s Response</th>
<th>Assigned Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eye opening</td>
<td>Spontaneous Opens eyes on own</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Speech Opens eyes on loud verbal command</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Pain Opens eyes to pain</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Pain Does not open eyes</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Verbal Speech Carries on a conversation correctly and is oriented to time and place</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Speech Seems confused or disoriented</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Speech Understands and talks to examiner, but makes no sense</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Speech Makes sounds that examiner cannot understand</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Speech Makes no sound</td>
<td>1</td>
</tr>
<tr>
<td>Best motor response</td>
<td>Commands Follows simple commands</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Pain Pulls examiner’s hand away</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Pain Pulls a part of his/her body away on painful stimuli</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Pain Flexes body inappropriately to pain</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Pain Decreberate posture</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Pain Has no motor response</td>
<td>1</td>
</tr>
</tbody>
</table>

Adapted from Teasdale & Jennett (1974)
Some inconsistencies remain regarding the terms *mild traumatic brain injury* and *concussion*. The increased awareness of the significance of the potential effects of concussion led to four international conferences on concussion in sport (2001, 2004, and 2008, 2012), which resulted in a consensus statement indicating that the terms *MTBI* and *concussion* should not be used interchangeably (McCrory et al., 2009; 2013). The panelists acknowledged that different injury constructs are involved in the two types of head injuries, but they did not provide a definition of MTBI. This consensus statement defines concussion as “a complex pathophysiological process affecting the brain, induced by traumatic biomechanical forces” (McCrory et al.) and a review of concussion in sport in 2012 echoed this recommended definition (Khurana & Kaye). In the comprehensive Clinical Practice Guidelines released by the Department of Veterans Affairs and the Department of Defense, however, these terms are deliberately used interchangeably. The Guidelines recommend that the terms *concussion* or *history of mild TBI* are preferred to indicate a transient condition, and that the terms *brain damage* or *brain injury* be avoided in patient care so not to reinforce potentially negative misperceptions regarding symptoms or recovery (Cifu et al., 2009). In an epidemiologic review by Laker (2011) the term *concussion* is used to refer to sports-related MTBI and *MTBI* is used to refer to non-sports-related injuries. The Canadian clinical practice guidelines do not distinguish between MTBI and concussion (Marshall, Bayley, McCullagh, Velikonja & Berrigan, 2012). For the purpose of the present research, the term *mild traumatic brain injury* (*MTBI*) will be used and includes injuries defined as concussion elsewhere.
It is estimated that a vast majority (75-90%) of reported TBIs meet criteria for MTBI and that the preponderance (approximately 80-90%) of these cases follow a predictable course with few, if any, ongoing symptoms. However, these estimates may be unreliable and suffer from heterogeneity in definitions (Cifu et al., 2009; Iverson & Lange, 2011). Accurate measures of the Loss of Consciousness, Alteration of Consciousness, Posttraumatic Amnesia and the Glasgow Coma Scale at the time of injury may not be available or may be misleading. For example, Loss of Consciousness can be difficult to assess since there is no reliable method to determine the depth of unconsciousness. Posttraumatic Amnesia can be underestimated due to brief moments of memory that create the illusion the victim has returned to normal functioning, or may be overestimated due to the inclusion of periods of sleep or when coma is medically induced. Impaired functioning due to prior ingestion of medications, alcohol, or other substance use can also confound assessments at time of injury. Often, sufferers of MTBI do not present for medical assessment unless unremitting symptoms are experienced for an extended period of time. Thus, the initial assessment may occur days, weeks or even months after the injury occurred.

Acute effects of an MTBI can include any combination of the following: physical (e.g., headache, nausea, vomiting, dizziness, fatigue, blurred vision, sleep disturbance, sensitivity to light/noise, balance problems, transient neurological abnormalities), cognitive (e.g., attention, concentration, memory, speed of information processing, judgment, executive function), or behavioral/emotional (e.g., depression, anxiety,
agitation, irritability, impulsivity, aggression) symptoms. The symptoms may resolve within minutes or hours, or may last several days or months post-injury. In a minority of cases, symptoms persist beyond six months and may last years (Cifu et al. 2009). The categorization of MTBI refers only to the initial severity of the injury and does not refer to the level of the severity of the symptoms (Cifu et al.). Long-lasting symptoms have been classified as Postconcussional Syndrome (PCS; The International Classification of Diseases, 10th Edition; ICD-10) and formerly Postconcussional Disorder (PCD; Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition; DSM-IV) but these are controversial conditions due to problematic differential diagnoses. In the recently revised DSM-V, the PCD diagnosis has been removed and a new category, Minor Neurocognitive Disorder due to Traumatic Brain Injury, has been added which may reduce diagnostic difficulties by focusing on cognitive decline and not including concomitant symptoms noted above.

Controversy has surrounded diagnoses of PCS and PCD for several reasons. For example, what may appear to be identical injuries may have significantly different effects on different people. There are numerous factors that may affect the outcome of an insult to the head as summarized in Table 1.3.
In order to be diagnosed with PCS (and formerly PCD), it would first need to be established that the person did, in fact, sustain a brain injury. It may be difficult to accurately ascertain acute symptoms if the patient initially presents weeks or months post-injury, at which time it is difficult to determine whether an injury to the brain actually occurred. In cases where an MTBI did occur, risk factors have been identified that may predispose an individual to develop persistent post-concussion symptoms. Other factors may have a direct causative effect on symptoms (e.g., nature of the injury; medical/legal iatrogenic factors) while additional issues may act to perpetuate negative outcomes. These factors are summarized in Table 1.4 below:
Table 1.4

Risk Factors for Persistent Symptoms and/or Poorer Overall Outcomes

<table>
<thead>
<tr>
<th>Pre-injury</th>
<th>Peri-injury</th>
<th>Post-injury</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Age (older)</td>
<td>- Lack of support system</td>
<td>- Compensation</td>
</tr>
<tr>
<td>- Gender (female)</td>
<td>- Acute symptom presentation (e.g., headaches,</td>
<td>- Litigation (malingering, delayed resolution)</td>
</tr>
<tr>
<td>- Low SES</td>
<td>dizziness, or nausea in the ER)</td>
<td>- Co-occurrence of psychiatric disorders</td>
</tr>
<tr>
<td>- Less education / Lower levels of intelligence</td>
<td>- Context of injury (stress, combat-related,</td>
<td>- Co-occurrence of chronic pain conditions</td>
</tr>
<tr>
<td>- Pre-neurological conditions</td>
<td>traumatic)</td>
<td>- Lack of support system</td>
</tr>
<tr>
<td>- Pre- or co-occurrence of mental health</td>
<td></td>
<td>- Low education</td>
</tr>
<tr>
<td>disorders (depression, anxiety, traumatic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>stress, or substance use)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(adapted from Cifu et al., 2009)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Patients with symptoms consistent with PCS have increased incidence of pre-existing and comorbid mental health conditions such as anxiety, mood, and substance use disorders. Notably, the persistent symptoms comprising PCS are not unique to MTBI. The symptoms occur frequently among healthy individuals and people with other conditions such as chronic pain, depression, anxiety disorders, or other injuries (Cifu et al., 2009; Halbauer et al., 2009; Iverson & Lange, 2011; Marshall, Bayley, McCullagh, Velikonja & Berrigan, 2012). Thus, a differential diagnosis can be challenging.

Neuropsychological testing is often required to assist in the diagnosis of an MTBI, particularly when persistent symptoms exist (Cifu, 2009; Halbauer, 2009; Iverson & Lange, 2011; Marshall, Bayley, McCullagh, Velikonja & Berrigan, 2012). Neuropsychological screening is also routinely used to establish baseline scores for players on sports teams at the onset of the sporting season, and is followed by further assessment if a head injury occurs (Khurana & Kaye, 2012; Makdissi et al., 2010;
Interpreting the data obtained from a neuropsychological evaluation may be particularly challenging when the patient initially presents weeks or months post-injury and at that point is also experiencing various comorbid difficulties known to potentially confound interpretation of test results. Indeed, while cognitive impairments are the hallmark symptoms of an MTBI, multiple comorbid conditions such as pain, fatigue, depression, and anxiety can also result in symptoms that are similar to those caused by an insult to the brain (Nicholson, 2000; Nicholson & Martelli, 2006).

Evidence suggests that each of these concomitant symptoms, in the absence of any type of traumatic brain injury, can be associated with particular cognitive deficits very similar to those that may result from an MTBI (Nicholson & Martelli, 2006; Nicholson, Martelli, & Zasler, 2001a). Any type of accident that has enough force to produce a potential brain injury likely has the concurrent potential to produce other physical injury, which in turn, may cause pain symptoms. In fact, chronic pain is the most common comorbid symptom reported by individuals with persistent complaints following a head injury (Nampiaparampil, 2008). Thus, chronic pain should be considered as a possible confound during a neuropsychological assessment for MTBI.

**Chronic Pain**

Pain is defined by the International Association for the Study of Pain (IASP; 2013) as: “an unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage”. Pain is considered chronic when it persists past a 3-6 month time period post-injury. Chronic pain can be a
demoralizing condition characterized not only by physical suffering but also by significant emotional distress, cognitive difficulties, and functional disability (Gatchel & Turk, 1999). Chronic pain can have a debilitating impact on an individual’s employment and income, as well as their familial and interpersonal life (Gatchel & Turk). The Canadian Pain Society reports that one in five adult Canadians suffers from chronic pain (Moulin, Clark, Speechley, & Morely-Forster, 2002; Schopflocher, Taenzer, & Jovey, 2011) and that pain is the most common reason for seeking health care (Todd et al., 2007).

Chronic pain is a common comorbid condition in individuals who have sustained a TBI. While accurate rates are difficult to determine due to the heterogeneity of TBI definitions, and different methods of measuring pain, estimates indicate that chronic pain is reported in approximately 75% of MTBI patients, 32% of STBI patients, and 43% of military TBI patients (Nampiaparampil, 2008). The lower rate of chronic pain reported by those with more severe brain injuries may be due to deficits that impair the patient’s ability to recognize or report pain (Gelber & Callahan, 2004; Young, 2007).

Multiple factors impact the experience of pain. Biological influences include preexisting physiological conditions, the precipitating injury or illness, as well as muscle atrophy and weakness that frequently result from inactivity. Some pain patients adopt avoidance behaviours believing that physical activity will exacerbate their pain and this lack of activity often leads to physical deconditioning, which may ultimately perpetuate their experience of pain (Turk, Robinson, & Burwinkle, 2004). Sleep disturbance and
fatigue may be caused by chronic pain and/or may result in heightened awareness of pain (Andersson & Hovelius, 2005; Call-Schmidt & Richardson, 2003; Menefee et al., 2000; Ohayon, 2005).

Numerous psychological factors, as reported by Gatchel and Turk (1999), may be involved in the subjective experience of pain including: preexisting and subsequent feelings of anxiety, tension, worry, depression, anger and hostility. Beliefs and attitudes about the meaning of the pain (e.g., fear of harm and/or disability), focusing excessively on the pain experience, feeling a lack of control, and even boredom, can influence the patient’s awareness of and adjustment to pain. Escape from unwanted responsibilities and/or financial compensation may also influence a patient’s experience of pain.

Thus, chronic pain is a multidimensional experience that can have a debilitating impact on functioning. In addition to the factors noted above, people who experience chronic pain often report cognitive impairments such as feeling “foggy” or having memory difficulties (McCracken & Iverson, 2001). Individuals with chronic pain show neuropsychological deficits on measures of attention, psychomotor speed, and speed of information processing (Hart et al., 2000), impairments that appear similar to those found in cases of mild brain injury (Nicholson, 2000). This overlap in symptoms suggests that chronic pain may be a confound in a TBI neuropsychological assessment.

**Neuropsychological Testing**

Recognition of the importance of neuropsychological (NP) testing following MTBI has increased due to the ability of such tests to detect subtle neurocognitive
deficits (Cifu et al., 2009; Johnson, Kegel, & Collins, 2011; McCrory et al., 2009; Podell, Gifford, Bougakov, & Goldberg, 2010; Putukian, 2011) even after the resolution of all other symptoms (Johnson, Kegel & Collins, 2011; Putukian, 2011). For instance, NP testing is an important component of assessing and managing sport-related concussions. Sports players are typically tested pre-season to provide baseline measures that can then be used to compare with test results obtained post-injury. These types of assessments are used to inform treatment and back-to-play decisions (reviews of neuropsychological assessment pertaining to sport-related concussions are provided by Putukian, 2011 and Johnson et al., 2011).

A neuropsychological assessment may be required when symptoms persist beyond a few weeks or months after any mild injury affecting the head, to determine the extent and nature of cognitive impairments and to identify whether, in fact, a brain injury is evident. Various comorbid symptoms including fatigue, depression, anxiety and/or chronic pain may exist at the time of evaluation, and chronic pain is noted as a principal complaint reported by individuals with persistent symptoms following head injury (Nampiaparampil, 2008; Nicholson, 2000). Such comorbid conditions may interfere with accurate attribution of cause when undertaking a NP evaluation.

Chronic pain is associated with impairments in cognitive functioning, creating a potential confounding factor in the differential diagnosis of MTBI and in understanding the impact of STBI. Deficits in attention, memory, speed of information processing, and executive control may be found in patients with either chronic pain and/or TBI (Hart,
Martelli & Zasler, 2000; Nicholson, 2000). The most fundamental cognitive impairment following injury to the brain has been described as a reduction in, “the basic capacity of the brain to engage efficiently in any cognitive task” (Lux, 2007, p. 954) and has been identified even in the mildest form of brain injury (Lux). A common method of evaluating diminished cognitive efficiency is through the measurement of the speed of information processing. Processing speed is important due to its impact on other cognitive functions (King, 1997; Lux, 2007). A reduction in the speed of information processing appears to underlie further cognitive impairments such as deficits in encoding, verbal comprehension, and adaptive responding to novel situations (Felmingham et al., 2004; Ferraro, 1996).

Processing speed can be defined as the amount of time required to complete a cognitive task and various methods are used to measure this construct (Martin & Bush, 2008). One common method of assessing speed of information processing is through reaction time (RT) tests. Reaction time measures have proven to be more sensitive to the effects of TBI than many of the other traditional neuropsychological tests in use (Bleiberg, Halpern, Reeves, & Daniel, 1998; Collins & Long, 1996; Maddocks & Salings, 1996). Simple and choice RT tests are easily administered, offer a valid method for evaluating cognitive function, and are recommended to be included in standard neuropsychological assessments for TBI (Braun, Daigneault, & Champagne, 1989; Elsass & Hartelius, 1985; Ferraro, 1996).
Computerized reaction time (RT) measures have demonstrated the ability to detect cognitive impairment even in cases where traditional neuropsychological tests have indicated normal functioning (Bleiberg, Halpern, Reeves, & Daniel, 1998; Bleiberg, Kane, Reeves, Garmoe, & Halpern 2000; Martin & Bush, 2008). Computerized RT tests provide measures in increments of one millisecond (ms). A 30-200 ms delay in reaction time has been observed in testing done with individuals who have sustained a MTBI (Bleiberg, Kane, Reeves, Garmoe, & Halpern). Identification of such speed-related deficits is not possible using traditional neuropsychological tests that record results in one-second increments (Bleiberg, Halpern, Reeves, & Daniel). Traditional neuropsychological tests often used to assess the speed of information processing include: The Trail-Making Test A & B (Reitan & Wolfson, 1985), the Digit Symbol Tests (Wechsler, 2008), the Symbol Digit Modality Test (Smith, 1982), and the Paced Auditory Serial Addition Task (Gronwell, 1977).

**Computerized Tests of Information Processing (CTIP)**

The CTIP (Tombaugh & Rees, 2000) was developed for use in standard clinical applications to assess the impact of TBI on the speed of information processing. The CTIP consists of three computerized tasks that progressively increase the amount of information required for processing. The most basic task is *Simple RT*, which simply requires the participant to press a key as soon as a single stimulus appears. This basic measure serves as a baseline for subsequent tasks. The second task, *Choice RT*, increases cognitive load by requiring the participant to make a decision regarding the form of the
stimulus perceived, and to select the appropriate response from one of two options on screen. The third task, *Semantic Search RT*, further increases cognitive demand by requiring the participant to process the meaning of the stimulus and then select the correct response from one of two options.

The CTIP has demonstrated the ability to distinguish among groups of people with varying levels of cognitive functioning. Significant differences in scores on all three CTIP tasks have been found between participants with an STBI and individuals with either MTBI or in a healthy control group. The MTBI participants performed significantly worse than a healthy control group on the Semantic RT test (Tombaugh, Rees, Stormer, Harrison, & Smith, 2007).

The CTIP has reliably demonstrated a “complexity effect”, wherein RT increases as difficulty of the task increases, and this effect was even greater for TBI patients as severity of injury increased (Tombaugh, Rees, Stormer, Harrison & Smith, 2007). Tombaugh et al. found that individuals with STBI have significantly slower RTs than either individuals with MTBI or those in a Control group on all three CTIP reaction time tests. Comparisons between individuals with MTBI and those in a Control group revealed no significant differences in performance on the Simple RT and Choice RT tests.

Evidence suggests that the precise measurements of processing speed obtained by the CTIP are more sensitive to subtle decrements in processing speed than other commonly used neuropsychological tests (Tombaugh, Rees, Stormer, Harrison & Smith, 2007).
Correlational analyses reveal little overlap between the CTIP and specific traditional neuropsychological tests, namely, The Trail-Making Test A & B, Digit Span Forward and Backward, Digit Symbol Substitution Test, and the Symbol Digit Modality Test, particularly for non-impaired individuals and those with STBI. These findings suggest the CTIP is measuring associated but not redundant abilities relative to those assessed by the NP processing speed tests. Thus, the CTIP appears to provide unique and sensitive measures that will assist in differential diagnoses in neuropsychological evaluations (Tombaugh & Rees, 2000; Tombaugh, Rees, Stormer, Harrison & Smith).

CTIP research has been conducted with individuals with multiple sclerosis (MS) who also typically experience a reduction in speed of information processing due to white matter degeneration (Kalmar & Chiaravalloti, 2008). For example, Reicker and colleagues found that MS participants performed significantly slower on all CTIP tasks than a healthy control group (Reicker, Tombaugh, Walker & Freedman, 2007). The MS participants also demonstrated a complexity effect, where their reaction times increased with each subsequent CTIP task. Tombaugh and colleagues compared the ability of the CTIP with the traditional 3.0 second Paced Auditory Serial Addition Test (PASAT) and the Adjusting-PASAT to detect deficits in the speed of information processing within a group of people with MS. Participants with MS demonstrated impairments in processing speed compared to a control group and the evidence suggests that the CTIP may offer a user-friendly alternative to the 3.0-second PASAT (Tombaugh, Berrigan, Walker, Freedman, 2010).
The CTIP has also demonstrated the ability to detect the simulation of attention deficits in TBI patients (Willison & Tombaugh, 2006) to an equal or better degree than that of the Test of Memory Malingering (TOMM; Tombaugh, 1996). In general, those attempting to simulate attention deficits demonstrated increased reaction times, more incorrect responses, and greater variability than either non-impaired individuals or those with TBI. Specific results varied depending on the cognitive demands of the particular RT test and the type of groups compared. For example, greater reaction time differences were observed between a group that was instructed to simulate TBI, and the MTBI and control groups on the Semantic RT test than on the Simple RT test. Comparatively, greater differences in reaction times occurred on the Simple RT test rather than the Semantic RT test when the simulation group was compared with the STBI group. The simulation group also produced a significantly higher number of incorrect responses on both the Choice and Semantic tests, and demonstrated greater variability on all three tests in comparison with the other three groups.

The CTIP possesses high test-retest reliability. Neither within-session nor between-session practice effects have been found with the CTIP, making it an ideal instrument for serial evaluations (Baird, Tombaugh, & Francis, 2007; Willison & Tombaugh, 2006). This allows the CTIP to be used on a repetitive basis when tracking recovery after a traumatic brain injury. The CTIP is also easy to administer, as it is a computer-based test that may be incorporated easily into a NP battery.

In summary, the assessment of reaction time as an index of cognitive functioning
is recommended in the evaluation of TBI and the CTIP is a user-friendly, neuropsychologically valid test that can accomplish this task. The CTIP appears to be a distinct and precise measure of processing speed that can be administered repeatedly, making it particularly useful in both the initial assessment of cognitive deficits and in monitoring neurological recovery over time. Potential confounds, however, must be considered in any neuropsychological evaluation and chronic pain is a primary complaint in those reporting persistent symptoms following trauma to the head. Therefore, it is important to ascertain the effect that chronic pain may have on CTIP scores.

The Present Research

Evidence supports the ability of the CTIP to differentiate among mild, severe, and non-brain injured individuals; between people with MS and healthy control participants; and shows promise as a viable measure of malingering. In order to extend its usefulness as an assessment instrument, it would be valuable to examine the ability of the CTIP to distinguish brain-injured patients from individuals with symptoms similar to those of documented brain injury. People with chronic pain have demonstrated cognitive impairments similar to those observed in MTBI (Nicholson, 2000), and in some cases moderate to severe brain injuries (Etherton, Bianchini, Greve & Heinly, 2005; Etherton et al., 2006; Grigsby, Rosenberg & Busenbark, 1995; Schwartz et al., 1987; Taylor, Cox, & Mailis, 1996). Chronic pain is a common comorbid symptom in individuals with TBI (Nampiaparampil, 2008), therefore, it can be difficult to accurately determine the cause of observed neuropsychological deficits in patients presenting with both pain and
potential brain injury.

The present study sought to determine whether the CTIP assessment of speed of information processing could effectively distinguish between those suffering from chronic pain without head injury and individuals with either an MTBI or an STBI. Data were collected for a Chronic Pain group without history of head injury, and for a healthy Control group without a history of head injury or chronic pain. Archival data was used to compare these two newly recruited groups with groups of people who had sustained a documented MTBI or STBI.

Performance on several traditional paper and pencil neuropsychological tests was also evaluated. All participants completed the following tests: The Trail-Making Test A & B (TMT); the Digit Symbol Substitution Test; and a version of the Digit Span test (either the Schmidt & Tombaugh (1995) or the Wechsler, (1997) version); as well as the Computerized Tests of Information Processing (CTIP). The traditional NP tests are well known, widely used measures in neuropsychological evaluations for traumatic brain injury. The majority of participants also completed tests to evaluate level of effort during the NP assessment: all of the participants in the MTBI group completed the 21-Word Test (Iverson, Franzen, & McCracken, 1991); 23% of the STBI patients completed the Test of Memory Malingering (TOMM; Tombaugh, 1996); and all of the Chronic Pain and Control group participants completed the Medical Symptom Validity Test (MSVT; Green, 2005). The MSVT is a well known, widely administered effort test that has been well researched within the chronic pain population. An examination of potential
confounding comorbid symptoms within the Chronic Pain group was also conducted. In particular, the effect of fatigue, sleepiness, depressive mood, and anxiety on speed of information processing as measured by the CTIP and the traditional NP tests, was evaluated.

**Research Objectives**

Several objectives were addressed in the present research. Preliminary analyses examined demographic variables across groups and assessed whether participants demonstrated adequate effort during neuropsychological testing. The primary aim of Study 1 was to determine whether there were significant differences among the groups (Chronic Pain, MTBI, STBI, and Controls) on CTIP reaction time scores and to examine the complexity effect of the CTIP for the Chronic Pain and Control groups. Study 2 assessed differences among the same groups (i.e., Chronic Pain, MTBI, STBI, and Controls) on several traditional NP tests and examined associations between the NP tests and the CTIP. Study 3 examined the effects of potentially confounding symptoms, such as fatigue, sleepiness, anxiety and depression, on cognitive performance in the Chronic Pain group.
Chapter 2

Study 1: Computerized Tests of Information Processing

Introduction

Impairment in the speed of information processing following TBI may be the most pervasive cognitive change experienced by the patient, and can have a significant impact on typical tasks of everyday living (Kinsella, 2008; Lux, 2007). Information processing speed is commonly measured using reaction time tests in neuropsychological evaluations. The CTIP consists of three distinct reaction time measures and was designed for use in standard clinical applications to assess the impact of traumatic brain injury on the speed of information processing. The precise measures produced by the CTIP are more sensitive to subtle decrements in processing speed than traditional paper and pencil tests commonly used in neuropsychological evaluations. Research to date indicates the CTIP has the ability to distinguish among mild, severe, and non-brain injured individuals (Tombaugh, Rees, Stormer, Harrison, & Smith, 2007). The test is also promoted as a measure of malingering due to its ability to detect the simulation of attention deficits in TBI patients (Willison & Tombaugh, 2006). It is important, however, to determine whether the CTIP is able to distinguish brain injured patients from individuals with symptoms similar to those of documented TBI.

Individuals with chronic pain have demonstrated particular cognitive impairments similar to those observed in patients with MTBI (Nicholson, 2000) and even those with moderate to severe brain injuries (Etherton, Bianchini, Greve & Heinly, 2005; Etherton et
al., 2006; Grigsby, Rosenberg & Busenbark, 1995; Schwartz et al., 1987; Taylor, Cox, & Mailis, 1996). Since chronic pain may be present in cases of suspected MTBI or STBI (Nampiaparampil, 2008), cognitive symptoms caused solely by chronic pain have the potential to interfere with accurate diagnosis of a brain injury in a NP evaluation. Therefore, a primary objective of this research was to determine the ability of the CTIP to differentiate between cognitive processing speed impairments caused by chronic pain and those caused by an MTBI or STBI.

Several additional objectives were examined in the present study for the Chronic Pain group. An evaluation of the complexity effect was conducted to determine whether an increase in reaction times occurred as cognitive demands increased across the three CTIP tasks. The impact of basic processing speed on the more advanced CTIP tasks was evaluated since the speed with which basic cognitive processes are performed is believed to limit how quickly more advanced cognitive functioning can occur. The accuracy of responding and the level of effort demonstrated during testing were also examined.

Assessment of adequate effort during testing procedures is an important component of neuropsychological evaluation. Studies have shown that level of effort and motivation can interfere with accurate determination of cognitive functioning, and are of particular concern in cases involving application for disability benefits or litigation (Lezak, Howieson, & Loring, 2004). Involvement in litigation and applications for disability benefits were also examined in the present study.

Specific hypotheses and preliminary analyses are summarized below:
**Hypothesis 1: Differences Among Groups.** A significant main effect for groups was expected. Since the present study is the first known to assess CTIP performance by people experiencing chronic pain, the analyses are considered exploratory and specific expectations were limited. It was hypothesized, however, that the Chronic Pain group would perform significantly worse than the healthy Control group on all three CTIP tasks. These results would be consistent with previous research demonstrating deficits in speed of information processing in chronic pain participants compared with healthy individuals (Hart, Martelli, & Zasler, 2000; Moriarty, McGuire, & Finn, 2011; Nicholson, 2000; Oosterman et al., 2012; Veldhuijzen et al., 2012).

In previous research, individuals with chronic pain have demonstrated deficits in cognitive functioning similar to those observed in MTBI (Nicholson, 2000), and in some cases moderate to severe brain injuries (Etherton, Bianchini, Greve & Heinly, 2005; Etherton et al., 2006; Grigsby, Rosenberg & Busenbark, 1995; Schwartz et al., 1987; Taylor, Cox, & Mailis, 1996). One of the main goals of the present research was to determine whether CTIP scores would indeed distinguish among those with chronic pain and individuals diagnosed with either a mild or severe TBI and therefore was exploratory in nature.

**Hypothesis 2: Complexity Effect.** The Chronic Pain and Control groups were expected to demonstrate the complexity effect as was found for the MTBI and STBI groups by Tombaugh et al. (2007). That is, it was hypothesized that there would be a significant main effect for test: reaction times would increase as the difficulty of the
tasks progressed across the three CTIP tests.

**Hypothesis 3: Prediction of Group Membership.** It was hypothesized that a combination of scores on the three CTIP tasks would correctly classify participants into each of the four groups (Pain, MTBI, STBI, Control) at a rate greater than chance.

**Hypothesis 4: Impact of Basic Processing Speed.** The speed with which basic cognitive processes are performed is believed to limit how quickly more advanced cognitive functioning can occur. The Simple RT task is a measure of the time taken to detect and respond to a stimulus thereby providing the most basic index of processing speed. Controlling for Simple RT was expected to reduce or eliminate differences between groups on the more advanced cognitive tasks. That is, it was hypothesized that controlling for Simple RT would reduce or eliminate group differences between the Chronic Pain group and the Control and two TBI groups on the Choice and Semantic RT tests. Such results would be consistent with the findings of Tombaugh and colleagues (2007). Specifically, there was no longer a significant difference between their MTBI and STBI groups on the Choice RT test, and the difference was reduced although not eliminated on the Semantic RT test, after controlling for Simple RT.

**Hypothesis 5: Accuracy of Responding.** It was hypothesized that the Chronic Pain and Control groups would demonstrate a high level of accuracy of responding (e.g., approximately 97%) as was found by Tombaugh and colleagues (2007) for the MTBI and STBI groups.
**Data Analyses**

The primary objectives of Study 1 involved evaluation of the CTIP reaction time scores. The CTIP presents 30 trials of each of the three RT tasks and the median of each of these sets of RT scores (measured in milliseconds) were utilized as the raw scores in the present research. While median scores may reduce the effects of potential outliers commonly found in reaction time data, outliers were identified and removed from all analyses as suggested by Tabachnick and Fidell (2007). Mean reaction time scores were calculated from the median raw scores for each group.

Preliminary analyses were conducted to examine level of effort during testing, disability status, involvement in legal proceedings, and general demographic descriptors. To assess level of effort during testing the majority of participants in the archival groups (MTBI and STBI) completed either the 21-Word Test (Iverson, Franzen, & McCracken, 1991), or the Test of Memory Malingering (TOMM; Tombaugh, 1996). The chronic pain and control group participants completed the Medical Symptom a Validity Test (MSVT; Green, 2005). Results of the MSVT were examined to determine if any participants scored below the appropriate cutoff point indicating less than adequate effort on the test. If scores on the MSVT suggested poor effort for any participants, their CTIP scores were to be examined and compared with the cutoff values identified by Willison and Tombaugh (2006) as indicators of potential malingering. A comparison of this nature would provide additional evidence to evaluate the ability of the CTIP to identify potential malingering or questionable effort. If any participants achieved scores below appropriate
cutoffs on the MSVT, they would be excluded from further analyses.

Disability status was examined and independent-samples t tests were performed to assess differences between the Disability and No Disability groups for each CTIP test. Demographic variables were examined among the groups using analyses of variance (ANOVAs) to assess age and years of education, and chi-square analysis to assess gender split.

The primary objectives of this study involved evaluation of group differences in CTIP test scores. To evaluate the first two hypotheses, a two factor (Group X Test) mixed model ANOVA was conducted. The first hypothesis was examined further by conducting a series of follow-up one-way ANOVAs to assess specific differences among the groups for each CTIP test. Pairwise comparisons, using the Bonferroni correction procedure to adjust the significance level to .05 for multiple comparisons, were performed to evaluate differences between specific groups. The second hypothesis was explored further with a follow-up repeated measures ANOVA to evaluate differences in reaction time scores as the complexity of the tests increased across the Simple, Choice, and Semantic tests, for the Chronic Pain and Control groups. Pairwise comparisons among the tests were conducted using the Bonferroni correction method.

The third hypothesis was examined using a discriminant function analysis to determine whether a combination of the three CTIP test scores would accurately predict group membership at a rate greater than chance. Mahalanobis distance scores were examined to determine whether multivariate outliers were present, and those found were
removed prior to conducting the analysis. The Box’s $M$ value was significant ($p < .001$) which suggests heterogeneity of the variance-covariance matrices. Box’s $M$ is a stringent test and the discriminant function analysis is considered robust to such heterogeneity if sample sizes are equal (Tabachnick & Fidell, 2007). Therefore, to achieve equal sample sizes one participant from the Chronic Pain group, and four participants from the MTBI group, were randomly removed from the analysis. To cross-validate these results, this procedure was repeated for ten trials. The analysis with classification results closest to the mean of the ten trials is reported.

The fourth hypothesis was explored by conducting one-way ANCOVAs to assess group differences on the Choice and Semantic RT tests using Simple RT scores as the covariate to control for the most basic cognitive processing measure. The homogeneity of slopes assumption was evaluated prior to conducting the ANCOVAs. Finally, pairwise comparisons using the Bonferroni correction method were performed following the ANCOVAs to assess specific group differences.

The fifth hypothesis was assessed through an examination of the number of correct responses for both the Choice and Semantic RT tests, for each group, and these findings were compared to those found by Tombaugh et al. (2007).

**Method**

**Participants**

Four groups of participants were recruited from the southeastern region of Ontario. Two of the groups (Chronic Pain, and Control) were newly recruited for the
The present study and the remaining two groups (MTBI, STBI) consisted of archival data (in an identity stripped SPSS file) provided by the late Dr. Tom Tombaugh of Carleton University, Ottawa, Ontario. Participants were selected for all groups such that the groups would be matched on three demographic variables: age, years of education, and gender. The Chronic Pain group was comprised of adults from the community (n=39) and the Control group consisted of healthy adults, without history of head injury, also recruited from the surrounding community (n=37). The Mild Traumatic Brain Injury (MTBI) group consisted of archival data from patients diagnosed with mild brain injuries (n=41); the Severe Traumatic Brain Injury (STBI) group consisted of archival data from patients diagnosed with severe brain injuries (n=39) (Tombaugh, Rees, Stormer, Harrison, & Smith, 2007). English was the primary language of all participants.

**Chronic Pain Group.** Adults who reported suffering from chronic pain and who had never experienced a head injury were recruited to participate in this group. Chronic pain was defined as any non-cancer related pain condition, that existed for a minimum duration of six months. Participants with chronic headaches were excluded from the study. Heterogeneous chronic pain conditions were reported by study participants. The most common primary sites of pain were: low back, shoulders/upper arms, and abdomen/stomach. The most common cause of pain was arthritis while other reported causes included: “unknown cause”, motor vehicle accident, and chronic illnesses such as fibromyalgia, Crohn’s Disease and chronic prostatitis. Recruiting occurred through several methods: 1) community dwelling adults reporting chronic pain who participated
in a previous epidemiological phone survey study (Tripp et al., 2006), and who granted permission to be contacted for future research purposes, were invited by telephone to participate in the present study; 2) advertisements were posted in offices of community-based health care providers (e.g., physicians, chiropractors, registered massage therapists); and 3) an invitation to participate was extended at a Public Pain Forum in Kingston, Ontario. Participants were offered the opportunity to have their name entered into a draw for $100 (specifically for the chronic pain group) as an incentive to participate. Copies of the posters and brochures used for recruitment are included in Appendix A.

**Control Group.** Adult participants without a history of head injury or chronic pain were recruited through community advertising (see brochures in Appendix A). These volunteers were offered the opportunity to have their name entered into a draw for $100 (for this participant group) as incentive to participate.

**Mild Traumatic Brain Injury Group (MTBI).** Data from adult patients suffering from a MTBI were drawn from a previously conducted hospital-based study in Ottawa, Ontario (Tombaugh, Rees, Stormer, Harrison, & Smith, 2007). All participants were tested within approximately one month of their injury. At the time of injury each patient had a Glasgow Coma Scale greater than 13 or experienced Loss of Consciousness for less than 5 minutes, consistent with guidelines used to categorize injury as MTBI (Cifu, 2009). The majority of participants in this group (27) suffered head injuries as a result of falls. Seven patients were injured in motor vehicle accidents, 5 were involved in
assaults, 1 in a sporting accident, and 1 was unspecified. All participants scored higher than a malingering cut-off score of 18 correct on the 21-Word Test (Iverson, Franzen, & McCracken, 1991). None of the patients were involved in litigation or disability claims.

**Severe Traumatic Brain Injury Group (STBI).** Data were collected previously (Tombaugh, Rees, Stormer, Harrison, & Smith, 2007) from patients with a STBI who were recruited through neuropsychologists and physiatrists in Ottawa, Ontario. All STBI participants were experiencing some type of significant cognitive difficulty. Glasgow Coma Scale scores were not available although Loss of Consciousness data was provided for 29 patients and ranged from “brief” to 3 months. The amount of time that had elapsed between time of injury and test date ranged from 22 days to 25 years. The majority of participants in this group (24) sustained head injuries as a result of motor vehicle accidents. Eleven participants were injured due to falls, two as a result of an assault, one due to sports injury and one injury was unspecified.

**Procedure**

A Letter of Information and Consent Form were reviewed and signed by all participants prior to data collection. Participants were screened for previous head injury, neurological disease, psychiatric conditions, medical illness, learning disabilities, or any other issues (e.g., visual impairment) that might affect test performance. Copies of the documentation used with the newly recruited Chronic Pain and Control Groups are presented in Appendices B, C, and D.

Newly recruited participants in the Chronic Pain and Control groups completed
the following questionnaires and neuropsychological tests. The measures of interest for the present study include a Background Questionnaire, the Medical Symptom Validity Test (MSVT; Green, 2005), and the Computerized Tests of Information Processing (CTIP; Tombaugh & Rees, 2000). The following measures were included in the subsequent two studies: the Trail-Making Test A & B (Reitan & Wolfson, 1985); the Digit Symbol Substitution Test (Wechsler, 1997); a version of the Digit Span test (either the Schmidt & Tombaugh, 1995; or the Wechsler, 1997, version); the Center for Epidemiological Studies Depression Scale (CES-D; Radloff, 1977); the State Trait Anxiety Inventory (STAI; Speilberger, 1983); and the Empirical Sleepiness and Fatigue Scales (ESFS; Bailes, et al., 2006). All measures are described in the applicable study.

The Chronic Pain and Control participants first completed the Background Questionnaire and Pain Questionnaire and the remaining measures were administered in random order to avoid any effects due to ordering (e.g., fatigue, influence of previous measure). Finally, a Debriefing Form (see Appendix E) was presented at completion of the session. Participants in the Control group took approximately one hour, and those in the Chronic Pain group took from one to three hours to complete all measures. Greater time to complete measures by the chronic pain group was due to more detailed responding on the pain questionnaire and brief breaks due to pain and/or fatigue.

Participants in the archival groups (MTBI and STBI) completed a flexible battery of neuropsychological tests which included the following core set of tests: the CTIP, the Trail-Making Test A & B (Reitan & Wolfson, 1985), Digit Span (Schmidt & Tombaugh,
1995) and the Digit Symbol Substitution Test (Wechsler, 1997). Test administration took approximately two hours to complete.

Materials

**Background Questionnaire.** The Background Questionnaire consisted of 9 items asking for age, gender, education level, marital status, a list of medications currently taken, amount of alcohol usually consumed, and whether any alcohol was consumed on the day the individual participated in the study (see Appendix F).

**Medical SymptomValidity Test (MSVT; Green, 2005).** The MSVT is a brief computerized memory test designed to assess effort and is used to identify whether NP test results may be considered a valid indication of ability. Four aspects of memory are assessed after the presentation of ten simple word pairs (e.g., soccer – ball). Immediate recognition (IR) requires the respondent to recognize one of the original words when paired with a new word (e.g., soccer – basketball) directly after presentation of the list. The delayed recognition (DR) subtest repeats this procedure, using a different foil word, after a ten minute delay. Paired associate recall (PA) requires the respondent to choose the second word from each pair when provided with the first word and a list of 6 different options. Finally, free recall (FR) requires the respondent to recall as many words as possible from the original list without prompts. At the end of the test, the respondent is asked whether s/he made a full effort on the test (yes or no). Test results are automatically compared with expected results according to normative data for diverse groups including patients with neurological disorders, MTBI, STBI, psychological
disorders, chronic pain patients, intellectually disabled children and adults, and normal controls. Validity of responses may be questionable if scores are lower than expected and the respondent has reported making full effort on the test. Scores below the 85% cut-off across primary sub-tests, 70% cut-off for Paired Associates, and 50% cut-off for Free Recall are considered to indicate poor effort. Sensitivity and specificity in detecting poor effort are reported near 100% (Green, 2005). Indication of poor effort on the MSVT would suggest caution regarding the validity of responses on other tests also administered (Heilbronner et al., 2009) and therefore the individual would be eliminated from the study.

**Computerized Tests of Information Processing (CTIP; Tombaugh & Rees, 2000).** The CTIP consists of three computerized tasks that progressively increase the amount of information that must be processed. As the cognitive load increases in each progressive task, a decrease in the speed of processing typically occurs. The first task, *Simple RT*, is the most basic measure and serves as a baseline for subsequent tasks. When a single stimulus (X) appears at the centre of the screen, the participant is required to press the space bar immediately. The amount of time required to process and react to the stimulus is recorded. The second task, *Choice RT*, increases the cognitive load by adding a decisional component to the process. The participant is required to press the right key when the word “DUCK” appears on the screen, and to press the left key when the word “KITE” appears on the screen. Here the participant must process two pieces of information: he/she must first process the stimulus, and then decide which is the
appropriate response based on the “form” of the stimulus. The third task, *Semantic Search RT*, further increases cognitive demand by including a conceptual aspect to the process. The participant must decide if a word belongs to a specific category and then choose the appropriate response. A word representing one of four categories (Weapon, Furniture, Bird, Fruit) is presented randomly on the computer screen on each trial. Approximately two seconds later another word is presented below the category, and the participant must decide if the second word is a member of the initial category word. The right key is depressed if the categories match and the left key is depressed if the categories do not match. In this third task the participant must process the meaning of the stimulus (conceptual/semantic processing) before deciding on the correct response. A significant increase in reaction time compared to the previous two tasks is evident in cognitively intact participants. Fifty trials are used for each of the three tasks. Relatively high test-retest reliability coefficients have been reported for all three reaction time tasks. Coefficients for the Simple RT task range from .36 to .84 with the lowest value reported for an initial retest within one week. Higher coefficients were found for subsequent weekly retests over 3 weeks and finally at 6 months. Test-retest reliability coefficients for the Choice RT and Semantic RT tasks over the same time periods are reported to be .54 to .84 (Baird, Tombaugh, & Francis, 2007).

**Pain Questionnaire.** The Pain Questionnaire (see Appendix G) consists of 20 items most of which were selected from the Philadelphia Pain Questionnaire (PPQ) and the Short-Form McGill Pain Questionnaire (SF-MPQ; Melzack, 1987). Thirteen items
from the PPQ were included to provide an overall description of the location, cause and duration of the pain. Pain severity is assessed on several dimensions (sensory, affective and intensity) using the SF-MPQ. Pain affect is more complex than pain intensity and there are fewer options available to assess it (Jensen & Karoly, 2001). The SF-MPQ consists of 15 word descriptors of pain that assess sensory and affective qualities of pain and an overall measure of pain intensity assessed by a numeric ratings scale from 0 – “no pain” to 10 – “worst possible pain”. Eleven descriptors represent the sensory dimension of pain experience (e.g., throbbing, stabbing, gnawing) and four descriptors represent the affective dimension (e.g., tiring-exhausting, fearful). Each descriptor is rated on a 4-point intensity scale ranging from 0 (none) to 3 (severe) and are summed to provide the Pain Rating Index-Total (PRI-T). Scores range from 0 to 45 where higher scores on the PRI-T indicate greater overall pain. The measure has two subscales: sensory subscale, scores range from 0 to 33 to provide the Pain Rating Index-Sensory (PRI-S); and the affective subscale, scores range from 0 to 12 to provide the Pain Rating Index-Affective (PRI-A). The SF-MPQ is a reliable and valid measure, commonly used in clinical pain applications (Melzack, 1987). Internal consistencies are reported to range from .70 - .89 (Burckhardt & Jones, 2003; Wright et al., 2001).

Results

Preliminary Analyses

Effort Testing. To assess level of effort during NP testing, all participants in the MTBI group completed the 21-Word Test (Iverson, Franzen, & McCracken, 1991) and
obtained a score greater than the malingering cutoff score of 18 correct responses. Ten of
the participants in the STBI group completed the TOMM (Tombaugh, 1996) and
achieved a score higher than the 45 correct criterion score.

All participants in the Chronic Pain and Control groups completed the Medical
Symptom Validity Test (MSVT; Green 2005) to assess effort during testing. All
participants achieved a score suggestive of adequate effort and therefore remained in the
present study.

**Disability.** None of the TBI participants were involved in disabilities claims
(Tombaugh et al., 2007). Nine out of the 39 participants with chronic pain reported
receiving some type of disability or worker’s compensation payment related to their pain
condition. One additional person reported planning an application for such payment.

Analyses were conducted for the Chronic Pain group to determine if there were
any significant differences in demographic variables or CTIP test scores between
participants applying for, or receiving, a disability payment (Disability group) and those
without such payment (No Disability group). Independent-samples *t* tests indicated there
were no significant differences between the Disability group and the No Disability group
for age: *t*(37) = -1.60, *p* = .12; education level: *t*(37) = .07, *p* = .95; Simple RT: *t*(37) =
.34, *p* = .73; Choice RT: *t*(37) = .07, *p* = .95; and Semantic RT: *t*(37) = -1.10, *p* = .28.

**Legal Proceedings.** None of the TBI participants (Tombaugh et al., 2007) or the
chronic pain participants were involved in litigation.
**Demographics.** Demographic information including mean age, years of education, and gender split for each group is summarized in Table 2.1.

One-way analyses of variance (ANOVAs) indicated there were no significant differences in age, $F(3, 152) = 2.36, p = .07$, or years of education, $F(3, 152) = 2.50, p = .06$, among the groups. A two-way contingency table analysis indicated the gender split among the groups was not significant, Pearson $\chi^2(3, N = 156) = 7.35, p = .06$, phi = .22.

Table 2.1

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (SD)</th>
<th>Years of education (SD)</th>
<th>Gender M/F</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>39.22 (16.31)</td>
<td>14.24 (2.02)</td>
<td>19/18</td>
<td>37</td>
</tr>
<tr>
<td>Chronic Pain</td>
<td>46.62 (13.97)</td>
<td>13.95 (2.59)</td>
<td>15/24</td>
<td>39</td>
</tr>
<tr>
<td>MTBI</td>
<td>38.63 (17.70)</td>
<td>13.80 (2.25)</td>
<td>28/13</td>
<td>41</td>
</tr>
<tr>
<td>STBI</td>
<td>39.10 (13.87)</td>
<td>12.90 (2.21)</td>
<td>22/17</td>
<td>39</td>
</tr>
</tbody>
</table>

*Note. MTBI = Mild traumatic brain injury; STBI = Severe traumatic brain injury*

**Computerized Tests of Information Processing Analyses**

**Descriptives.** Examination of the CTIP reaction time scores revealed three outliers all of which were removed prior to any subsequent analyses as suggested by Tabachnick and Fidell (2007): one participant in the MTBI group whose scores were all greater than 4 SD above the mean (Simple RT 681 ms; Choice RT 1115 ms; Semantic RT 1813 ms); an MTBI participant whose scores for the Choice and Semantic tests were greater than 3 SD above the mean (Simple RT 322 ms; Choice RT 1011 ms; Semantic RT 1709 ms); and one participant in the STBI group whose Semantic RT score was 5 SD above the mean (Simple RT 478 ms; Choice RT 889 ms; Semantic RT 2892 ms).
Reaction time scores for the Simple, Choice and Semantic subtests for each group are summarized in Table 2.2 (outliers removed).

Table 2.2

*Computerized Tests of Information Processing Mean Reaction Time Scores (in milliseconds)*

<table>
<thead>
<tr>
<th>GROUP</th>
<th>N</th>
<th>Mean Reaction Time Scores (ms) (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Simple</td>
</tr>
<tr>
<td>Control</td>
<td>37</td>
<td>314 (32.41)</td>
</tr>
<tr>
<td>MTBI</td>
<td>41</td>
<td>306 (51.27)</td>
</tr>
<tr>
<td>Chronic Pain</td>
<td>39</td>
<td>342 (53.25)</td>
</tr>
<tr>
<td>STBI</td>
<td>39</td>
<td>367 (82.62)</td>
</tr>
</tbody>
</table>

*Note.* MTBI = Mild traumatic brain injury; STBI = Severe traumatic brain injury

**Reaction Time Analyses.** To examine the first two hypotheses, the assessment of differences in reaction time scores among the groups and evaluation of the complexity effect, a two factor (Group X Test) mixed model ANOVA was conducted. All effects were significant, Group: $F(3, 152) = 15.10, p < .001$; Test: $F(2, 304) = 719.71, p < .001$; and Group X Test: $F(6, 304) = 7.48, p < .001$. The significant main effects confirm that reaction times differed significantly among the groups and that reaction time increased as the tests became more complex. The significant interaction indicates that differences among the groups increased as the tests became progressively more difficult. Each hypothesis is explored in more detail below.

**Hypothesis 1: Differences in Reaction Time Scores Among Groups.** The primary aim of study 1 was to determine whether the CTIP scores would differ between groups of patients suffering from a TBI and those with chronic pain. The significant main
effect of Group in the above-noted ANOVA confirmed there was a significant difference in reaction time scores among the groups. A subsequent series of one-way ANOVAs indicated a significant effect for all three reaction time tests: Simple RT, $F(3, 152) = 9.01, p < .001$, partial $\eta^2 = .15$; Choice RT, $F(3, 152) = 10.74, p < .001$, partial $\eta^2 = .18$; and Semantic RT, $F(3, 152) = 12.03, p < .001$, partial $\eta^2 = .19$.

Results of pairwise comparisons between groups using the Bonferroni correction procedure are presented in Table 2.3 (Simple RT), Table 2.4 (Choice RT), and Table 2.5 (Semantic RT). Most notably, there were significant differences between the Chronic Pain group and both the Control and MTBI groups while there were no significant differences in reaction times between the Chronic Pain and STBI groups. These results are summarized in Figure 2.1.

Table 2.3

*Simple RT Scores: Pairwise Comparisons Between Groups*

<table>
<thead>
<tr>
<th>Group (I)</th>
<th>Group (J)</th>
<th>Mean Difference (I – J)</th>
<th>Std. Error</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chronic Pain</td>
<td>Control</td>
<td>28.26</td>
<td>13.30</td>
<td>.21</td>
</tr>
<tr>
<td></td>
<td>MTBI</td>
<td>35.74*</td>
<td>12.96</td>
<td>.04</td>
</tr>
<tr>
<td></td>
<td>STBI</td>
<td>-24.82</td>
<td>13.12</td>
<td>.36</td>
</tr>
<tr>
<td>Control</td>
<td>Chronic Pain</td>
<td>-28.26</td>
<td>13.30</td>
<td>.21</td>
</tr>
<tr>
<td></td>
<td>MTBI</td>
<td>7.49</td>
<td>13.14</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>STBI</td>
<td>-53.08*</td>
<td>13.30</td>
<td>.001</td>
</tr>
<tr>
<td>MTBI</td>
<td>Chronic Pain</td>
<td>-35.74*</td>
<td>12.96</td>
<td>.04</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>-7.49</td>
<td>13.14</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>STBI</td>
<td>-60.57*</td>
<td>12.96</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>STBI</td>
<td>Chronic Pain</td>
<td>24.82</td>
<td>13.12</td>
<td>.36</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>53.08*</td>
<td>13.30</td>
<td>.001</td>
</tr>
<tr>
<td></td>
<td>MTBI</td>
<td>60.57*</td>
<td>12.96</td>
<td>&lt; .001</td>
</tr>
</tbody>
</table>

*Note.* *The mean difference is significant at the .05 level using Bonferroni correction procedure; MTBI = Mild traumatic brain injured; STBI = Severe traumatic brain injured
Table 2.4

*Choice RT Scores: Pairwise Comparisons Between Groups*

<table>
<thead>
<tr>
<th>Group (I)</th>
<th>Group (J)</th>
<th>Mean Difference (I – J)</th>
<th>Std. Error</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chronic Pain</td>
<td>Control</td>
<td>85.80*</td>
<td>28.99</td>
<td>.02</td>
</tr>
<tr>
<td></td>
<td>MTBI</td>
<td>95.98*</td>
<td>28.26</td>
<td>&lt;.01</td>
</tr>
<tr>
<td></td>
<td>STBI</td>
<td>-39.82</td>
<td>28.61</td>
<td>1.00</td>
</tr>
<tr>
<td>Control</td>
<td>Chronic Pain</td>
<td>-85.80*</td>
<td>28.99</td>
<td>.02</td>
</tr>
<tr>
<td></td>
<td>MTBI</td>
<td>10.18</td>
<td>28.65</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>STBI</td>
<td>-125.62*</td>
<td>28.99</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>MTBI</td>
<td>Chronic Pain</td>
<td>-95.98*</td>
<td>28.26</td>
<td>&lt;.01</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>-10.18</td>
<td>28.65</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>STBI</td>
<td>-135.80*</td>
<td>28.26</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>STBI</td>
<td>Chronic Pain</td>
<td>39.82</td>
<td>28.61</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>125.62*</td>
<td>28.99</td>
<td>&lt;.001</td>
</tr>
<tr>
<td></td>
<td>MTBI</td>
<td>135.80*</td>
<td>28.26</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

*Note.* *The mean difference is significant at the .05 level using the Bonferroni correction procedure; MTBI = Mild traumatic brain injured; STBI = Severe traumatic brain injured

Table 2.5

*Semantic RT Scores: Pairwise Comparisons Between Groups*

<table>
<thead>
<tr>
<th>Group (I)</th>
<th>Group (J)</th>
<th>Mean Difference (I – J)</th>
<th>Std. Error</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chronic Pain</td>
<td>Control</td>
<td>197.88*</td>
<td>62.01</td>
<td>.01</td>
</tr>
<tr>
<td></td>
<td>MTBI</td>
<td>178.96*</td>
<td>60.44</td>
<td>.02</td>
</tr>
<tr>
<td></td>
<td>STBI</td>
<td>-116.44</td>
<td>61.19</td>
<td>.35</td>
</tr>
<tr>
<td>Control</td>
<td>Chronic Pain</td>
<td>-197.88*</td>
<td>62.01</td>
<td>.01</td>
</tr>
<tr>
<td></td>
<td>MTBI</td>
<td>-18.92</td>
<td>61.27</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>STBI</td>
<td>-314.32*</td>
<td>62.01</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>MTBI</td>
<td>Chronic Pain</td>
<td>-178.96*</td>
<td>60.44</td>
<td>.02</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>18.92</td>
<td>61.27</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>STBI</td>
<td>-295.40*</td>
<td>60.44</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>STBI</td>
<td>Chronic Pain</td>
<td>116.44</td>
<td>61.19</td>
<td>.35</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>314.32*</td>
<td>62.01</td>
<td>&lt;.001</td>
</tr>
<tr>
<td></td>
<td>MTBI</td>
<td>295.40*</td>
<td>60.44</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

*Note.* *The mean difference is significant at the .05 level using the Bonferroni correction procedure; MTBI = Mild traumatic brain injured; STBI = Severe traumatic brain injured
Figure 2.1. Computerized Tests of Information Processing (CTIP) subtest (Simple, Choice, Semantic) results (mean raw scores ± SEM) for Controls (n = 37), Mild traumatic brain injured (MTBI; n = 41), Chronic Pain (Pain; n = 39), and Severe traumatic brain injured (STBI; n = 39) groups. Corresponding letters (a,b,c,d) indicate significant differences between groups for each subtest.
Hypothesis 2: Complexity Effect. The complexity effect occurs when an increase in reaction time is demonstrated as tasks become progressively more demanding. A significant main effect of Test was found in the above-noted mixed model ANOVA. Follow-up repeated measures ANOVAs were conducted to evaluate differences in reaction time scores as the complexity of the tests increased across the Simple, Choice, and Semantic tests, for the Chronic Pain and Control groups. The complexity effect was demonstrated by the MTBI and STBI groups as previously reported by Tombaugh and colleagues (2007).

As hypothesized, results of the repeated measures ANOVAs revealed significant effects for both groups: Wilks’s $\Lambda = .09, F(2, 37) = 193.37, p < .001, \eta^2 = .91$ for the Chronic Pain group; and Wilks’s $\Lambda = .07, F(2, 35) = 233.97, p < .001, \eta^2 = .93$ for the Control group. Pairwise comparisons confirmed there were significant differences among all three subtests for both groups as shown in Table 2.6. Thus, the complexity effect was demonstrated for both groups: reaction times increased (i.e., from Simple, to Choice, to Semantic) as the difficulty of the task increased, as shown in Figure 2.1.

Table 2.6
Pairwise Comparisons of Differences in Reaction Time Scores (ms) Between CTIP Tests

<table>
<thead>
<tr>
<th>Group</th>
<th>Subtests (I - J)</th>
<th>Mean Difference (I – J)</th>
<th>SE</th>
<th>Sig*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chronic Pain</td>
<td>Simple - Choice</td>
<td>-296</td>
<td>18.81</td>
<td>&lt;.001</td>
</tr>
<tr>
<td></td>
<td>Choice - Semantic</td>
<td>-375</td>
<td>28.95</td>
<td>&lt;.001</td>
</tr>
<tr>
<td></td>
<td>Simple – Semantic</td>
<td>-671</td>
<td>35.28</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Control</td>
<td>Simple - Choice</td>
<td>-229</td>
<td>11.32</td>
<td>&lt;.001</td>
</tr>
<tr>
<td></td>
<td>Choice - Semantic</td>
<td>-263</td>
<td>32.83</td>
<td>&lt;.001</td>
</tr>
<tr>
<td></td>
<td>Simple – Semantic</td>
<td>-502</td>
<td>35.73</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

*Note: All tests were significant at .05 level using Bonferroni correction procedure
Figure 2.2. Mean reaction time (RT; ms) for Simple, Choice, and Semantic subtests of the Computerized Tests of Information Processing for Controls (Ctrls), Mild traumatic brain injured (MTBI), Chronic Pain (Pain), and Severe traumatic brain injured (STBI) groups.

**Hypothesis 3: Prediction of Group Membership.** A discriminant function analysis was conducted to determine whether a combination of scores on the three CTIP tests would classify participants correctly into each of the four groups (MTBI, STBI, Chronic Pain, Control) at a rate greater than chance. Prior to conducting the analysis, three multivariate outliers with scores greater than the Mahalanobis distance critical value (11.34) were removed: 2 MTBI participants (scores 11.73 and 12.48) and 1 Chronic Pain participant (score 16.10).
The discriminant function analysis produced a significant overall Wilk’s lambda, 
\[ \Lambda = .79, \chi^2 (9, N = 148) = 34.15, p < .01, \] indicating that overall the reaction time tests did
differentiate among the four groups. None of the remaining functions were significant
and therefore only the first function is interpreted.

Table 2.7 presents the correlations between each CTIP test and the discriminant
function as well as the standardized weights. Based on these coefficients, the Semantic
RT test has the strongest ability to predict group membership. Examination of the group
means revealed that the STBI group had the highest mean \( M = .71 \) on the discriminant
function followed by the Chronic Pain \( M = .24 \), Control \( M = -.49 \), and MTBI \( M = -
.46 \) groups.

Table 2.7

<table>
<thead>
<tr>
<th>CTIP Test</th>
<th>Standardized Coefficients</th>
<th>Correlations with Discriminant Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Semantic RT</td>
<td>.58</td>
<td>.89</td>
</tr>
<tr>
<td>Choice RT</td>
<td>.30</td>
<td>.83</td>
</tr>
<tr>
<td>Simple RT</td>
<td>.31</td>
<td>.75</td>
</tr>
</tbody>
</table>

As can be seen in Table 2.8, the classification results indicate that the model
correctly predicts group membership for 41% of the participants in this study which is
64% higher than the proportional by chance accuracy rate of 25%. Finally, to assess the
accuracy of the classification procedure in a new sample, the leave-one-out technique resulted in 34% of the cases being correctly classified, a rate that is 36% greater than the by chance accuracy rate.

Table 2.8

*Prediction of Group Membership from the Discriminant Analysis*

<table>
<thead>
<tr>
<th>Classification Results&lt;sup&gt;a,c&lt;/sup&gt;</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groups</td>
<td>MTBI</td>
<td>STBI</td>
<td>Control</td>
<td>Pain</td>
<td></td>
</tr>
<tr>
<td>Original Count</td>
<td>MTBI</td>
<td>13</td>
<td>8</td>
<td>10</td>
<td>6</td>
</tr>
<tr>
<td>STBI</td>
<td>8</td>
<td>22</td>
<td>3</td>
<td>4</td>
<td>37</td>
</tr>
<tr>
<td>Control</td>
<td>9</td>
<td>4</td>
<td>18</td>
<td>6</td>
<td>37</td>
</tr>
<tr>
<td>Pain</td>
<td>12</td>
<td>11</td>
<td>6</td>
<td>8</td>
<td>37</td>
</tr>
<tr>
<td>%</td>
<td>MTBI</td>
<td>35.1</td>
<td>21.6</td>
<td>27.0</td>
<td>16.2</td>
</tr>
<tr>
<td>STBI</td>
<td>21.6</td>
<td>59.5</td>
<td>8.1</td>
<td>10.8</td>
<td>100.0</td>
</tr>
<tr>
<td>Controls</td>
<td>24.3</td>
<td>10.8</td>
<td>48.6</td>
<td>16.2</td>
<td>100.0</td>
</tr>
<tr>
<td>Pain</td>
<td>32.4</td>
<td>29.7</td>
<td>16.2</td>
<td>21.6</td>
<td>100.0</td>
</tr>
<tr>
<td>Cross-validated&lt;sup&gt;b&lt;/sup&gt; Count</td>
<td>MTBI</td>
<td>11</td>
<td>9</td>
<td>12</td>
<td>5</td>
</tr>
<tr>
<td>STBI</td>
<td>8</td>
<td>18</td>
<td>3</td>
<td>8</td>
<td>37</td>
</tr>
<tr>
<td>Control</td>
<td>10</td>
<td>4</td>
<td>16</td>
<td>7</td>
<td>37</td>
</tr>
<tr>
<td>Pain</td>
<td>12</td>
<td>13</td>
<td>7</td>
<td>5</td>
<td>37</td>
</tr>
<tr>
<td>%</td>
<td>MTBI</td>
<td>29.7</td>
<td>24.3</td>
<td>32.4</td>
<td>13.5</td>
</tr>
<tr>
<td>STBI</td>
<td>21.6</td>
<td>48.6</td>
<td>8.1</td>
<td>21.6</td>
<td>100.0</td>
</tr>
<tr>
<td>Control</td>
<td>27.0</td>
<td>10.8</td>
<td>43.2</td>
<td>18.9</td>
<td>100.0</td>
</tr>
<tr>
<td>Pain</td>
<td>32.4</td>
<td>35.1</td>
<td>18.9</td>
<td>13.5</td>
<td>100.0</td>
</tr>
</tbody>
</table>

a. 41.2% of original grouped cases correctly classified.
b. Cross validation is done only for those cases in the analysis. In cross validation, each case is classified by the functions derived from all cases other than that case.
c. 33.8% of cross-validated grouped cases correctly classified.
**Hypothesis 4: Impact of Basic Processing Speed.** The speed with which basic cognitive processes are conducted is believed to limit how quickly more complex cognitive processing can occur. To assess the presence of this effect using the CTIP RT measures, two ANCOVAs were conducted to control for the effect of Simple RT on the Choice and Semantic RT tests.

Preliminary analyses are routinely conducted prior to ANCOVAs to evaluate the homogeneity-of-slopes assumption. In the present analyses, it was expected that basic processing speed as measured by the covariate, Simple RT, would be directly related to the more advanced CTIP measures, Choice and Semantic RT. The purpose of the analyses was to determine to what degree the Simple RT task would account for differences among the groups on the two more advanced tests. An examination of the interaction between the covariate (Simple RT) and the factor (Groups) indicated, however, that there were no significant differences among the groups as a function of the covariate for Choice RT, \( F(3, 148) = .93, \text{MSE} = 10,509.88, p = .43, \text{partial } \eta^2 = .02 \); whereas for Semantic RT, differences among the groups were found to vary as a function of the covariate: \( F(3, 148) = 6.48, \text{MSE} = 360,417.72, p < .001, \text{partial } \eta^2 = .12 \).

ANCOVAs were conducted indicating that controlling for Simple RT reduced but did not eliminate the significant main effect of Group for both reaction time tests: Choice RT, \( F(3, 151) = 3.39, \text{MSE} = 11,302.96, p = .02, \text{partial } \eta^2 = .06 \); and Semantic RT, \( F(3, 151) = 5.33, \text{MSE} = 328,800.70, p < .01, \text{partial } \eta^2 = .10 \). While group membership still accounted for a significant portion of the variance in each analysis, Simple RT accounted
for the greatest percentage of variance in the two advanced reaction time tests as assessed by partial $\eta^2$. For the Choice RT test, Simple RT scores accounted for 30% of the variance while group membership accounted for 6%. For the Semantic RT test, Simple RT scores accounted for 16% of the variance while group membership accounted for 10%.

While the main effect of Group was significant, pairwise comparisons using the Bonferroni correction procedure indicated that group differences were eliminated for the Choice RT scores, and only two significant group differences remained for the Semantic RT scores: the STBI group was significantly slower than both the MTBI group ($p = .02$) and the Control group ($p < .01$).

**Hypothesis 5: Accuracy of Responses.** The Choice and Semantic subtests require participants to select the appropriate stimulus on each of 30 trials per subtest. The mean performance for each subtest for all four groups was highly accurate at 97% (i.e., 29 correct). These results were expected and are consistent with those found by Tombaugh and colleagues (2007) for both the MTBI and STBI groups on both tests (97% correct). No further analyses regarding accuracy of responses were conducted.

**Discussion**

Preliminary analyses evaluated demographic factors across the groups and assessed whether participants appeared to demonstrate adequate effort during testing. The primary aim of Study 1 was to determine whether the speed of information processing as assessed by CTIP RT scores, varied among individuals suffering from a
MTBI, STBI, chronic pain, and healthy control groups. Results and implications are discussed below.

**Preliminary Analyses**

**Effort Testing.** All participants were considered to have applied adequate effort during testing as evidenced by their results on the MSVT (Green 2005), 21-Word Test (Iverson, Franzen, & McCracken, 1991), or the TOMM (Tombaugh, 1996). Based on these results, all participants were retained in the present study. Since none of the participants who completed the MSVT (Chronic Pain and Control groups) scored below cutoff points, comparisons with the CTIP cutoff values identified by Willison and Tombaugh (2006), as indicators of potential malingering were not possible.

**Disability and Legal Proceedings.** None of the participants in either of the TBI groups were involved in disabilities claims and there were no significant differences in CTIP test scores between Chronic Pain participants who were receiving disability payments and those who were not. None of the participants in any of the groups reported being involved in any litigation related to their health status.

**Demographic Comparisons.** There were no significant differences in age, level of education, or gender split among the groups.

**CTIP Reaction Time Scores**

**Hypothesis 1: Differences in Reaction Time Scores Among Groups.** As hypothesized, the Chronic Pain group demonstrated impaired performance on the CTIP. In comparison with the healthy control group, the Chronic Pain group demonstrated
significantly longer reaction times on the Choice and Semantic, but not the Simple RT tests. These results are consistent with studies indicating that individuals with chronic pain demonstrate impairments in some types of cognitive functioning in comparison with healthy individuals (Hart, Martelli, & Zasler, 2000; Moriarty, McGuire, & Finn, 2011; Nicholson, 2000; Oosterman et al., 2012; Veldhuijzen et al., 2012).

Notably, there were no significant differences in any of the CTIP reaction time scores between the Chronic Pain and the STBI group. Further, the chronic pain group scored significantly worse than the MTBI group on all of the CTIP tests. That is, participants in the Chronic Pain group performed worse than participants who had sustained a mild brain injury, and were statistically similar to those who had sustained a severe brain injury. These results are consistent with those found in studies using traditional paper and pencil NP tests that did not find significant differences between the performance of chronic pain participants and those who had sustained a moderate to severe brain injury (Etherton, Bianchini, Greve & Heinly, 2005; Etherton et al., 2006; Grigsby, Rosenberg & Busenbark, 1995; Schwartz et al., 1987; Taylor, Cox, & Mailis, 1996). These results also support research confirming self-reported impairments in cognitive functioning by people experiencing chronic pain (McCracken & Iverson, 2001).

Various theories have been proposed to explain cognitive deficits in chronic pain including the effects of concomitant symptoms such as sleep disturbance, fatigue, depressive symptoms and anxiety. It is well known that any of these factors can negatively impact cognitive functioning (Lezak et al., 2004) and all of these symptoms
are common comorbid conditions with chronic pain (Hart, Martelli, & Zasler, 2000; Martelli, Zasler, Bender, & Nicholson, 2004; Moriarty, McGuire, & Finn, 2011; Nicholson, 2000). These factors are addressed more fully in Chapter 4, and the potential direct effects of chronic pain itself on cognition are discussed in Chapter 5.

**Hypothesis 2: Complexity Effect.** As was hypothesized, the present study replicated the complexity effect, which asserts that reaction times will increase as the difficulty of cognitive processing increases across tasks. As expected, the scores for the Choice RT test were significantly higher than the Simple RT test scores, and the scores for the Semantic RT test were significantly higher than the Choice RT test, for both the Chronic Pain and New Control groups. These results are consistent with the findings of Tombaugh and colleagues (2007) among the MTBI and STBI groups. These findings provide additional evidence confirming that the Choice RT task is more demanding, and requires additional processing time than does the Simple RT task. Similarly, the Semantic RT test is the most cognitively demanding of all three CTIP tasks, and requires the greatest amount of processing time.

**Hypothesis 3: Prediction of Group Membership.** The primary aim of the present study was to determine whether the CTIP scores would differentiate among Chronic Pain, TBI and healthy control participants. A discriminant function analysis correctly classified 41% of participants in the present study and estimated accurate classification of 34% of participants in future samples. While these rates are superior to chance agreement (25%), there is considerable room for clinical error based on this
classification model. For example, it was predicted that 35% of future chronic pain participants would be classified as STBI patients, and 32% would be classified as MTBI participants. Only 13.5% would be correctly classified as members of the Chronic Pain group. While approximately 30% of MTBI participants were correctly classified, 32% were classified as healthy controls, 24% as STBI patients, and 13.5% as individuals with chronic pain. Therefore, in the present research, the CTIP alone did not provide a reliable method for distinguishing between symptoms of chronic pain and brain injury. Study 2 examines the predictive ability of several traditional neuropsychological tests to correctly classify participants into appropriate groups.

**Hypothesis 4: Impact of Basic Processing Speed.** Slowing in the basic speed of information processing is believed to underlie reductions in the time taken to process more cognitively demanding stimuli. Simple RT scores were thus used as a baseline measure of processing speed and were entered as a covariate in analyses of the two more advanced cognitive tasks. Results of these analyses provided additional support for the theory that generalized slowing may be responsible for deficits in higher-order cognitive processes.

As hypothesized, the differences between the Chronic Pain group and the Control and MTBI groups, on the Choice and Semantic RT tests, were no longer statistically significant after controlling for Simple RT. These results suggest that a generalized slowing of basic processing speed is evident in people with chronic pain and this, in turn, reduces their processing speed on more demanding cognitive tasks. Once the effects of
basic processing speed were controlled, there were no significant differences in reaction
time on more advanced cognitive tasks between the chronic pain participants and
participants with a mild brain injury or those in the healthy control group. These results
with the Chronic Pain group are consistent with those found with TBI patients
(Tombaugh et al., 2007; Felminghan et al., 2004; Ferraro, 1996).

**Hypothesis 5: Accuracy of Responding.** As hypothesized, accuracy of
responding was high on the two CTIP tests that required participants to choose the
appropriate stimuli. Participants in both the Chronic Pain and Control groups achieved a
97% level of accuracy on the Choice and Semantic RT tests, as was found for the
archival MTBI and STBI groups by Tombaugh and colleagues (2007). The mean number
of correct responses for all groups was 29 out of 30 items.

**Summary.** In Study 1, CTIP scores distinguished between individuals with
chronic pain and those in the healthy control and MTBI groups. The CTIP did not
distinguish between the chronic pain and STBI participants, underscoring the degree of
impairment in information processing speed experienced by those with chronic pain. The
discriminant function analysis indicated the Semantic RT test was the strongest predictor
of group membership and while a method was derived that would provide better than
chance classification of participants, there was still considerable room for clinical error.
That is, it did not provide a reliable method of differentiating chronic pain from brain
injury. The similarity in CTIP reaction time scores between the Chronic Pain and the
STBI groups demonstrates the difficulty in differential diagnoses through
neuropsychological testing. While STBI, by definition, is typically identified by corroborating factors (e.g., Loss of Consciousness, Posttraumatic Amnesia, Glasgow Coma Scale, diagnostic imaging), a NP evaluation would determine the extent of cognitive deficits. The lack of significant differences in test scores between the Chronic Pain and STBI groups indicates that the actual severity of an STBI, or potential MTBI, can be difficult to assess if the patient also presents with chronic pain.

Study 2 in the subsequent Chapter examines the results of traditional paper and pencil NP tests for the same four groups of participants, and compares these results to those of the CTIP. Study 3 (i.e., Chapter 4) examines the effect of particular concomitant symptoms, namely fatigue, sleepiness, depressive symptoms and anxiety, as well as various measures of pain, on cognitive performance within the Chronic Pain group. Limitations of the studies, and theoretical and clinical implications, are discussed in the final Chapter.
Chapter 3

Study 2: Traditional Neuropsychological Tests

Introduction

A reduction in the speed of information processing is considered a hallmark symptom of traumatic brain injury and is therefore an important component to be assessed in neuropsychological evaluation of potential TBI (Lux, 2007). Various methods are used to assess information processing speed and they are not equivalent. The construct of speed of information processing may be divided into two distinct categories: simple versus complex. Simple measures assess very basic elements of attention and concentration whereas complex measures require more cognitive resources (Chiaravalloti, Christodoulou, Demaree, & DeLuca, 2003). For example, the Paced Auditory Serial Addition Test (PASAT; Gronwall, 1977) can be considered a complex measure of processing speed. The test involves the oral presentation of a series of single digit numbers and the examinee is instructed to add the 2 most recent numbers and report the sum aloud during the inter-stimulus interval. The numbers are presented with increasing rapidity until the participant is unable to respond efficiently. This complex task requires sustained attention, use of working memory, and simultaneous performance of several other cognitive functions under increasing time constraints. In comparison, reaction time tests require the individual to recognize a stimulus and perform a corresponding simple motor response. Thus, reaction time tests are ideal examples of simple measures of information processing speed.
The three reaction time tasks of the CTIP provide appropriate examples of tests of differing abilities all considered measures of *simple* information processing speed as defined by Chiaravalloti and colleagues (2003). The most basic reaction time tasks, such as the Simple RT of the CTIP, are typically considered a “pure” measure of speed of information processing and can be used as a baseline measure in covariate analyses to control for a generalized decrease in cognitive processing on more complex tests. These types of analyses have provided evidence for the theory that a generalized slowing of information processing in cases of TBI may be responsible for deficits in other attentional and cognitive processes (Felminghan et al., 2004; Ferraro, 1996).

There are numerous ways to measure speed of information processing. Several examples of traditional paper and pencil NP tests that have been used to measure relatively simple information processing include the Trail-Making Test A & B (TMT; Reitan & Wolfson, 1985), the Digit Symbol Substitution Test (Wechsler, 1997), and the Digit Span Test) (Schmidt & Tombaugh, 1995; Wechsler, 1997). These tests are the focus of the present study.

A thorough neuropsychological evaluation must consider potential confounds and chronic pain is associated with specific cognitive deficits similar to those demonstrated by individuals with mild or even moderate-severe brain injury. Therefore, comparisons of test performance between individuals with chronic pain without history of head injury, and individuals who have sustained either a mild or severe brain injury are useful to inform differential diagnosis. Investigations have confirmed that participants with
chronic pain often perform significantly worse on tests of information processing speed than healthy controls and in relation to normative test data (Hart, Martelli, & Zasler, 2000; Moriarty, McGuire, & Finn, 2011; Nicholson, 2000; Oosterman et al., 2012; Veldhuijzen et al., 2012). Despite these findings, relatively little data are available regarding direct comparisons of chronic pain and TBI participants on tests of this nature. Two studies found that individuals who had sustained an MTBI performed worse than participants with chronic pain on traditional measures of information processing speed (Bell, Primeau, Sweet, & Lofland, 1999; Meyers & Rohling, 2004). The majority of research available suggests that performance by chronic pain participants on traditional NP tests is similar to individuals with mild (Nicholson, 2000) or even moderate-severe TBI (Etherton, Bianchini, Greve, & Heinly, 2005; Etherton et al., 2006; Grigsby, Rosenberg, & Busenbark, 1995; Schwartz et al., 1987; Taylor, Cox, & Mailis, 1996).

Study 2 aimed to compare scores on traditional NP tests among chronic pain, MTBI, STBI, and healthy control groups. Associations between the traditional NP test scores and the CTIP were also examined. Information regarding groups, demographic comparisons, and evaluation of level of effort during testing are described in the previous chapter. As detailed in Study 1, the Chronic Pain and Control groups were newly recruited, while the MTBI and STBI groups were archival (Tombaugh et al., 2007).

Tombaugh et al. (2007) found that participants in the STBI group performed significantly worse on all the traditional NP tests (except Trails A) than did the MTBI and Control groups, while no significant differences in performance were identified.
between the latter two groups. The one exception noted above occurred with the Trails A test which is a very basic measure of processing speed requiring tracking of a numerical sequence. The only significant difference found in Trails A scores was between the STBI and MTBI groups. None of the traditional NP tests were correlated with the CTIP scores for the STBI or Control groups. Moderate correlations were found between these tests for the MTBI group. The current study assessed performance of chronic pain participants in comparison to those with MTBI or STBI and healthy controls on the traditional NP tests, and examined the relationship between scores on these traditional tests and the CTIP. Specific hypotheses are outlined below:

**Hypothesis 1: Group Differences.** Chronic Pain participants were expected to demonstrate impaired performance on the traditional NP tests in comparison with the Control group consistent with previous evaluations of information processing speed (Hart, Martelli, & Zasler, 2000; Moriarty, McGuire, & Finn, 2011; Nicholson, 2000; Oosterman et al., 2012; Veldhuijzen et al., 2012). Further, since individuals with chronic pain have previously demonstrated cognitive impairments similar to those observed in cases of MTBI (Nicholson, 2000) and even moderate-severe TBI (Etherton, Bianchini, Greve, & Heinly, 2005; Etherton et al., 2006; Grigsby, Rosenberg, & Busenbark, 1995; Schwartz et al., 1987; Taylor, Cox, & Mailis, 1996), the Chronic Pain group in the present study was expected to perform similarly to the MTBI and possibly the STBI groups on the traditional NP tests.
**Hypothesis 2: Associations Between NP Tests and the CTIP.** Moderate significant correlations between the CTIP and the traditional NP tests were found for the MTBI, but not the STBI, groups (Tombaugh et al., 2007). Chronic pain participants have been found to perform similarly to MTBI participants (Nicholson, 2000) and even moderate-severe TBI patients on traditional NP tests (Etherton, Bianchini, Greve, & Heinly, 2005; Etherton et al., 2006; Grigsby, Rosenberg, & Busenbark, 1995; Schwartz et al., 1987; Taylor, Cox, & Mailis, 1996). It was hypothesized, therefore, that moderate significant correlations would be found between the CTIP and traditional NP tests for the Chronic Pain group.

**Hypothesis 3: Prediction of Group Membership.** It was hypothesized that a combination of scores on the CTIP and NP tests would correctly classify participants into each of the four groups (Pain, MTBI, STBI, Control) at a rate greater than chance. This analysis was exploratory in nature in terms of which tests would be the strongest predictors of group membership.

**Data Analyses**

The primary objectives of Study 2 involved evaluation of group differences in test scores of the traditional NP tests, and assessment of the relationships between the NP and CTIP test scores. After removing three participants in Study 1 due to outlying scores on the CTIP, no univariate outliers were detected for the NP tests.

Preliminary analyses were conducted to examine level of effort during testing, disability status, involvement in legal proceedings, and general demographic descriptors,
details of which are reported in Study 1. In the present study, independent-samples $t$ tests were performed to evaluate differences between the Disability and No Disability groups (within the Chronic Pain group) for each NP test.

Descriptive statistics were calculated and are reported for all of the NP tests for each group. To examine the first hypothesis, analyses of variance (ANOVAs) were conducted. Where significant main effects were found, pairwise comparisons using the Bonferroni correction procedure to adjust to $p < .05$ for multiple comparisons were conducted.

To examine the second hypothesis, Pearson correlational analyses were conducted to determine the strength and directions of the relationships among the NP tests and the CTIP scores within groups.

The third hypothesis was examined using a discriminant function analysis to determine whether a combination of the CTIP and NP test scores would accurately predict group membership at a rate greater than chance and to explore which tests would prove to be the strongest predictors of group membership. Mahalanobis distance scores were examined to determine whether multi-variate outliers were present and those found were removed prior to conducting the analysis. The Box’s $M$ value was significant ($p < .001$) which suggests heterogeneity of the variance-covariance matrices. Box’s $M$ is a stringent test and the discriminant function analysis is considered robust to such heterogeneity if sample sizes are equal (Tabachnick & Fidell, 2007). Therefore, to achieve equal sample sizes participants from the Chronic Pain, MTBI, and Control
groups were randomly removed from the analysis to match the lowest sample size (STBI group). To cross-validate these results, this procedure was repeated for ten trials. The analysis with classification results closest to the mean of the ten trials is reported (D. Klinger, personal communication, February 14, 2014).

**Method**

**Participants**

The four groups of participants are described in Study 1 (i.e., Chronic Pain, MTBI, STBI, and Control).

**Procedure and Materials**

The measures of interest for the present investigation include: the Computerized Tests of Information Processing (CTIP; Tombaugh & Rees, 2000); The Trail-Making Test A & B (Reitan & Wolfson, 1985); the Digit Symbol Substitution Test (Wechsler, 1997) and one of two versions of the Digit Span (Schmidt & Tombaugh (1995) or Wechsler (1997). The procedure and CTIP are described in Study 1; the remaining tests are described below.

**Trail-Making Test A & B (TMT-A, TMT-B; Reitan & Wolfson, 1985).** The TMT is a visuomotor tracking test which requires the respondent to draw a line joining 25 randomly placed numbers in numerical sequence as quickly as possible (Trails A). Subsequently, the respondent is required to draw a line joining 25 numbers and 25 letters in an alternate numerical-alphabetical sequence as quickly as possible (Trails B). Test measures are obtained by recording the time required to complete each “trail”. The TMT
is a widely used test with reported reliability coefficients ranging mostly above .60 to .98 (Spreen & Strauss, 1998).

**Digit Span (Schmidt & Tombaugh, 1995) and Digit Span (Wechsler, 1997).** These two versions of the Digit Span test are essentially the same tests, typically administered within a test battery (Learning and Memory Battery or WAIS respectively) with different corresponding norms produced by different authors. In Digit Span tests, a “Forward” task is presented by reading a series of digits at a rate of one per second and the respondent is required to repeat the digits in the precise order in which they were presented. Difficulty increases as the number of digits increases with every second trial, beginning with 3 digits and increasing to 9 digits in the final two trials. The procedure is repeated, with a different series of digits in each trial, until the respondent is unable to correctly recall two sequences of the same length. A “Backward” task follows the same procedure except that the respondent is required to recall the digits in reverse order of presentation. The series of numbers range from 2 to 8 digits in the “Backward” task. Test measures are obtained by recording the total number of series recalled correctly. Digit Span is a commonly used test with reported test-retest reliability coefficients ranging from .66 to .89 (Lezak, Howieson, & Loring, 2004).

**Digit Symbol Substitution Test (Wechsler, 1997).** In the Digit Symbol Substitution Test, a diagram of nine distinct symbols, each paired with one digit from 1 to 9, is presented to the respondent. Below this diagram is a series of boxes containing one digit (ranging from 1 to 9) at the top followed by an empty box below. The task requires
the respondent to write the corresponding symbol in the empty box below each digit as quickly as possible. The test is measured by the total number of correctly copied symbols completed in a period of 120 seconds. Test-retest reliability correlation coefficients are reported to be in the range of .82 to .88 (Matarazzo & Herman, 1984; Wechsler, 1997) and .74 for people with MTBI (Hinton-Bayre et al., 1997, in Lezak et al., 2004).

Results

Preliminary Analyses

Effort Testing. Level of effort during testing was assessed and reported in Study 1. There was no evidence of poor effort during the testing for any of the participants therefore none were excluded on this basis.

Disability. Disability status was assessed and reported in Study 1. Analyses were conducted to determine if there were any significant differences in scores on the traditional NP tests between the Disability and No Disability groups. Mean test scores for the Trails A, Trails B, Digit Symbol, and Digit Span tests for the Disability and No Disability groups are summarized in Table 3.1. A series of independent-samples t tests indicated there were no significant differences between the two disability groups on Trails A: \( t(37) = -1.59, p = .12 \) and Digit Span: \( t(37) = 1.87, p = .07 \) while significant differences were found on Trails B: \( t(37) = -2.33, p = .03 \) and Digit Symbol: \( t(37) = 2.55, p = .02 \).
Table 3.1

*Mean neuropsychological test scores for those receiving or applying for disability, and those not receiving disability payments*

<table>
<thead>
<tr>
<th>GROUP</th>
<th>N</th>
<th>Trails A M (SD)</th>
<th>Trails B M (SD)</th>
<th>Digit Symbol M (SD)</th>
<th>Digit Span M (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disability</td>
<td>10</td>
<td>34 (9.40)</td>
<td>90 (29.33)</td>
<td>61 (10.67)</td>
<td>13 (4.30)</td>
</tr>
<tr>
<td>No Disability</td>
<td>29</td>
<td>29 (7.88)</td>
<td>68 (23.48)</td>
<td>72 (13.21)</td>
<td>16 (3.51)</td>
</tr>
<tr>
<td>Total Pain Group</td>
<td>39</td>
<td>30 (8.44)</td>
<td>74 (26.45)</td>
<td>69 (13.52)</td>
<td>15 (3.84)</td>
</tr>
</tbody>
</table>

**Legal Proceedings.** As reported in Study 1, none of the participants were involved in litigation.

**Demographics.** Demographic analyses are presented in Table 2.1 in Study 1. As reported, there were no significant differences found in age, level of education, or gender composition among the groups.

**Neuropsychological Test Analyses**

**Descriptives.** Descriptive statistics for all of the NP tests for each group are summarized in Table 3.2.
Table 3.2

*Descriptive Statistics for Neuropsychological Tests*

<table>
<thead>
<tr>
<th>Test</th>
<th>Group</th>
<th>N</th>
<th>M</th>
<th>(SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digit Symbol</td>
<td>Control</td>
<td>37</td>
<td>77</td>
<td>(13.42)</td>
</tr>
<tr>
<td></td>
<td>MTBI</td>
<td>36</td>
<td>81</td>
<td>(14.87)</td>
</tr>
<tr>
<td></td>
<td>Chronic Pain</td>
<td>39</td>
<td>69</td>
<td>(13.52)</td>
</tr>
<tr>
<td></td>
<td>STBI</td>
<td>30</td>
<td>63</td>
<td>(20.23)</td>
</tr>
<tr>
<td>Digit Span</td>
<td>Control</td>
<td>37</td>
<td>17</td>
<td>(3.73)</td>
</tr>
<tr>
<td></td>
<td>MTBI</td>
<td>38</td>
<td>19</td>
<td>(4.03)</td>
</tr>
<tr>
<td></td>
<td>Chronic Pain</td>
<td>39</td>
<td>15</td>
<td>(3.84)</td>
</tr>
<tr>
<td></td>
<td>STBI</td>
<td>35</td>
<td>14</td>
<td>(3.06)</td>
</tr>
<tr>
<td>Trails A</td>
<td>Control</td>
<td>37</td>
<td>26</td>
<td>(8.45)</td>
</tr>
<tr>
<td></td>
<td>MTBI</td>
<td>38</td>
<td>24</td>
<td>(6.88)</td>
</tr>
<tr>
<td></td>
<td>Chronic Pain</td>
<td>39</td>
<td>30</td>
<td>(8.44)</td>
</tr>
<tr>
<td></td>
<td>STBI</td>
<td>38</td>
<td>34</td>
<td>(16.47)</td>
</tr>
<tr>
<td>Trails B</td>
<td>Control</td>
<td>37</td>
<td>60</td>
<td>(19.99)</td>
</tr>
<tr>
<td></td>
<td>MTBI</td>
<td>38</td>
<td>54</td>
<td>(19.30)</td>
</tr>
<tr>
<td></td>
<td>Chronic Pain</td>
<td>39</td>
<td>74</td>
<td>(26.45)</td>
</tr>
<tr>
<td></td>
<td>STBI</td>
<td>35</td>
<td>85</td>
<td>(45.48)</td>
</tr>
</tbody>
</table>

*Note.* MTBI = Mild traumatic brain injury; STBI = Severe traumatic brain injury

**Hypothesis 1: Group Differences.** A series of one-way ANOVAs were conducted to assess differences in test scores among the groups. Results indicated significant differences among the groups for each test: Digit Symbol, $F(3, 138) = 8.41, p < .001, \eta^2 = .16$; Digit Span, $F(3, 145) = 12.53, p < .001, \eta^2 = .21$; Trails A, $F(3, 145) = 6.46, p < .001, \eta^2 = .12$; and Trails B, $F(3, 145) = 7.98, p < .001, \eta^2 = .14$. Pairwise comparisons using the Bonferroni correction procedures were conducted for each test to identify significant group differences as summarized in Table 3.3. Notably, the Chronic Pain group performed significantly worse on all of the NP tests, except Trails A, in
comparison with the MTBI group, while there were no significant differences between the Chronic Pain and STBI groups on the same tests. These results are summarized in Figure 3.1.

Table 3.3

*Neuropsychological Tests: Significant Pairwise Comparisons Between Groups*

<table>
<thead>
<tr>
<th>NP Test</th>
<th>Group (I)</th>
<th>Group (J)</th>
<th>Mean Difference (I – J)</th>
<th>Std. Error</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digit Symbol</td>
<td>PAIN</td>
<td>MTBI</td>
<td>-11.22</td>
<td>3.58</td>
<td>.01</td>
</tr>
<tr>
<td></td>
<td>STBI</td>
<td>Control</td>
<td>-13.74</td>
<td>3.80</td>
<td>&lt;.01</td>
</tr>
<tr>
<td></td>
<td>STBI</td>
<td>MTBI</td>
<td>-17.40</td>
<td>3.83</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Digit Span</td>
<td>PAIN</td>
<td>MTBI</td>
<td>-3.79</td>
<td>.84</td>
<td>&lt;.001</td>
</tr>
<tr>
<td></td>
<td>STBI</td>
<td>Control</td>
<td>-2.80</td>
<td>.87</td>
<td>.01</td>
</tr>
<tr>
<td></td>
<td>STBI</td>
<td>MTBI</td>
<td>-4.97</td>
<td>.87</td>
<td>&lt;.001</td>
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<tr>
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<td>Control</td>
<td>7.86</td>
<td>2.50</td>
<td>.01</td>
</tr>
<tr>
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<td>MTBI</td>
<td>9.97</td>
<td>2.48</td>
<td>.001</td>
</tr>
<tr>
<td>Trails B</td>
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<td>19.61</td>
<td>6.66</td>
<td>.02</td>
</tr>
<tr>
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<td>STBI</td>
<td>Control</td>
<td>24.33</td>
<td>6.89</td>
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</tr>
<tr>
<td></td>
<td>STBI</td>
<td>MTBI</td>
<td>30.44</td>
<td>6.84</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

*Note:* All significant mean differences using the Bonferroni correction procedure are shown above; MTBI = Mild traumatic brain injury; STBI = Severe traumatic brain injury
Figure 3.1. Traditional neuropsychological test results (mean raw scores ± SEM) for Controls (n = 37), Mild traumatic brain injured (MTBI; n = 38), Chronic Pain (Pain; n = 39), and Severe traumatic brain injured (STBI; n = 35) groups. Corresponding letters (a,b,c) indicate significant differences between groups for each test.
Hypothesis 2: Associations Between the NP tests and the CTIP. Pearson correlation coefficients were calculated to determine the strength and directions of the relationships among the NP tests and the CTIP scores within groups. Results are summarized in Table 3.4.

The scores on the three CTIP tests were significantly inter-correlated in all groups except between the Simple RT and Semantic RT tasks in the STBI group. The Simple reaction time test was not significantly correlated with any of the traditional NP tests in any of the groups except with Digit Symbol in the Chronic Pain and Control groups, and with Trails B in the Control group. The Choice reaction time test was moderately correlated with all of the NP tests for the MTBI group, and with the Digit Symbol test for the Control group. It was not significantly correlated with any of the NP tests for either the STBI or Chronic Pain groups. The Semantic reaction time test was not significantly correlated with any of the NP tests for the STBI group. It was significantly correlated with the Digit Symbol test for all other groups, and with Digit Span for the MTBI group, and both Trails tests for the Pain group.

There were moderate to high correlations among the NP tests for all groups. Digit Symbol was strongly correlated with Trails A and B for most groups, and with Digit Span for the Control group. Digit Span was moderately correlated with Trails B for all groups except MTBI. Trails A and B were significantly correlated in all groups. All correlations were in the expected direction, indicating that as performance improved on one test, improvement also occurred on the other test.
<table>
<thead>
<tr>
<th>Group</th>
<th>Simple</th>
<th>Choice</th>
<th>Semantic</th>
<th>Digit Symbol</th>
<th>Digit Span</th>
<th>Trails A</th>
<th>Trails B</th>
</tr>
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<td>(39) .68**</td>
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<tr>
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<td>(39) -.35*</td>
<td>(39) -.28</td>
<td>(39) -.57**</td>
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<td>(39) -.38*</td>
<td>(39) -.09</td>
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<td>(39) .18</td>
<td>(39) .34*</td>
<td>(39) -.58**</td>
<td>(39) -.32*</td>
<td>(39) .49**</td>
<td>---</td>
</tr>
<tr>
<td>MTBI</td>
<td>(41) .48**</td>
<td>---</td>
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<td>---</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>(41) .70**</td>
<td>(41) .57**</td>
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<td>---</td>
</tr>
<tr>
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<td>(36) -.27*</td>
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<tr>
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<td>(38) -.44**</td>
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<tr>
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<td>(36) -.08</td>
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<td>(38) .17</td>
<td>(38) .42**</td>
<td>(38) .26</td>
<td>(35) -.52**</td>
<td>(36) -.31</td>
<td>(38) .62**</td>
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</tr>
<tr>
<td>STBI</td>
<td>(39) .55**</td>
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<td>---</td>
<td>---</td>
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<td>---</td>
</tr>
<tr>
<td></td>
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<td>(39) .56**</td>
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<tr>
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<td>(35) -.02</td>
<td>(35) -.19</td>
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<td>(35) .09</td>
<td>(35) .15</td>
<td>(30) -.59**</td>
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<td>(35) .29</td>
<td>(35) .15</td>
<td>(30) -.55**</td>
<td>(35) -.41*</td>
<td>(35) .50**</td>
<td>---</td>
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<tr>
<td>Control</td>
<td>(37) .52**</td>
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<td>---</td>
</tr>
<tr>
<td></td>
<td>(37) .70**</td>
<td>(37) .62**</td>
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<td>(37) -.39*</td>
<td>(37) -.47**</td>
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<td>(37) .46**</td>
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<td>(37) .28</td>
<td>(37) .21</td>
<td>(37) -.21</td>
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<td></td>
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<td>(37) .22</td>
<td>(37) .25</td>
<td>(37) -.54**</td>
<td>(37) -.39*</td>
<td>(37) .64**</td>
<td>---</td>
</tr>
</tbody>
</table>

Note. * p < .05; ** p < .01
Hypothesis 3: Prediction of Group Membership. A discriminant function analysis was conducted to determine whether a combination of scores on the CTIP and NP tests could accurately predict group membership (MTBI, STBI, Pain, Controls) at a rate greater than chance and to determine which of the tests would be the strongest predictors of group membership. Prior to conducting the analysis, one multivariate outlier with a score greater than the Mahalanobis distance critical value (18.48) was removed from the analysis (Chronic Pain participant; score 32.41).

The discriminant function analysis produced a significant overall Wilk’s lambda, $\Lambda = .60$, $\chi^2(21, N = 120) = 58.91, p < .01$, indicating that overall the CTIP and NP tests did differentiate among the four groups. None of the remaining functions were significant and therefore only the first function is interpreted.

Table 3.5 presents the correlations between each CTIP and NP test and the discriminant function as well as the standardized weights. Based on these coefficients, the Digit Span test has the strongest ability to predict group membership followed by Simple RT and Trails A. Examination of the group means revealed that the STBI group had the highest mean ($M = .89$) on the discriminant function followed by the Pain ($M = .51$), Control ($M = -.42$), and MTBI ($M = -.99$) groups.
Table 3.5

*Standardized Function Coefficients and Correlations of CTIP and NP Tests with the Discriminant Function*

<table>
<thead>
<tr>
<th></th>
<th>Standardized Function Coefficients</th>
<th>Correlations between variables and discriminant function</th>
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<tbody>
<tr>
<td>Simple RT</td>
<td>.44</td>
<td>.55</td>
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<tr>
<td>Choice RT</td>
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<td>.54</td>
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<tr>
<td>Semantic</td>
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<td>.61</td>
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<tr>
<td>Trails A</td>
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<td>.49</td>
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<td>.02</td>
<td>.56</td>
</tr>
<tr>
<td>Digit Symbol</td>
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<td>-.60</td>
</tr>
<tr>
<td>Digit Span</td>
<td>-.59</td>
<td>-.69</td>
</tr>
</tbody>
</table>

As can be seen in Table 3.6, the classification results indicate that the model correctly predicts group membership for 47.5% of the participants in this study which is almost twice as high as the proportional by chance accuracy rate of approximately 25%. Finally, to assess the accuracy of the classification procedure in a new sample, the leave-one-out technique resulted in 35% of the cases being correctly classified, a rate that is 40% greater than the by chance accuracy rate.
Table 3.6

**Prediction of Group Membership from the Discriminant Analysis**

**Classification Results**

<table>
<thead>
<tr>
<th>Groups</th>
<th>MTBI</th>
<th>STBI</th>
<th>Control</th>
<th>Pain</th>
<th>Total</th>
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<tr>
<td>Pain</td>
<td>5</td>
<td>13</td>
<td>6</td>
<td>6</td>
<td>30</td>
</tr>
<tr>
<td>%</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>MTBI</td>
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<td>100.0</td>
</tr>
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<td>Control</td>
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<td>Cross-validated Count</td>
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<td>7</td>
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<td>3</td>
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<td>30</td>
</tr>
<tr>
<td>Control</td>
<td>10</td>
<td>6</td>
<td>12</td>
<td>2</td>
<td>30</td>
</tr>
<tr>
<td>Pain</td>
<td>5</td>
<td>15</td>
<td>7</td>
<td>3</td>
<td>30</td>
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<td>%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MTBI</td>
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<td>16.7</td>
<td>23.3</td>
<td>100.0</td>
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<td>40.0</td>
<td>6.7</td>
<td>100.0</td>
</tr>
<tr>
<td>Pain</td>
<td>16.7</td>
<td>50.0</td>
<td>23.3</td>
<td>10.0</td>
<td>100.0</td>
</tr>
</tbody>
</table>

a. 47.5% of original grouped cases correctly classified.
b. Cross validation is done only for those cases in the analysis. In cross validation, each case is classified by the functions derived from all cases other than that case.
c. 35.0% of cross-validated grouped cases correctly classified.

**Discussion**

The primary objective of the present study was to contrast scores among the study groups (i.e., Chronic Pain, MTBI, STBI, Controls) on traditional NP tests (i.e., Trails A and B, Digit Symbol, Digit Span) and to examine the relationships between these NP
tests and the CTIP. Analyses were performed to determine which tests best predict group membership and how well the test scores would classify participants into appropriate groups.

**Traditional Neuropsychological Tests**

**Hypothesis 1: Group Differences.** Contrary to expectations, there were no significant differences in scores for any of the traditional NP tests between the Chronic Pain group and the Control group. These results are contrary to the findings of a number of studies in which chronic pain patients demonstrated impairments in the speed of information processing in comparison with healthy controls or compared to normative data (Hart, Martelli, & Zasler, 2000; Moriarty, McGuire, & Finn, 2011; Nicholson, 2000; Oosterman et al., 2012; Veldhuijzen et al., 2012). Further, these results are inconsistent with the findings of Study 1 of the present research examining CTIP scores among the groups. The Chronic Pain group demonstrated impaired performance on both the Choice and Semantic RT tests compared with healthy control participants. Therefore, considering the Study 2 results, the CTIP appears more sensitive to, and perhaps better able to quantify, precise impairments in information processing speed than the traditional NP tests in this particular sample of chronic pain participants. The CTIP appears to provide a relatively “pure” measure of information processing speed with less dependence on other functions such as visual acuity, fine motor, and memory skills required by the traditional NP tests. Reaction time scores, measured in milliseconds on the CTIP, are more precise than stop-watch measures used in the Trails A and B, and
Digit Symbol tests.

There were no significant differences in scores for any of the traditional NP tests between the Chronic Pain and the STBI groups. These results are consistent with those found in Study 1 in which there were no significant differences between these two groups on any of the CTIP tests. Further, the Chronic Pain group scored significantly worse than the MTBI group on all of the traditional NP tests except Trails A. These results are also consistent with Study 1 in which the Chronic Pain group performed significantly worse than the MTBI group on all of the CTIP tests. These findings are generally consistent with several studies that revealed that participants with chronic pain demonstrated particular cognitive impairments similar to individuals with moderate to severe brain injury (Etherton, Bianchini, Greve, & Heinly, 2005; Etherton et al., 2006; Grigsby, Rosenberg, & Busenbark, 1995; Schwartz et al., 1987; Taylor, Cox, & Mailis, 1996). These results underscore the difficulty in determining a differential diagnosis for potential brain injury in the presence of chronic pain.

Traditional Neuropsychological Tests and the CTIP

**Hypothesis 2: Associations Between NP Tests and the CTIP.** Research by Tombaugh and colleagues (2007) demonstrated significant correlations among the three CTIP tasks for all groups, while little overlap was found between the CTIP scores and those of the traditional NP tests for the STBI and Control groups. Such findings appear to indicate that the CTIP measures a somewhat different construct, or a more precise measure of a similar construct, presumably the speed at which information is processed,
than is assessed by the other NP tests. The present study provided some support for this position.

All three CTIP tests were strongly intercorrelated among almost all groups, similar to the findings of Tombaugh and colleagues (2007). The only exception was between the Simple and Semantic RT tasks in the STBI group. Thus, Study 2 results provide further evidence that the CTIP reaction time tasks measure similar yet distinct aspects of speed of information processing. In the Chronic Pain group, the Digit Symbol test was correlated with the Simple and Semantic RT tests, and both the Trails A and B tests were moderately correlated with the Semantic RT tests. In the Control group, the Digit Symbol test was moderately correlated with all three CTIP tests, and the Trails A test was moderately correlated with the Simple RT test. The Digit Span test was not significantly correlated with CTIP scores for either the Chronic Pain or Control groups.

While some significant correlations were evident between the traditional NP tests and the CTIP scores, they were moderate. Therefore, it appears as if the CTIP reaction time tasks are assessing somewhat different aspects of information processing than traditional NP tests. For example, different aspects of attention, memory, visual acuity, and motor dexterity are utilized in each of the traditional NP tests. Thus, the CTIP may add unique information in a NP assessment.

**Hypothesis 3: Prediction of Group Membership.** One of the main goals of the present study was to determine whether a combination of the traditional NP and CTIP test scores would distinguish the four groups (Chronic Pain, MTBI, STBI, Control) and to
identify which of the tests would best predict group membership. The discriminant function analysis indicated the Digit Span test was the strongest predictor of group membership, followed by the Simple RT and Trails A tests. It is interesting to note that this combination of predictors taps into a range of cognitive abilities. Digit Span requires use of auditory attention, working memory and immediate verbal recall. The Simple RT task, considered a relatively “pure” measure of information processing speed, requires visual attention and a basic motor response (depression of one key). The Trails A test requires visual conceptualization and visuomotor tracking. Thus the strongest predictor is one of the most cognitively demanding tests included in this study while the second predictor is the most simplistic measure and is thought to assess the more basic cognitive functioning underlying more demanding tasks.

The discriminant function analysis accurately classified 47.5% of participants in the current study and estimated the correct classification of 35% of participants in future samples. While these rates are an improvement over chance agreement (25%), there remains substantial room for clinical error based on this classification process. For example, it was predicted that 50% of future chronic pain participants would be classified as STBI patients, 23% as healthy controls, and 17% as MTBI participants. Only 10% would be correctly categorized into the chronic pain group. While approximately 37% of STBI participants would be classified accurately, 43% would be classified as individuals with chronic pain, 10% as MTBI participants, and 10% as healthy controls. Therefore, in the present research, the selected neuropsychological tests (including the CTIP) did not
provide a dependable method for distinguishing between symptoms of chronic pain and brain injury.

**Summary.** In the current study, the specified combination of traditional NP tests and CTIP scores did not provide a dependable method to distinguish between chronic pain and brain injured individuals although the classification model improved upon chance agreement. The results illustrate the importance of utilizing corroborating evidence in the process of differential diagnosis and indicated the CTIP can contribute to this process. While the Simple RT measure was one of the most influential predictors of group membership, each CTIP test appeared to measure aspects of information processing speed that are distinct from those measured by the traditional NP tests examined here. The CTIP appeared to be more sensitive to the effect of chronic pain than the traditional NP tests as evidenced by the difference in scores between the Chronic Pain and Control groups on the Choice and Semantic RT tests but not the NP tests. None of the NP test scores for the Chronic Pain group differed significantly from the STBI group providing additional evidence that chronic pain can be a confounding factor in the differential diagnosis of a brain injury. Various concomitant symptoms, also with the potential to influence cognitive functioning, are often present with chronic pain and must therefore be taken into consideration in a neuropsychological assessment. Several of the most common comorbid symptoms, fatigue, sleepiness, depressive symptoms, and anxiety, as well as various pain measures, are the focus of the following study presented in chapter 4.
Chapter 4
Study 3: Effects of Confounding Symptoms in Chronic Pain

Introduction

The overall objective of the present research was to examine whether the speed of information processing, as assessed by the precise measurement of the CTIP, would assist in a differential diagnosis of MTBI in the presence of chronic pain. Chronic pain has been reported to be present in as many as 75% of patients suffering from MTBI (Nampiaparampil, 2008). To address this issue, performance on the CTIP (Study 1) and specific traditional neuropsychological tests (Study 2) was compared among Chronic Pain, MTBI, STBI, and Control groups. The results of these two studies have provided additional evidence that individuals with chronic pain can experience impairments in information processing speed that appear similar in NP testing to participants who have incurred a STBI. These results are consistent with several other studies that indicate cognitive deficits observed in individuals with chronic pain may appear similar to those with moderate-severe TBI (Etherton, Bianchini, Greve, & Heinly, 2005; Etherton et al., 2006; Grigsby, Rosenberg, & Busenbark, 1995; Schwartz et al., 1987; Taylor, Cox, & Mailis, 1996).

Multiple factors impact the experience of chronic pain, and a biopsychosocial model best captures the multidimensional components of pain. For example, biological factors that influence pain perception include preexisting physiological conditions, the precipitating injury or illness, sleep disturbance, and physical deconditioning as a result
of decreased activity. Psychological features that influence the experience of chronic pain include preexisting and subsequent feelings of depression, anxiety, worry, anger, and hostility, as well as various beliefs and attitudes regarding the meaning of the pain (e.g., concerns of further harm), hypervigilance, and catastrophizing. Social issues that may influence the experience of chronic pain may involve excessive attention or sympathy, overly solicitous friends and family, and interference in social interactions. (Gatchel & Turk, 1999). Any or all of these factors may impact an individual’s experience of chronic pain and may facilitate or inhibit adjustment to the condition.

Further, evidence confirms that many of the symptoms often associated with chronic pain are known to cause cognitive impairments even in the absence of pain or brain injury (Lezak, Howieson, & Loring, 2004). Some of the most common symptoms concomitant with chronic pain include fatigue, sleepiness, depressive symptoms and anxiety, and each of these symptoms has the potential to interfere with cognitive functioning (Hart, Martelli, & Zasler, 2000; Martelli, Zasler, Bender, & Nicholson, 2004; Moriarty, McGuire, & Finn, 2011; Nicholson, 2000). Thus, this final study focuses on the impact that such symptoms, along with the level of experienced pain, have on cognitive functions as measured by the CTIP and traditional NP tests in individuals with chronic pain.

A neuropsychological assessment for possible MTBI is most commonly requested when symptoms persist beyond a few weeks or months and pain is frequently a co-occurring complaint (Nampiaparampil, 2008). The most common form of chronic pain
following head injury is posttraumatic headache (Nicholson, 2000). However, to examine the effect of pain itself and to avoid possible confound related to the nature of a headache, individuals reporting chronic headaches were excluded. The participants in the present study reported a variety of chronic pain conditions (i.e., arthritis, fibromyalgia, injuries, etc.) that affected primarily low back, shoulders/upper arms, and abdomen/stomach, and had existed for a minimum of six months. Individuals were excluded if they had any history of head injury.

With speed of information processing shown to be a hallmark symptom of MTBI (Lux, 2007) and chronic pain (Hart, Martelli, & Zasler, 2000; Study 1), it remained the main cognitive variable of interest in this study. Level of effort and potential disincentives created by litigation or disability claims were also examined (Study 1), as they are important considerations in the context of a neuropsychological assessment. To assess whether particular aspects of pain impact cognitive functioning, the duration, frequency, site of pain, intensity, primary cause, and overall rating of pain were assessed. Thus, the primary objective of Study 3 was to examine the extent to which potentially confounding symptoms, e.g., various pain ratings, sleepiness, fatigue, depression, and anxiety, predict scores on measures of processing speed. Age and level of education can have an impact on speed of information processing scores (Lezak, Howieson, & Loring, 2004) so these variables were examined and controlled for as appropriate. Specific hypotheses are outlined below:
**Hypothesis 1: Impact of Comorbid Symptoms on CTIP Scores in Chronic Pain.** It was hypothesized that each of the comorbid symptoms: pain, sleepiness, fatigue, depression, and anxiety, would be a significant predictor of reaction time scores for each of the CTIP tests.

**Hypothesis 2: Impact of Comorbid Symptoms on Traditional NP Test Scores in Chronic Pain.** It was hypothesized that each of the comorbid symptoms: pain, sleepiness, fatigue, depression, and anxiety, would be a significant predictor of scores attained on each of the traditional NP tests.

**Data Analyses**

Preliminary analyses were conducted, and three univariate outliers were removed, in Studies 1 and 2. Level of effort and impact of disability status were determined to be acceptable in the previous two studies. None of the participants were involved in litigation. Correlational analyses were conducted to assess whether age or level of education were associated with any of the CTIP or NP test scores and were controlled for where required.

Descriptive statistics were calculated to examine the duration and frequency of pain, areas and usual intensity of pain, primary causes of pain, overall ratings of pain, and comorbid symptoms. Correlational analyses were performed to examine the relationships among ratings of pain and comorbid symptoms, as well as their relationship to the CTIP and traditional NP test scores. Finally, multiple regression analyses were conducted to
determine whether the pain and comorbid variables would predict CTIP and traditional NP test scores.

**Method**

**Participants**

The Chronic Pain group described in Study 1 comprised the sole participants for this study.

**Procedure and Materials**

The procedure is described in Study 1. The measures of interest for the present investigation include a Pain Questionnaire, the Computerized Tests of Information Processing (CTIP), The Trail-Making Test A & B, the Digit Symbol Substitution Test, Digit Span, the Center for Epidemiological Studies Depression Scale (CES-D; Radloff, 1977), the State Trait Anxiety Inventory (STAI; Speilberger, 1983), and the Empirical Sleepiness and Fatigue Scales (ESFS; Bailes, et al., 2006). The Pain Questionnaire and the CTIP were described in Study 1 and the traditional neuropsychological tests were described in Study 2. The questionnaires used to evaluate the comorbid symptoms are described below.

**Center for Epidemiological Studies Depression Scale (CES-D; Radloff, 1977).** The CES-D is a 20-item inventory (see Appendix H) assessing depressive symptoms within the last week. Example items include: “I had trouble keeping my mind on what I was doing” and “My sleep was restless”. Scores above 16 suggest clinical depression. Radloff reports internal consistency for the general population and patient samples of .84-
.90 and test-retest reliability of .48-.67. The CES-D correlates highly with clinician-rating measures of depression, such as the Hamilton Depression Rating Scale and global ratings (Radloff, 1977). In the current study, the Chronbach’s alphas were .90 for the Control group and .92 for the Chronic Pain group.

**State Trait Anxiety Inventory (STAI; Speilberger, 1983).** The STAI is a 40-item self-report instrument that measures the presence and severity of anxiety in both adult men and women. The STAI differentiates between the temporary condition of “state anxiety” and the more general and long-standing quality of “trait anxiety.” By administering the state portion of the measure, the items assess how patients currently feel, and include both items that are very specific to anxiety and others that relate more to general symptoms of psychological distress. Responses are rated on a 4-point scale from 1 “not at all” to 4 “very much so”. Examples of statements include: “I feel calm”, “I feel upset”, and “I am worried”. Speilberger *et al.* reported good internal reliability over several months (Chambers, Power, & Durham, 2003). The internal consistency for the State Anxiety measure of the STAI ranges from .45 to .92, with the higher coefficients typically found when the scale is administered under conditions of psychological stress (e.g., administered immediately after a challenging intelligence test) (Spielberger, Gorsusch, & Lushene, 1970). Test-retest reliability for the State Anxiety measure of the STAI tends to be low, as would be expected for a measure that is influenced by situational factors (Speilberger *et al.*, 1970). In the current study, the Chronbach alphas for the State Anxiety measure were .87 for the New Control Group and .91 for the...
Chronic Pain group. Speilberger and colleagues report the test-retest reliability for the Trait Anxiety measure of the STAI to be .86 and concurrent validity to be .73 with the Anxiety Scale Questionnaire (ASC) and .85 with the Manifest Anxiety Scales (MAS). In the current study, the Chronbach alphas for the Trait Anxiety measure were .92 for both the New Control and Chronic Pain groups. A copy of both the State and Trait scales are presented in Appendix I.

**Empirical Sleepiness and Fatigue Scales (ESFS; Bailes, et al., 2006).** The ESFS measures the conceptually distinct constructs of sleepiness (as related to daytime sleep tendency) and fatigue (more broadly related to insomnia, psychological maladjustment, and poorer perceived health function). Both scales are derived from existing commonly used, although confounded, self-report instruments [Stanford Sleepiness Scale (Hoddes et al., 1973); Epworth Sleepiness Scale (Johns, 1991); Fatigue Severity Scale (Krupp et al., 1989); and Chalder Fatigue Scale (Chalder et al., 1993)]. Six items assess level of sleepiness by asking “How likely are you to doze off or fall asleep in the following situations, in contrast to just feeling tired?” in situations such as, “sitting and reading”, “watching TV”, and “sitting and talking to someone”. Responses range along a 4-point rating scale from “Never doze off (0)” to “High chance of dozing off (3)”. Three items assess level of fatigue: “Exercise brings on my fatigue”, “I start things without difficulty but get weak as I go on”, and “I lack energy”. Responses range along a 6-point Likert scale indicating “Strongly disagree (1)” to “Strongly agree (6)”. While high internal consistency is reported to range from .92 to .95 for the Sleepiness
Scale, and from .74 to .86 for the Fatigue Scale, correlations between the two scales range from .06 to .33 indicating the scales are able to distinguish between the two constructs. Test-retest correlations have been reported at .69 and .88 for the total Sleepiness Scale scores, and .87 and .91 for the Fatigue Scale (Bailes, et al., 2006). In the current study, the Cronbach alphas were as follows: .68 for the New Control group and .74 for the Chronic Pain group for the Sleepiness scale and .65 for the New Controls and .55 for the Chronic Pain group for the Fatigue scale. The correlations between the two scales were low for both groups: .14 for the New Control group and .13 for the Chronic Pain group.

Two individual items were added to this measure and were assessed independently of the above items. Participants were asked to indicate: “How tired you feel now” and “How fatigued you feel now” on an 11-point scale ranging from “Not at all” (0) to “Extremely” (10) to capture their level of these constructs at time of testing. A copy of the ESFS measure is included in Appendix J.

Results

Preliminary Analyses

Effort Testing. Level of effort during testing was assessed and reported in Study 1. There was no evidence of poor effort during the testing for any of the participants therefore none were excluded on this basis.
Disability. Disability status was assessed and reported in Study 1. As reported in that first study, there were no significant differences in scores on the CTIP between the Disability and No Disability groups. In Study 2, there was a significant difference in scores between the two disability groups on the Trails B and Digit Symbol tests. Since all participants successfully passed the effort level testing and there were no significant differences in scores on the majority of tests included in the two studies, disability status was not distinguished in any subsequent analyses. It is reasonable to consider that individuals who are receiving disability payments may be experiencing a greater level of disability than some who are not receiving such payments, and this may be evidenced in reduced performance level on neuropsychological testing.

Legal Proceedings. As reported in Study 1, none of the participants were involved in litigation.

Demographics. The present study examines the Chronic Pain group which has a mean age of 46.62 years (SD = 13.97) and mean education level of 13.95 years (SD = 2.59) as detailed in Study 1. Since age and level of education can have an impact on the speed of information processing (Lezak, Howieson, & Loring, 2004; Sheppard & Vernon, 2008), correlational analyses were performed to determine whether either of these variables were significantly related to any of the CTIP or NP test scores within the Chronic Pain group. Three significant Pearson correlation coefficients were found between age and the following tests: Trails B ($r = .40$), Digit Symbol ($r = -.48$), and Digit Span ($r = -.40$). Age was not significantly correlated with any of the CTIP tasks or with
Trails A. There were no significant correlations between level of education and any of the CTIP or NP tests. Age was therefore controlled for in subsequent analyses performed for the three NP tests noted above.

**Duration and Frequency of Pain.** It was important to have the present sample of chronic pain participants identify the duration and frequency of their pain. It is valuable to record such self-report features of medical groups for the consideration of symptom impact and for future comparisons of such groups in research or clinical practice. As shown in Table 4.1, pain durations varied widely from a minimum of 1.5 years to a maximum of 40 years. The frequency of pain varied from a low of 1 hour to a full 24 hours per day, with a mean report of experiencing pain for approximately 58% of a day. With a large SD of 10.16 these data indicate that the average chronic pain group participant may report pain from about 4 to 24 hours a day. In regard to the number of days per week with reported pain, the frequency was reported at low of 1 to a high of 7 days per week, with the mean accounting for approximately 87% of the days per week. The SD indicates that most participants reported pain between more than half of their week to everyday of their week (4.37-7 days). A similar trend was shown for days per month reported in pain, with a range from 2-31 days, with an average accounting for approximately 80% of the days per month reported as painful. Most participants were likely to experience pain from approximately 16-31 days per month. As a final indicator of pain frequency, the group reported on their percentage of time in pain. As one might expect from the other data, there was a range of time from 10-100% reported, with the
average report of greater than half of their time spent in pain. These data indicate that the pain participants were in pain from approximately 20-93% of their time.

Table 4.1
Descriptive Statistics for the Duration and Frequency of Pain

<table>
<thead>
<tr>
<th>Duration</th>
<th>N</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of Years</td>
<td>38</td>
<td>1.50</td>
<td>40.00</td>
<td>11.97</td>
<td>10.86</td>
</tr>
<tr>
<td>Hours per day</td>
<td>36</td>
<td>1.00</td>
<td>24.00</td>
<td>13.82</td>
<td>10.16</td>
</tr>
<tr>
<td>Days per week</td>
<td>37</td>
<td>1.00</td>
<td>7.00</td>
<td>6.08</td>
<td>1.71</td>
</tr>
<tr>
<td>Days per month</td>
<td>38</td>
<td>2.00</td>
<td>31.00</td>
<td>24.71</td>
<td>8.97</td>
</tr>
<tr>
<td>% of Time in Pain</td>
<td>39</td>
<td>10</td>
<td>100</td>
<td>56.41</td>
<td>36.74</td>
</tr>
</tbody>
</table>

Correlations were calculated to determine the strength and directions of the relationships between the duration and frequency of pain variables and the scores on the CTIP and the traditional neuropsychological tests. Bivariate correlations were calculated between the pain variables and the CTIP and Trails A scores. Partial correlations were calculated between the pain variables and the remaining three NP tests in order to control for age. The correlations are presented in Table 4.2. Digit Span was the only test to be significantly associated with any of the pain measures. The moderate negative correlations indicate that performance on the Digit Span test decreased as duration of pain increased.
Table 4.2

*Correlations between Duration and Frequency of Pain, CTIP, and NP Test Scores*

<table>
<thead>
<tr>
<th></th>
<th>No. of Years</th>
<th>Hours per Day</th>
<th>Days per Week</th>
<th>Days per Month</th>
<th>% of Time in Pain</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bivariate Correlations</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Simple RT</td>
<td>-.18</td>
<td>-.11</td>
<td>-.14</td>
<td>-.11</td>
<td>-.22</td>
</tr>
<tr>
<td>Choice RT</td>
<td>-.14</td>
<td>.04</td>
<td>.10</td>
<td>.10</td>
<td>.11</td>
</tr>
<tr>
<td>Semantic RT</td>
<td>-.02</td>
<td>.20</td>
<td>.16</td>
<td>.20</td>
<td>.22</td>
</tr>
<tr>
<td>Trails A</td>
<td>.07</td>
<td>.10</td>
<td>.03</td>
<td>.09</td>
<td>.02</td>
</tr>
<tr>
<td><strong>Partial Correlations (controlling for age)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trails B</td>
<td>.28</td>
<td>.26</td>
<td>-.20</td>
<td>-.31</td>
<td>.03</td>
</tr>
<tr>
<td>Digit Symbol</td>
<td>.09</td>
<td>-.19</td>
<td>-.19</td>
<td>-.13</td>
<td>-.04</td>
</tr>
<tr>
<td>Digit Span</td>
<td>-.30</td>
<td>-.39*</td>
<td>-.37*</td>
<td>-.36*</td>
<td>-.36*</td>
</tr>
</tbody>
</table>

*Note. *p* ≤ .05

**Areas and Usual Intensity of Pain.** Chronic pain participants were asked to report their primary site of pain and to rank all other sites where pain occurs. Responses ranged from 1 to 15 sites of pain. The most common primary area was low back (reported by 21%), followed by shoulders/upper arms (reported by 15%), and abdomen/stomach (reported by 15%). The most common secondary sites of pain were the low back, lower legs, and feet (each reported by approximately 13%), and the most common third sites of pain were the low back and lower legs (each reported by 10%). Participants were also asked to rate the usual intensity of pain at each site on a scale from 0 (no pain) to 10 (worst pain imaginable). The most common ratings of pain intensity at the primary pain site were: 8 (reported by 26%), 7 (reported by 23%), 10 (reported by
18%), and 9 (reported by 13%). Descriptive statistics are summarized in Table 4.3.

Table 4.3
Descriptive Statistics of Usual Intensity of Pain at Each Pain Site

<table>
<thead>
<tr>
<th>Ranked Pain Sites&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Mean&lt;sup&gt;b&lt;/sup&gt;</th>
<th>SD</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site 1</td>
<td>7.51</td>
<td>2.04</td>
<td>39</td>
</tr>
<tr>
<td>Site 2</td>
<td>6.69</td>
<td>2.25</td>
<td>35</td>
</tr>
<tr>
<td>Site 3</td>
<td>6.06</td>
<td>2.29</td>
<td>32</td>
</tr>
<tr>
<td>Site 4</td>
<td>5.46</td>
<td>2.40</td>
<td>28</td>
</tr>
<tr>
<td>Site 5</td>
<td>5.32</td>
<td>2.38</td>
<td>22</td>
</tr>
<tr>
<td>Site 6</td>
<td>5.35</td>
<td>2.70</td>
<td>20</td>
</tr>
<tr>
<td>Site 7</td>
<td>5.58</td>
<td>2.94</td>
<td>12</td>
</tr>
<tr>
<td>Site 8</td>
<td>5.67</td>
<td>3.00</td>
<td>9</td>
</tr>
<tr>
<td>Site 9</td>
<td>5.67</td>
<td>3.50</td>
<td>9</td>
</tr>
<tr>
<td>Site 10</td>
<td>5.00</td>
<td>3.46</td>
<td>7</td>
</tr>
<tr>
<td>Site 11</td>
<td>5.50</td>
<td>3.11</td>
<td>4</td>
</tr>
<tr>
<td>Site 12</td>
<td>6.00</td>
<td>2.00</td>
<td>3</td>
</tr>
<tr>
<td>Site 13</td>
<td>8.00&lt;sup&gt;*&lt;/sup&gt;</td>
<td>---</td>
<td>1</td>
</tr>
<tr>
<td>Site 14</td>
<td>8.00&lt;sup&gt;*&lt;/sup&gt;</td>
<td>---</td>
<td>1</td>
</tr>
<tr>
<td>Site 15</td>
<td>6.00&lt;sup&gt;*&lt;/sup&gt;</td>
<td>---</td>
<td>1</td>
</tr>
</tbody>
</table>

Note. <sup>a</sup>=pain sites ranked according to intensity of pain; <sup>b</sup>=pain intensity rated 0 (no pain) to 10 (worst pain imaginable); *indicates value for one participant

**Primary Causes of Pain.** Chronic pain participants were asked to report the primary cause of their pain and to rank all additional causes. The majority of participants reported only one or two causes of pain with only one person reporting the maximum of five causes (69%, 38%, 21%, and 3% reported 2, 3, 4, or 5 causes respectively). The most common cause of pain was arthritis: 12 cases (31%) reported to be primary cause, 6 cases (15%) reported as second cause of pain, with a total of 21 participants (54%) reporting arthritis as at least one cause of their pain. The next most common cause of
pain was an “Unknown Cause” (reported by 13%), followed by a motor vehicle accident (reported by 10%) and “chronic illness” (such as, fibromyalgia, Crohn’s Disease, chronic prostatitis; reported by 10%).

**Overall Pain.** Overall pain was assessed using the Short-Form McGill Pain Questionnaire (SF-MPQ; Melzack, 1987). Participants were asked to complete the measure twice: once in reference to their “usual pain”, and subsequently to describe their “current pain (during the last 24 hours)”. Two participants omitted responses for the “usual pain” rating. The missing data were replaced with mean scores (Tabachnick & Fidell, 2007; ratings for both participants of their “usual intensity of pain” for their primary site of pain were approximately equivalent to the mean score for that measure).

Descriptive statistics for both “usual” and “current” ratings of the SF-MPQ are displayed in Table 4.4.

Table 4.4

*Descriptive Statistics of Overall Ratings of Pain*

<table>
<thead>
<tr>
<th>SF-MPQ</th>
<th>Mean</th>
<th>SD</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pain Rating Index – Total (Usual)</td>
<td>19.23</td>
<td>9.62</td>
<td>39</td>
</tr>
<tr>
<td>Pain Rating Index – Sensory (Usual)</td>
<td>14.46</td>
<td>6.78</td>
<td>39</td>
</tr>
<tr>
<td>Pain Rating Index – Affective (Usual)</td>
<td>4.77</td>
<td>3.84</td>
<td>39</td>
</tr>
<tr>
<td>Pain Rating Index – Total (Current)</td>
<td>12.21</td>
<td>9.88</td>
<td>39</td>
</tr>
<tr>
<td>Pain Rating Index – Sensory (Current)</td>
<td>9.72</td>
<td>7.34</td>
<td>39</td>
</tr>
<tr>
<td>Pain Rating Index – Affective (Current)</td>
<td>2.49</td>
<td>3.16</td>
<td>39</td>
</tr>
</tbody>
</table>

*Note.* SF-MPQ = Short-Form – McGill Pain Questionnaire
**Pain Ratings: Current and Past Week.** Chronic pain participants were asked to rate their “Current Pain – now” at the time of data collection, as well as “Pain at its least”, “Worst pain” and “Average pain” during the previous week, on a scale ranging from 0 (no pain) to 10 (worst imaginable pain). Thirty-three participants (85%) were experiencing some level of pain, with ratings ranging from 2 to 10, at the time of data collection. Participants were also asked to select a descriptor (rated from 0 to 5) for their current pain: 15% reported “no pain” (0); 5% reported “mild” (1); 56% reported “discomforting” (2); 13% reported “distressing” (3); 3% reported “horrible” (4); and 8% reported “excruciating” (5). Descriptive statistics for these scales are presented in Table 4.5.

Table 4.5

*Descriptive Statistics of Pain Ratings Currently and During Past Week*

<table>
<thead>
<tr>
<th>Pain Rating</th>
<th>Mean</th>
<th>SD</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pain Now</td>
<td>4.69&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.94</td>
<td>39</td>
</tr>
<tr>
<td>Least Pain – past week</td>
<td>3.64&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.39</td>
<td>39</td>
</tr>
<tr>
<td>Worst Pain – past week</td>
<td>7.64&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.40</td>
<td>39</td>
</tr>
<tr>
<td>Average Pain – past week</td>
<td>5.28&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.31</td>
<td>39</td>
</tr>
<tr>
<td>Pain Descriptor</td>
<td>2.05&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.28</td>
<td>39</td>
</tr>
</tbody>
</table>

Note. <sup>a</sup>=scale ranges 0 (no pain) to 10 (worst pain); <sup>b</sup>=scale ranges 0 (no pain) to 5 (worst pain)

**Ratings of Pain, CTIP Reaction Time Scores, and Traditional Neuropsychological Tests Scores.** Correlations were calculated to determine the strength and directions of the relationships between ratings of pain, CTIP reaction time scores, and the traditional neuropsychological tests scores. Bivariate correlations were calculated between the pain variables and between the pain variables and the CTIP
and Trails A scores. Partial correlations were calculated between the pain variables and the remaining three NP tests in order to control for age. The correlations are presented in Tables 4.6, and 4.7. As expected, strong positive correlations were observed among the various pain measures. None of the pain ratings were significantly correlated with the Simple RT or Trails A & B test scores. Total Current Pain (SF-MPQ) was the variable most strongly associated with the Choice RT test. Pain Descriptor was the variable most strongly correlated with the Semantic RT and Digit Symbol tests. Current Affective Pain (SF-MPQ) was most strongly correlated with the Digit Span test. Correlations were in the hypothesized directions indicating that test performance decreased as pain increased.
Table 4.6

*Correlations between Ratings of Pain*

<table>
<thead>
<tr>
<th></th>
<th>aUsual Intensity</th>
<th>Pain Now</th>
<th>Least Pain</th>
<th>Worst Pain</th>
<th>Avg Pain</th>
<th>aUsual Pain Desc.</th>
<th>bTotal Usual Sensory Usual</th>
<th>bAffect Usual</th>
<th>bTotal Current Sensory Current</th>
<th>bAffect Current</th>
</tr>
</thead>
<tbody>
<tr>
<td>aUsual Intensity</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pain Now</td>
<td>.58</td>
<td>---</td>
<td>---</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Least Pain</td>
<td>.53</td>
<td>.56</td>
<td>---</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Worst Pain</td>
<td>.61</td>
<td>.59</td>
<td>.58</td>
<td>---</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average Pain</td>
<td>.73</td>
<td>.74</td>
<td>.68</td>
<td>.83</td>
<td>---</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pain Descriptor</td>
<td>.50</td>
<td>.84</td>
<td>.52</td>
<td>.50</td>
<td>.65</td>
<td>---</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>bTotal (Usual)</td>
<td>.69</td>
<td>.59</td>
<td>.63</td>
<td>.72</td>
<td>.74</td>
<td>.55</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>bSensory (Usual)</td>
<td>.61</td>
<td>.50</td>
<td>.59</td>
<td>.70</td>
<td>.71</td>
<td>.53</td>
<td>.95</td>
<td>---</td>
<td></td>
<td></td>
</tr>
<tr>
<td>bAffective (Usual)</td>
<td>.64</td>
<td>.59</td>
<td>.52</td>
<td>.57</td>
<td>.60</td>
<td>.45</td>
<td>.83</td>
<td>.61</td>
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<tr>
<td>bTotal (Current)</td>
<td>.53</td>
<td>.70</td>
<td>.54</td>
<td>.55</td>
<td>.70</td>
<td>.74</td>
<td>.76</td>
<td>.73</td>
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<tr>
<td>bSensory (Current)</td>
<td>.48</td>
<td>.67</td>
<td>.53</td>
<td>.54</td>
<td>.68</td>
<td>.73</td>
<td>.72</td>
<td>.75</td>
<td>.47</td>
<td>.98</td>
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<tr>
<td>bAffective (Current)</td>
<td>.53</td>
<td>.63</td>
<td>.45</td>
<td>.47</td>
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<td>.61</td>
<td>.70</td>
<td>.56</td>
<td>.78</td>
<td>.86</td>
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</table>

*Note.* N = 39; a = at primary pain site; b = Short-Form – McGill Pain Questionnaire; All correlations significant at \( p \leq .01 \).
Table 4.7

**Correlations between Ratings of Pain, Computerized Tests of Information Processing, and Traditional Neuropsychological Tests**

<table>
<thead>
<tr>
<th></th>
<th>aUsual Intensity</th>
<th>Pain Now</th>
<th>Least Pain</th>
<th>Worst Pain</th>
<th>Avg Pain</th>
<th>Pain Descriptor bUsual</th>
<th>bTotal Sensory</th>
<th>bAffect Usual</th>
<th>bTotal Current</th>
<th>bSensory Current</th>
<th>bAffect Current</th>
</tr>
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<tbody>
<tr>
<td><strong>Bivariate Correlations</strong></td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Simple RT</td>
<td>.04</td>
<td>-.02</td>
<td>-.12</td>
<td>.08</td>
<td>.10</td>
<td>.10</td>
<td>.05</td>
<td>.10</td>
<td>-.06</td>
<td>.11</td>
<td>.15</td>
</tr>
<tr>
<td>Choice RT</td>
<td>.21</td>
<td>.32*</td>
<td>.06</td>
<td>.23</td>
<td>.28</td>
<td>.31*</td>
<td>.22</td>
<td>.23</td>
<td>.14</td>
<td>.35*</td>
<td>.28</td>
</tr>
<tr>
<td>Semantic RT</td>
<td>.11</td>
<td>.38*</td>
<td>.07</td>
<td>.16</td>
<td>.25</td>
<td>.48**</td>
<td>.20</td>
<td>.22</td>
<td>.11</td>
<td>.37*</td>
<td>.39*</td>
</tr>
<tr>
<td>Trails A</td>
<td>.18</td>
<td>.04</td>
<td>.05</td>
<td>.06</td>
<td>.14</td>
<td>.10</td>
<td>.04</td>
<td>.01</td>
<td>.09</td>
<td>.04</td>
<td>.01</td>
</tr>
<tr>
<td><strong>Partial Correlations (controlling for age)</strong></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>Trails B</td>
<td>.03</td>
<td>.17</td>
<td>.09</td>
<td>-.06</td>
<td>.04</td>
<td>.26</td>
<td>.06</td>
<td>.01</td>
<td>.12</td>
<td>.18</td>
<td>.17</td>
</tr>
<tr>
<td>Digit Symbol</td>
<td>-.10</td>
<td>-.30</td>
<td>-.31</td>
<td>-.17</td>
<td>-.21</td>
<td>-.42**</td>
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<td>-.26</td>
<td>-.11</td>
<td>-.36*</td>
<td>-.39*</td>
</tr>
<tr>
<td>Digit Span</td>
<td>-.36*</td>
<td>-.40**</td>
<td>-.28</td>
<td>-.26</td>
<td>-.36*</td>
<td>-.38*</td>
<td>-.46**</td>
<td>-.43**</td>
<td>-.40**</td>
<td>-.49**</td>
<td>-.44**</td>
</tr>
</tbody>
</table>

*Note.* N = 39; a= at primary pain site; b = Short-Form – McGill Pain Questionnaire; *p ≤ .05; **p ≤ .01.
Comorbid Symptoms. The Empirical Sleepiness and Fatigue Scale (ESFS; Bailes, et al., 2006) and two additional items assessing “Tired Now” and “Fatigued Now”, the Center for Epidemiological Studies Depression Scale (CES-D; Radloff, 1977) and the State Trait Anxiety Inventory (STAI; Speilberger, 1983) were used to measure the presence of these symptoms in the chronic pain group. Data were missing for only three individual items (on the CES-D) and these were replaced by using a mean score inter-item replacement procedure (Tabachnick & Fidell, 2007). Descriptive statistics for these measures are presented in Table 4.8.

Table 4.8

Descriptive Statistics for Measures of Comorbid Symptoms

<table>
<thead>
<tr>
<th>Comorbid Symptom Measures</th>
<th>Mean</th>
<th>SD</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tired Now</td>
<td>5.03</td>
<td>2.79</td>
<td>39</td>
</tr>
<tr>
<td>Fatigued Now</td>
<td>4.79</td>
<td>2.96</td>
<td>39</td>
</tr>
<tr>
<td>ESFS – Tired Total</td>
<td>6.15</td>
<td>4.10</td>
<td>39</td>
</tr>
<tr>
<td>ESFS – Fatigue Total</td>
<td>7.69</td>
<td>3.94</td>
<td>39</td>
</tr>
<tr>
<td>ESFS – Tired &amp; Fatigue Total</td>
<td>13.85</td>
<td>5.95</td>
<td>39</td>
</tr>
<tr>
<td>CES-D Total Score</td>
<td>15.13</td>
<td>11.12</td>
<td>39</td>
</tr>
<tr>
<td>STAI (State Form) Total Score</td>
<td>34.36</td>
<td>9.51</td>
<td>39</td>
</tr>
<tr>
<td>STAI (Trait Form) Total Score</td>
<td>40.87</td>
<td>11.31</td>
<td>39</td>
</tr>
</tbody>
</table>

Note. ESFS = Empirical Sleepiness and Fatigue Scales; CES-D = Center for Epidemiological Studies Depression Scale; STAI = State Trait Anxiety Inventory

Correlation coefficients were calculated to determine the strength and direction of the relationships between comorbid symptoms, CTIP reaction time scores, and the traditional NP tests scores. Bivariate correlations were calculated between the
comorbid symptoms and between the comorbid symptoms and the CTIP and Trails A scores. Partial correlations were calculated between the comorbid symptoms and the remaining three NP tests in order to control for age. The correlations are presented in Tables 4.9 and 4.10. Strong positive correlations were observed among the various comorbid symptoms. None of the comorbid symptoms were significantly correlated with the Simple RT test, and the Sleepiness (ESFS) scale was the only variable significantly associated with the Trails A test. Several comorbid symptoms were moderately correlated with each of the other tests as can be seen in Table 4.10.

Correlation coefficients were calculated to determine the strength and direction of the relationships between comorbid symptoms and ratings of pain and are presented in Table 4.11. As can be seen from the Table, Fatigued Now, Fatigued (ESFS), Sleepiness and Fatigued Total (ESFS), and Depressive Symptoms (CES-D) are significantly correlated with almost all of the pain variables. Trait Anxiety (STAI) is moderately related to several pain variables while State Anxiety (STAI) is not significantly associated with any of the pain variables.
Table 4.9

Correlations between Comorbid Symptoms

<table>
<thead>
<tr>
<th></th>
<th>Tired Now</th>
<th>Fatigued Now</th>
<th>ESFS Sleepiness</th>
<th>ESFS Fatigued</th>
<th>ESFS Total</th>
<th>CES-D Total</th>
<th>STAI State</th>
<th>STAI Trait</th>
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<tbody>
<tr>
<td>Tired Now</td>
<td>---</td>
<td></td>
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<tr>
<td>Fatigued Now</td>
<td>.74**</td>
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<tr>
<td>ESFS Sleepiness</td>
<td>.09</td>
<td>.18</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ESFS Fatigued</td>
<td>.52**</td>
<td>.49**</td>
<td>.09</td>
<td>---</td>
<td></td>
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<tr>
<td>ESFS Total</td>
<td>.40**</td>
<td>.45**</td>
<td>.75**</td>
<td>.73**</td>
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<td></td>
<td></td>
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<tr>
<td>CES-D Total</td>
<td>.51**</td>
<td>.60**</td>
<td>.54**</td>
<td>.41**</td>
<td>.64**</td>
<td>---</td>
<td></td>
<td></td>
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<tr>
<td>STAI – State</td>
<td>.34*</td>
<td>.46**</td>
<td>.40**</td>
<td>.04</td>
<td>.30**</td>
<td>.46**</td>
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</tr>
<tr>
<td>STAI – Trait</td>
<td>.46**</td>
<td>.61**</td>
<td>.59**</td>
<td>.24</td>
<td>.57**</td>
<td>.80**</td>
<td>.61**</td>
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</table>

Note. N = 39; *p ≤ .05; **p ≤ .01; ESFS = Empirical Sleepiness and Fatigue Scales; CES-D = Center for Epidemiological Studies Depression Scale; STAI = State Trait Anxiety Inventory.
Table 4.10

Correlations between Comorbid Symptoms, Computerized Tests of Information Processing, and Traditional Neuropsychological Tests

<table>
<thead>
<tr>
<th></th>
<th>Tired Now</th>
<th>Fatigued Now</th>
<th>ESFS Sleepiness</th>
<th>ESFS Fatigued</th>
<th>ESFS Total</th>
<th>CES-D Total</th>
<th>STAI State</th>
<th>STAI Trait</th>
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</thead>
<tbody>
<tr>
<td><strong>Bivariate Correlations (not controlling for age)</strong></td>
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<tr>
<td>Simple RT</td>
<td>.21</td>
<td>.21</td>
<td>.16</td>
<td>-.06</td>
<td>.07</td>
<td>.35</td>
<td>.06</td>
<td>.23</td>
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<tr>
<td>Choice RT</td>
<td>.12</td>
<td>.28</td>
<td>.37*</td>
<td>-.04</td>
<td>.23</td>
<td>.42**</td>
<td>.20</td>
<td>.41**</td>
</tr>
<tr>
<td>Semantic RT</td>
<td>.27</td>
<td>.41**</td>
<td>.42**</td>
<td>.33*</td>
<td>.50**</td>
<td>.63**</td>
<td>.22</td>
<td>.45**</td>
</tr>
<tr>
<td>Trails A</td>
<td>.10</td>
<td>-.01</td>
<td>.33*</td>
<td>.12</td>
<td>.31</td>
<td>.19</td>
<td>-.15</td>
<td>.07</td>
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<tr>
<td><strong>Partial Correlations (controlling for age)</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Trails B</td>
<td>.20</td>
<td>.25</td>
<td>.39*</td>
<td>.09</td>
<td>.32*</td>
<td>.45**</td>
<td>.40**</td>
<td>.44**</td>
</tr>
<tr>
<td>Digit Symbol</td>
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<td>-.28</td>
<td>-.42**</td>
<td>-.25</td>
<td>-.45**</td>
<td>-.53**</td>
<td>-.32*</td>
<td>-.33*</td>
</tr>
<tr>
<td>Digit Span</td>
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<td>-.26</td>
<td>-.21</td>
<td>-.54**</td>
<td>-.49**</td>
<td>-.30</td>
<td>-.29</td>
<td>-.35*</td>
</tr>
</tbody>
</table>

*Note. N = 39; *p < .05; **p < .01; ESFS = Empirical Sleepiness and Fatigue Scales; CES-D = Center for Epidemiological Studies Depression Scale; STAI = State Trait Anxiety Inventory.*
### Table 4.11

**Correlations between Comorbid Symptoms and Ratings of Pain**

<table>
<thead>
<tr>
<th>Pain Ratings</th>
<th>Tired Now</th>
<th>Fatigued Now</th>
<th>ESFS Sleepiness</th>
<th>ESFS Fatigued</th>
<th>ESFS Total</th>
<th>CES-D Total</th>
<th>STAI State</th>
<th>STAI Trait</th>
</tr>
</thead>
<tbody>
<tr>
<td>Usual Intensity ^a</td>
<td>.32*</td>
<td>.38**</td>
<td>.22</td>
<td>.25</td>
<td>.32*</td>
<td>.37*</td>
<td>.07</td>
<td>.28</td>
</tr>
<tr>
<td>Pain Now</td>
<td>.40**</td>
<td>.59**</td>
<td>.20</td>
<td>.56**</td>
<td>.51**</td>
<td>.52**</td>
<td>.11</td>
<td>.38*</td>
</tr>
<tr>
<td>Least Pain</td>
<td>.21</td>
<td>.28</td>
<td>.17</td>
<td>.46**</td>
<td>.42**</td>
<td>.44**</td>
<td>.13</td>
<td>.25</td>
</tr>
<tr>
<td>Worst Pain</td>
<td>.34*</td>
<td>.31*</td>
<td>.20</td>
<td>.41**</td>
<td>.41**</td>
<td>.35*</td>
<td>.03</td>
<td>.21</td>
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<tr>
<td>Average Pain</td>
<td>.33*</td>
<td>.44**</td>
<td>.13</td>
<td>.59**</td>
<td>.48**</td>
<td>.44**</td>
<td>-.01</td>
<td>.25</td>
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<tr>
<td>Pain Descriptor</td>
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<td>.56**</td>
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<td>.45**</td>
<td>.47**</td>
<td>.55**</td>
<td>.23</td>
<td>.41**</td>
</tr>
<tr>
<td>^aTotal (Usual)</td>
<td>.35*</td>
<td>.44**</td>
<td>.29</td>
<td>.49**</td>
<td>.53**</td>
<td>.43**</td>
<td>.15</td>
<td>.35*</td>
</tr>
<tr>
<td>^aSensory (Usual)</td>
<td>.23</td>
<td>.36*</td>
<td>.32*</td>
<td>.43**</td>
<td>.51**</td>
<td>.42**</td>
<td>.19</td>
<td>.35*</td>
</tr>
<tr>
<td>^aAffective (Usual)</td>
<td>.48**</td>
<td>.46**</td>
<td>.16</td>
<td>.47**</td>
<td>.43**</td>
<td>.33**</td>
<td>.03</td>
<td>.24</td>
</tr>
<tr>
<td>^aTotal (Current)</td>
<td>.28</td>
<td>.43**</td>
<td>.23</td>
<td>.45**</td>
<td>.46**</td>
<td>.40**</td>
<td>.20</td>
<td>.30</td>
</tr>
<tr>
<td>^aSensory (Current)</td>
<td>.21</td>
<td>.43**</td>
<td>.24</td>
<td>.41**</td>
<td>.44**</td>
<td>.41**</td>
<td>.24</td>
<td>.32*</td>
</tr>
<tr>
<td>^aAffective (Current)</td>
<td>.37*</td>
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<td>.15</td>
<td>.46**</td>
<td>.41**</td>
<td>.31*</td>
<td>.08</td>
<td>.19</td>
</tr>
</tbody>
</table>

*Note. N = 39; ^a = Short-Form – McGill Pain Questionnaire; *p < .05; **p < .01; ESFS = Empirical Sleepiness and Fatigue Scales; CES-D = Center for Epidemiological Studies Depression Scale; STAI = State Trait Anxiety Inventory*
Hypothesis 1: Impact of Comorbid Symptoms on CTIP Scores. The main objective of Study 3 was to examine the predictive nature of potentially confounding symptoms, specifically pain, fatigue, sleepiness, depressive symptoms, and anxiety, on the processing speed of participants suffering from chronic pain. Correlation coefficients between the confounding symptoms and the CTIP were examined to select the strongest potential predictors to be entered into multiple regression analyses to predict CTIP reaction time scores. Comorbid symptoms were examined for redundancy prior to performing the regression analyses.

None of the pain variables (Table 4.7) or the comorbid symptoms (Table 4.10) were significantly associated with the Simple RT test, therefore multiple regression was not performed for this subtest.

The following variables were significantly correlated with the Choice RT test: Current Total Pain (SF-MPQ; \( r = .35 \)), Sleepiness (ESFS; \( r = .37 \)), Depressive Symptoms (CES-D; \( r = .42 \)), and Trait Anxiety (STAI; \( r = .41 \)), as shown in Tables 4.7 and 4.10. These variables were examined for redundancy and two, Depressive Symptoms and Trait Anxiety, were highly correlated (Table 4.9; \( r = .80 \)) and therefore combined (using Z-scores) to create a new variable representing Negative Affect (Tabachnick & Fidell, 2007). Redundancy was reassessed by examining correlation coefficients among the three potential predictors (Current Total Pain, Sleepiness, Negative Affect). Results ranged from .23 to .59 and therefore all were entered into the regression model.

The multiple regression analysis for the Choice reaction time scores was
significant, $F(3, 35) = 3.16, p = .04$, with a multiple correlation coefficient of .46 indicating that approximately 21% of the variance in the Choice reaction time scores may be accounted for by the combination of the pain and comorbid symptoms entered. None of these predictors, however, was significant individually. Squared semi-partial correlations indicate that Current Total Pain (SF-MPQ) accounted for less than 1%, Sleepiness accounted for approximately 2%, and Negative Affect accounted for approximately 7% of unique variance.

Similar analyses were performed for the Semantic RT test. The Pain Descriptor ($r = .48$) was the pain variable most strongly associated with the Semantic test (Table 4.7) -- and most of the comorbid symptoms were significantly correlated with this reaction time measure (Table 4.10). Sleepiness and Fatigued Total (ESFS; $r = .50$) was the strongest potential predictor of the four sleep and fatigue related variables. Both of the mood related variables, Depressive Symptoms (CES-D; $r = .63$), and Trait Anxiety (STAI; $r = .45$) were significantly correlated with the Semantic test. Since these two variables are highly correlated (Table 4.9; $r = .80$), and Depressive Symptoms (CES-D) were more strongly associated with the Semantic test, only the depression variable was selected to be entered into the regression model.

The multiple regression analysis examining the prediction of the Semantic reaction time scores was significant, $F(3, 35) = 8.89, p < .001$, with a multiple correlation coefficient of .66 indicating that 43% of the variance in Semantic reaction time scores may be accounted for by the combination of the pain and comorbid symptoms entered into the model. Squared semi-partial correlations indicated that the Depressive Symptoms scale was the only variable to account for a significant portion of unique
variance, 15%, while the Pain Descriptor accounted for 3%, and Sleepiness and Fatigued (ESFS) accounted for approximately 2% of unique variance.

**Hypothesis 2: Impact of Comorbid Symptoms on Traditional NP Test Scores.**

The present study also examined the predictive nature of potentially confounding symptoms, specifically pain, fatigue, sleepiness, depressive symptoms, and anxiety, on the scores achieved by participants suffering from chronic pain on traditional neuropsychological tests (Trails A & B, Digit Symbol, and Digit Span). First, potentially confounding variables were examined to determine which measures would represent the strongest predictors of the scores attained on the traditional neuropsychological tests. Potential predictors were examined for redundancy and evaluated to be entered into multiple regression analyses. Since age was significantly correlated with three of the traditional NP tests, and age can affect speed of cognitive processing (Lezak, Howieson, & Loring, 2004) this demographic variable was controlled by being entered first into the regression equations for these particular tests.

A regression analysis was not performed for the Trails A test. The Trails A test was not significantly correlated with age, and was significantly associated with only one symptom: Sleepiness (ESFS; $r = .33$). The squared correlation coefficient indicates that Sleepiness accounts for approximately 11% of the variance in the Trails A scores.

None of the pain variables (Table 4.7) were significantly associated with scores on the Trails B test; however, several comorbid symptoms were found to be significantly correlated with this NP test. The Sleepiness (ESFS; $r = .39$) variable was the strongest potential predictor of the sleep and fatigue related variables. All three mood related variables, Depressive Symptoms (CES-D; $r = .45$), Trait Anxiety (STAI; $r = .44$), and
State Anxiety (STAI; \( r = .40 \)) were significantly correlated with scores on the Trails B test. Since Depressive Symptoms and Trait Anxiety were highly correlated, these two variables were combined to form Negative Affect as previously described. Correlation coefficients among the three potential predictors of Trails B test scores (Sleepiness, State Anxiety, Negative Affect) ranged from .23 to .59 and therefore all were entered into the regression model.

A multiple regression analysis, controlling for age, was conducted to determine whether the foregoing comorbid symptoms would predict Trails B test scores. The initial regression model examining the prediction of the Trails B test scores from age was significant, \( F(1, 37) = 6.97, p = .01 \), with a multiple correlation coefficient of .40 indicating that 16\% of the variance in the Trails B raw scores may be accounted for by age. Inclusion of the comorbid symptoms in the second model also produced a significant overall regression equation, \( F(4, 34) = 5.30, p < .01 \), with a multiple correlation coefficient of .62, indicating that approximately 38\% of the variance in the Trails B scores may be accounted for by the linear combination of all four variables. Thus, after controlling for age, the three comorbid symptoms accounted for an additional 22\% of variance in the test scores. Age, however, was the only variable to account for a significant portion of variance individually. In the second model, squared semi-partial correlations indicated that age accounted for 29\% of the variance while Sleepiness (ESFS) accounted for approximately 2\%, State Anxiety (STAI) accounted for approximately 4\%, and Negative Affect accounted for approximately 5\% of unique variance.
Similar analyses were performed for the Digit Symbol test. The Pain Descriptor ($r = -0.42$) was the pain variable most strongly associated with the Digit Symbol test (Table 4.7) and several of the comorbid symptoms were significantly correlated with this NP measure (Table 4.10). Sleepiness and Fatigued Total (ESFS; $r = -0.45$) was the strongest potential predictor of the sleep and fatigue related variables. All three of the mood related variables, Depressive Symptoms (CES-D; $r = -0.53$), Trait Anxiety (STAI; $r = -0.33$), and State Anxiety (STAI; $r = -0.32$), were significantly correlated with the Digit Symbol test. Since Depressive Symptoms and Trait Anxiety were highly correlated (Table 4.9; $r = 0.80$), and Depressive Symptoms (CES-D) was more strongly associated with the Digit Symbol test, only the depression variable was selected to be entered into the regression model. Correlation coefficients among the four potential predictors (Pain Descriptor, Sleepiness and Fatigued, Depressive Symptoms, and State Anxiety) ranged from .23 to .64 and all were therefore entered into the regression model.

A multiple regression analysis, controlling for age, was conducted to determine whether the foregoing comorbid symptoms would predict Digit Symbol test scores. The initial regression model examining the prediction of the Digit Symbol test scores from age was significant, $F(1, 37) = 11.22, p < .01$, with a multiple correlation coefficient of .48 indicating that 23% of the variance in the Digit Symbol scores may be accounted for by age. Inclusion of the comorbid symptoms in the second model also revealed a significant overall regression equation, $F(5, 33) = 6.06, p < .001$, with a multiple correlation coefficient of .69, indicating that approximately 48% of the variance in the Digit Symbol scores may be accounted for by the linear combination of all five variables. Thus, after controlling for age, the four comorbid symptoms accounted for an additional
25% of variance in the test scores. Age, however, was the only variable to account for a significant portion of variance individually. In the second model, squared semi-partial correlations indicated that age accounted for 30% of the variance while the Pain Descriptor accounted for approximately 2%, Sleepiness and Fatigued (ESFS) accounted for approximately 2%, State Anxiety (STAI) accounted for approximately 1%, and Depressive Symptoms accounted for approximately 6% of unique variance.

Finally, similar analyses were performed for the Digit Span test. Current Affective Pain (ESFS; r = -.52) was the pain variable most strongly associated with the Digit Span test (Table 4.7) and several of the comorbid symptoms were significantly correlated with this NP measure (Table 4.10). Fatigued (ESFS; r = -.54) was the strongest potential predictor of the sleep and fatigue related variables while Trait Anxiety (STAI; r = -.35), was the only mood related variable to be significantly correlated with the Digit Symbol test. Correlation coefficients among the three potential predictors (Current Affective Pain, Fatigue, and Trait Anxiety) ranged from .19 to .46 and therefore all were entered into the regression model.

A multiple regression analysis, controlling for age, was conducted to determine whether the foregoing comorbid symptoms would predict Digit Span test scores. The initial regression model examining the prediction of the Digit Span test scores from age was significant, \( F(1, 37) = 6.88, p = .01 \), with a multiple correlation coefficient of .40 indicating that 16% of the variance in the Digit Span scores may be accounted for by age. Inclusion of the comorbid symptoms in the second model also revealed a significant overall regression equation, \( F(4, 34) = 8.78, p < .001 \), with a multiple correlation coefficient of .71, indicating that approximately 51% of the variance in the Digit Span
scores may be accounted for by the linear combination of all four variables. Thus, after controlling for age, the three comorbid symptoms accounted for an additional 35% of variance in the test scores. Three variables accounted for a significant portion of variance individually as indicated by squared semi-partial correlations: Age (18%), Current Affective Pain (12%), and Fatigue (13%). Trait Anxiety accounted for only 5% of unique variance.

**Discussion**

The primary aim of Study 3 was to examine the predictive nature of various ratings of pain, sleepiness, fatigue, depression, and anxiety, on the speed of information processing in a group of chronic pain participants. It was determined (in Studies 1 and 2) that disability status was considered acceptable, that is, there was no suspicion of disincentive in testing due to involvement in disabilities claims and none of the participants were involved in any legal proceedings.

**Hypothesis 1: Impact of Comorbid Symptoms on CTIP Scores.** It was hypothesized that particular pain ratings, and measures of sleepiness, fatigue, depression, and anxiety, would be significant predictors of reaction time scores for the CTIP within the sample of chronic pain participants. None of the pain ratings or comorbid symptoms had a significant relationship with the Simple RT scores. Several factors combined, namely Current Total Pain, Sleepiness and Negative Affect (a composite score of Depressive Symptoms and Trait Anxiety), were significantly associated with the Choice RT scores, however, none of these variables accounted for a significant portion of variance individually. The combination of Pain Descriptor, Sleepiness and Fatigued Total, and Depressive Symptoms, were significantly associated with the Semantic RT
scores, with only the Depressive Symptoms variable accounting for a significant portion of variance individually. Therefore, there was a cumulative effect of several symptoms having an impact on cognitive functioning as demonstrated through increased reaction times on the Choice and Semantic RT tests. Depressive symptoms in particular appeared to have the strongest impact on Semantic RT scores, which is consistent with slowed mental processing commonly seen in people with depression (Lezak, Howieson, & Loring, 2004).

**Hypothesis 2: Impact of Comorbid Symptoms on Traditional NP Test Scores.**

Similar to the previous analyses, it was hypothesized that ratings of pain, sleepiness, fatigue, depression, and anxiety, would be significant predictors of scores attained on the traditional NP tests within the sample of chronic pain participants. Sleepiness was the only variable found to have a significant impact on the Trails A scores. A combination of several symptoms, Sleepiness, State Anxiety, and Negative Affect, were significantly associated with performance on the Trails B test. Similarly, several factors combined were significantly associated with the Digit Symbol scores: Pain Descriptor, Total Sleepiness and Fatigued, Depressive Symptoms and State Anxiety. Finally, Current Affective Pain, and Fatigued accounted for a significant portion of variance in the Digit Span scores.

It is noteworthy that scores on three of the NP tests were more sensitive to the effect of age than were scores on the CTIP. The Trails B test requires complex visual scanning and is dependent on motor speed and agility. The Digit Symbol test requires visual acuity and speeded motor performance and agility. The Digit Span test is dependent on auditory and verbal processing as well as short-term memory recall. It
appears that these functions may decline more rapidly with age than the processes that are utilized to perform the CTIP tasks. The Simple RT task requires visual recognition of a simple stimulus followed by pressing one designated key. The Choice RT task requires the cognitive processing of two pieces of information, forming a decision, and differentially responding by pressing one of two keys. The Semantic RT task requires conceptual/semantic processing and selectively responding by pressing one of two keys.

Of further interest is the finding that the Digit Span test was the strongest predictor of group membership (Study 2) and it is the only test in which measures of pain and fatigue accounted for a significant portion of variance individually. It could be speculated that the skills required to complete this test, such as auditory attention, short-term memory, and immediate verbal recall, are more sensitive to the effects of fatigue and chronic pain, thereby proving to be more effective in predicting group membership than other tests examined in the present research.

Several further generalizations are apparent from the foregoing analyses. In six of the seven tests evaluated (all tests except Simple RT), at least one symptom or some combination of the symptoms examined accounted for a significant portion of the variance in test scores. In all six cases, sleepiness and/or fatigue were associated with test scores. For five tests (Choice RT, Semantic RT, Digit Span, Digit Symbol, Trails B), some measure of affect (depressive symptoms and/or anxiety), and for four tests (Choice RT, Semantic RT, Digit Span, Digit Symbol), some measure of pain, was associated with test scores. Thus, Study 3 provides supporting evidence that sleepiness and/or fatigue, pain, and affect, can have an impact on cognitive functioning. The Study has also provided evidence that specific NP tests are differentially sensitive to the effects of these
particular symptoms. Overlapping effects of the comorbid symptoms are also evident, adding to the difficulty in trying to tease apart particular effects (Lezak, Howieson, & Loring, 2004).

It is important to note that participants in this study were screened for, and excluded, if they had a history of psychiatric condition or medical illness. Therefore, the levels of depressive symptoms, anxiety, sleepiness and fatigue may not be as high as might be experienced by individuals with chronic pain in the general population. Notably, the participants in this study reported a heterogeneous selection of chronic pain conditions, which may inherently produce varying impacts in terms of specific pain symptoms as well as differing types and degrees of comorbid symptoms. Further, all chronic pain participants were recruited from the community and were not necessarily seeking medical attention for their condition. As pointed out by Hart, Martelli and Zasler (2000), chronic pain is subjective and may be experienced quite differently among various individuals. Thus, a community sample of people suffering from chronic pain may differ in terms of level of pain severity, disability, or interference in daily life, compared with a clinical sample drawn from a tertiary care center. Additional limitations to this study and various theoretical implications are examined in the following chapter.

**Summary.** The results of this study confirm that comorbid symptoms such as specific measures of pain, sleepiness, fatigue, and symptoms of depression and anxiety, are associated with impairments in cognitive functioning. The tests used in the present research (CTIP, Trails A & B, Digit Symbol, Digit Span) show differential sensitivity to age and concomitant symptoms, underscoring the value of using multiple measurement methods.
Chapter 5: General Discussion

Theoretical and Clinical Implications

A neuropsychological referral for a differential diagnosis of MTBI can be complicated by concomitant conditions that have the potential to confound assessment results. The primary purpose of this research was to examine one of the potential confounds that can be experienced following trauma to the head and evaluate its relationship to particular measures of cognitive functioning. When a serious insult to the head occurs there is often damage to other bodily systems which can result in chronic pain. Considerable evidence indicates that pain has the potential to confound the results of a neuropsychological evaluation. Information processing speed is one of the key aspects of cognitive functioning evaluated in a NP assessment to determine whether in fact a brain injury has occurred, however, deficits in processing speed have also been demonstrated by individuals with chronic pain (without any history of head trauma). Thus, the present study examined the impact of chronic pain on particular measures of information processing speed.

Reaction time has been shown to be a particularly sensitive measure of processing speed and the CTIP provides a series of RT measures that were designed to assess the impact of traumatic brain injury in standard clinical applications. In order to use the CTIP effectively, however, it is necessary to understand the impact of various symptoms on CTIP performance. Therefore, the ability of the CTIP to differentiate among participants with chronic pain, MTBI or STBI and healthy individuals was examined. These results were compared with performance on traditional paper and pencil neuropsychological tests, and the effects of other frequently comorbid symptoms were
studied within the chronic pain group.

Results indicated that the CTIP scores distinguished slower processing speeds between chronic pain participants and individuals in both the healthy control and MTBI groups, whereas the traditional NP test scores failed to distinguish between the chronic pain and healthy control groups. There were however, no significant differences in performance on any of the CTIP reaction time tasks or any of the traditional NP tests, between the chronic pain and the STBI groups. These results suggest that individuals with chronic pain experience noteworthy impairments in speed of information processing and that traditional paper and pencil tests may not be accurately describing this deficit.

The precise mechanisms for cognitive impairments in those with chronic pain are not entirely understood. It is well known, however, that people suffering with long-lasting pain conditions frequently experience sleep disturbance, fatigue, depression and anxiety (e.g., Gatchel et al., 2007). Substantial research confirms that each of these symptoms alone can contribute to cognitive deficits and therefore may be involved in the impairments demonstrated by those with chronic pain (Hart, Martelli, & Zasler, 2000; Lezak, Howieson, & Loring, 2004; Nicholson & Martelli, 2006). Still, there was only minimal evidence that these factors contributed to the difficulties demonstrated by the chronic pain participants in the present study, yet their test scores were comparable to those with STBI.

Several overlapping theories have been suggested to explain the impact of chronic pain on cognitive functioning (Hart, Martelli, & Zasler, 2000; Moriarty, McGuire, & Finn, 2011) and may provide insight into the results of this study. One theory suggests that cognitive impairments occur as a result of increased demand on attentional functions
carried out in the brain (Eccleston & Crombez, 1999). The IASP defines pain as “an unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage” (Merskey & Bogduk, 1994), and as Moriarty and colleagues (2011) point out, this concept takes into account that pain is a perception and in order for pain to be perceived consciously, cognitive processing must occur. By its very nature, pain is likely to demand attentional resources. Awareness of pain, and responses such as hypervigilance, rumination, and purposeful distraction, require cognitive processing. Therefore, the perception of, and response to, chronic pain consumes valuable cognitive resources thereby causing a reduction in resources available for other tasks. Thus, increased cognitive demands may reduce the speed of cognitive processing resulting in deficits in scores on tests such as the CTIP and traditional paper and pencil NP tests.

A second theory of pain-related cognitive dysfunction suggests morphological changes in the brain contribute to cognitive impairment. A growing body of research is producing compelling evidence of gross changes, as well as subtle regional changes, in brain morphology in individuals with various types of chronic pain (Apkarian, Hashmi & Baliki, 2011; Baliki, Schnitzer, Bauer & Apkarian, 2011; May, 2011; Moriarty, McGuire & Finn, 2011; Seminowicz et al., 2011). For example, patients with chronic lower back pain and fibromyalgia have been shown to have a reduction in the total volume of grey matter in comparison with healthy control participants (Moriarty, McGuire & Finn). Cortical grey matter forms the outermost layer of the brain, the cerebral cortex, and is directly involved in thought processes, perceptual awareness and motor control (Lezak, Howieson & Loring, 2004). A reduction in grey matter occurs with ageing and this has
been found to be associated with a decline in the speed of information processing (Salthouse, 1996). Thus, this supports the concept that a reduction in the density of grey matter in the brain associated with chronic pain may also be associated with a decrease in the speed of information processing.

While some inconsistencies have been reported in this area of research, there is substantial evidence of decreased grey matter volume in particular regions of the brain associated with specific chronic pain conditions. Such findings have been referred to as “brain signatures” and have been reported for chronic back pain, complex regional pain syndrome, and knee osteoarthritis (see Baliki, Schnitzer, Bauer & Apkarian, 2011, for full review). Strong evidence supporting this theory was found when particular morphological changes in grey matter were reversed once pain was substantially relieved (Apkarian, Hashmi & Baliki, 2011; Seminowicz et al., 2011). In research with chronic low back pain patients, Seminowicz and colleagues found that the left dorsolateral prefrontal cortex (DLPFC) appeared thinner in the chronic pain patients compared with controls prior to treatment (surgery or facet joint injections). Six months following treatment the chronic pain patients had increased thickness in the left DLPFC and this correlated with reduced levels of both pain and disability. Additionally, activity in the left DLPFC of the pain patients during an attention-demanding cognitive task was abnormal prior to treatment and normalized after treatment.

Further, specific decreases in regional grey matter have been associated with the duration and the intensity of chronic pain, and possibly the interaction of these two factors. The reduction in grey matter is believed to be associated with a reorganization of the anatomical network of the brain that reflects the entire experience of pain including
suffering, coping, and cognitive processing (Apkarian, Hashmi & Baliki, 2011; Baliki, Schnitzer, Bauer & Apkarian, 2011; Moriarty, McGuire & Finn, 2011).

Moriarty and colleagues (2011) propose a theoretical model describing the potential mechanisms involved in pain-related cognitive impairments. Morphological changes included in the model involve the insular cortex (IC), the anterior cingulate cortex (ACC), the dorsolateral prefrontal cortex (PFC), the hippocampus and the amygdala. The IC is involved in the experience of emotions and believed to contribute to the affective processing of pain and pain control. The ACC is involved in selective attention, working memory, and error awareness, and the PFC is involved in processing pain as well as working memory and recognition, and executive functioning. The hippocampus is involved in the transfer of information from short-term to long-term memory as well as spatial navigation, while the amygdala also plays a role in processing memories as well as decision-making and emotional reactions. It is suggested that each of these areas plays a role in various chronic pain symptoms including associated cognitive impairments.

Neurochemical dysregulation interacts with morphological changes in the model proposed by Moriarty et al. (2011). A number of neurotransmitter systems, including glutamate, GABA, monoamines (including serotonin, dopamine, norepinephrine and epinephrine) acetylcholine, endocannabinoid, and N-acetyl aspartate, are all potential candidates for involvement in both pain and cognitive processing. The effects of analgesic medications on cognitive functioning provide one source of evidence of the impact of neurochemical activity. Pharmacological treatments produce varied results and are associated with both impairments and improvements in cognitive function (Moriarty,
A complex interaction among morphological changes, neurochemical dysregulation and competing demands for limited resources comprise the model proposed by Moriarty et al. (2011) to explain pain-related cognitive impairments. There is mounting evidence that suggests the sum of these changes produce distinct “brain signatures” for specific types of chronic pain (Baliki, Schnitzer, Bauer & Apkarian, 2011). The current study, as in many others, addressed chronic pain as a distinct classification, differing from acute pain, healthy control groups, or various other clinical groups. Such an approach is consistent with the “neuromatrix” theory of pain, which suggests a unitary network of brain regions become activated during the experience of pain (Melzack, 1999; Moriarty et al., 2011). Apkarian and colleagues (2011) suggest instead that there appears to be distinct brain activity patterns related to specific chronic pain conditions. The experience of chronic pain does not appear to be a sustained or enhanced activation of the regions of the brain implicated in acute pain.

The experience of chronic pain and its impact on processing speed is likely unique to each individual and dependent on a vast range of pre-existing and concomitant biopsychosocial factors (Gatchel et al., 2007). As indicated by Von Korff and Dunn (2008), “chronic pain appears to be a continuum rather than a distinct class” (p. 267) and is likely best considered a multi-dimensional continuum. Von Korff and Dunn recommend the use of a multi-factorial Risk Score, assessing various aspects of pain intensity and duration, interference with various activities, depressive symptoms, and number of pain sites, as a method of classifying pain conditions. Their research has indicated the Risk Score to have better predictive validity for pain outcomes than the use
of pain duration alone. Thus, this underscores the usefulness of assessing and quantifying various dimensions of the pain experience.

In sum, numerous factors are involved in the chronic pain experience, many of which may have an impact on cognitive functioning thereby creating potential confounds in neuropsychological assessments. An individual presenting for assessment of persistent symptoms following trauma to the head may be experiencing many of the same types of symptoms as those with chronic pain. The difficulty is to determine whether in fact a brain injury has occurred when the individual is experiencing many other symptoms. By definition, if injury to the brain has occurred, it may involve neurochemical and/or morphological changes in the brain. Even in MTBI, diffuse axonal injuries are common and will vary depending on the nature and force of the insult (Lux, 2007). The present study does not provide a definitive method to distinguish chronic pain from mild or severe brain injured participants.

A thorough neuropsychological assessment will screen for a multitude of symptoms including pain, depression, anxiety, sleep disturbance and fatigue. Since any of these symptoms may impact cognitive functioning, treatment of these conditions may be warranted prior to assessment for potential brain injury. As detailed in the preceding chapters, it may remain difficult to tease apart the influence of various comorbid symptoms on cognitive functioning, but a neuropsychological assessment can contrast examinee performance versus healthy individuals. The present results provide the first known data to confirm that chronic pain participants perform significantly worse on two of the CTIP tasks (Choice, Semantic) than a healthy control group. Further, this research is the first to indicate a lack of significant differences in CTIP scores between chronic
pain participants and individuals who had sustained an STBI.

**Study Limitations and Future Research**

There are several limitations inherent in the current study and a number of important issues are identified that may inform future research. First, sample sizes ranged from 37 to 41 participants. These are relatively small groups and caution should be applied when generalizing results. Future research will benefit from larger sample sizes. Further, the present study sampled community dwelling chronic pain participants with the majority of these individuals reporting mild to moderate levels of pain, and a minority receiving some form of disability payment. Caution should be exercised in generalizing the current results to individuals experiencing more severe and debilitating levels of chronic pain as might be found in medical/hospitalized samples. Higher levels of pain are expected to produce greater levels of cognitive processing impairment. It would be informative to assess such samples to determine the impact of more severe pain conditions on CTIP scores.

Since chronic pain was the condition of primary interest in the present research, participants were screened and eliminated from the study if they experienced symptoms of neurological disease, psychiatric disorders, or medical illness. Thus, only relatively mild comorbid symptoms were present in the chronic pain sample. Comorbid clinical conditions, however, are common in individuals suffering from chronic pain (e.g., Demyttenaere et al., 2007; Sharp & Keefe, 2006). Therefore, while the screening was necessary to address the primary aim of the study, the results may not be readily generalizable to a typical chronic pain population that may experience more severe comorbid symptoms. With many of the common comorbid symptoms (i.e., depression,
anxiety, fatigue) associated with deficits in speed of information processing (Lezak, Howieson & Loring, 2004), it may be speculated that greater processing speed impairments might be demonstrated by such a sample. It would be useful to evaluate the effect of more severe affective symptoms concomitant with chronic pain on CTIP scores.

The present research addressed chronic pain as a general classification, and included a heterogeneous sample of pain conditions. A similar approach has frequently been used in chronic pain research (e.g., Hart, Martelli & Zasler, 2000) with the intended benefit of being generalizable to the condition of chronic pain itself regardless of underlying cause. However, increasing evidence, particularly that found in recent imaging studies, suggests that various types of chronic pain and degrees of chronicity and/or intensity may have differential impact on brain morphology and/or neurochemistry and therefore, potentially on cognitive functioning. While an attempt was made to assess various pain characteristics within the chronic pain group, limited effects were found. Examination of distinct chronic pain conditions may be more effective than evaluating chronic pain as a general category; however, this was not possible with the data collected in the current study.

As noted, increasing evidence from neuroimaging studies is providing key insights into the potential mechanisms involved in cognitive impairments experienced with various chronic pain conditions (Apkarian, Hashmi & Baliki, 2011; Moriarty, McGuire & Finn, 2011). Continuing efforts in this area are well warranted and can inform future directions in neuropsychological testing and research. For example, Apkarian and colleagues (2011) suggest that reductions in the density of regional grey matter are specific to chronic back pain, osteoarthritis, and CRPS. Differing
morphological changes in the brain specific to a particular pain condition provides compelling evidence to suggest differences in cognitive functioning in individuals with these various types of pain. Further, similar research suggests particular morphological changes are associated with the duration and intensity of chronic pain. Thus, future neuropsychological research would benefit from focusing on specific types of pain conditions with an evaluation of duration and intensity, rather than examining chronic pain as a general category. While research of this nature has been conducted, there still remain inconsistencies in results (Hart, Martelli & Zasler, 2000; Moriarty, McGuire & Finn, 2011). The inclusion of computerized tests such as the CTIP may assist in determining differences among groups. Test results recorded in milliseconds are more precise than stop-watch procedures utilized in many paper and pencil NP tests.

Further, some evidence suggests a reversal in the changes to brain morphology and functioning with substantial relief of chronic pain (Apkarian, Hashmi & Baliki, 2011; Seminowicz et al., 2011). Thus, there is evidence suggesting that successful treatment of chronic pain may indeed reverse impairments in cognitive functioning. Therefore, to expand upon this area of research, it would be useful to assess CTIP test scores before and after treatment for specific chronic pain conditions, to determine whether there is an appreciable degree of improvement in cognitive functioning following treatment.

Another potential limitation in the present study is related to the ongoing pharmacological treatments of participants at the time of testing. The use of analgesic medication affects neurochemistry with the potential to either impair or improve cognitive functioning (Cifu et al., 2009; Moriarty, McGuire & Finn, 2011; Seminowicz et al., 2011). Multimodal analgesia is often required to adequately treat ongoing pain
conditions. Various pharmacological treatments are used in pain management including, non-steroidal anti-inflammatory drugs (NSAIDs), opioids, tricyclic antidepressants, and anticonvulsants. In some cases the drugs may be responsible for impaired cognitive functioning, or, may exacerbate existing cognitive deficits. Investigations into these effects have produced inconsistent results (e.g., see review in Moriarty, McGuire & Finn). Suggested reasons for such varied responses include development of tolerance to the medications, and, the possibility of cognitive improvement with effective pain relief. Therefore, while analgesics may exacerbate cognitive impairments, the effective relief of chronic pain may alleviate associated cognitive impairment. It can be difficult to effectively assess the effect of analgesics on cognitive functioning due to ethical considerations in seeking a non-medicated chronic pain control group (Moriarty, McGuire & Finn).

While an effort was made to collect data regarding medication usage within the chronic pain group in the present study, reliable data was not obtained. Participants in the chronic pain group were requested to bring a list of medications with them at time of data collection, but they frequently forgot to do so, or the information was incomplete. Efforts to acquire this information after test administration were seldom successful. Further, usage of medications among the TBI participants in the archival groups is unknown. Therefore, it is uncertain whether the cognitive performance of any of the participants in the present research was affected by the use of medication. In theory, the use of analgesics could potentially increase or decrease test scores on the CTIP or the traditional NP tests and should be evaluated in the future.

The present research relied on the use of archival data for the TBI samples and
was limited to the information available for these groups. The data for the MTBI sample was collected within approximately one month of the date of injury and therefore may not be generalizable to cases where symptoms have persisted for an extended period of time. Significantly more time had elapsed post-injury, 3.3 years on average, with a range of 22 days to 25 years, at the time data was collected from the STBI group. Participants in this group were recruited from neuropsychologists and physiatrists and were experiencing some type of significant cognitive difficulty. Therefore these individuals appear to be representative of typical STBI patients who may be seen for neuropsychological evaluation.

There was no information provided regarding pain and other concomitant symptoms for the archival TBI groups. It is well documented that people who have suffered a mild traumatic brain injury are also likely to incur pain, and often experience sleep disturbance, fatigue, and symptoms of anxiety and depression as well (Cifu et al., 2009). All of these symptoms have the potential to impact cognitive functioning. Since the MTBI participants were tested within approximately one month of injury, if injury-related pain was present at time of testing, it would not meet criteria for “chronic” pain (typically a minimum of six months duration). Therefore, the pain may be less likely to have a “brain signature” impacted by brain morphological and neurochemical changes to the extent discussed above. While an increase in attentional demands may occur as a result of pain, the available resources may not be depleted to the extent observed in chronic conditions. In the STBI group, significantly more time had elapsed post-injury at the time data was collected. Therefore, the presence of chronic pain as well as other concomitant symptoms is possible, but data of this nature was not provided. As the
present study has confirmed, chronic pain appears to have the potential to impair the speed of information processing. Therefore, it is important to assess the potential impact of concomitant symptoms, especially pain, as well as anxiety, depression, and fatigue, on CTIP scores in patients with suspected mild or severe brain injury.

Finally, it is noted that the correlational nature of the analyses in the present study precludes any assumption of causation. That is, the present study confirms there appears to be a relationship between chronic pain and impairments in the speed of information processing, but does not provide evidence that chronic pain causes impairments in information processing speed. Continued research in the areas of morphological and neurochemical changes in the brain, related to chronic pain, may be the best method to explore a causal relationship between chronic pain and deficits in cognitive functioning.

**Conclusions**

The present study provided the first known evidence that chronic pain participants performed significantly worse on the CTIP in comparison with healthy control and MTBI groups. It is noteworthy that there were no significant differences in CTIP scores between the Chronic Pain group and the STBI group. This study therefore provides additional evidence that individuals with chronic pain appear to experience notable deficits in the speed of information processing. These results also highlight the importance of screening for chronic pain during a NP assessment. If chronic pain is not treated prior to a NP evaluation it may be impossible to disentangle the effects of chronic pain from potential brain injury.

Concomitant conditions measured in the chronic pain group, such as symptoms of depression, anxiety, sleepiness, and fatigue, appeared to have minimal impact on the
CTIP and NP test scores in the present sample.

Discriminant function analyses indicated that the Semantic RT test was the strongest predictor of group membership among the CTIP tasks, although the Digit Span test proved to be the overall strongest predictor of group membership when all tests were examined together. Particular combinations of tests were able to correctly classify participants at a rate superior to chance agreement but there was still considerable room for clinical error. While the model with the strongest predictive ability produced results almost twice as high as chance agreement, only half of the sample was classified correctly. These results illustrate the importance of employing multiple sources of corroborating evidence in the process of differential diagnosis.

Thus, the present study has provided novel information to the area of NP assessment in the presence of chronic pain.
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pain and pain-related disability in urban and rural settings in southeastern Ontario.


Appendix A

MA-CPR Telephone Script – Previous Contacts

Hello, my name is (Mary Acreman), I’m from Queen’s University. We were talking with someone in your home a couple of years ago regarding health related research and the person we spoke with indicated we could call again in the future regarding further research.

Were we talking with you? Or someone else? . . .

We are conducting a new study and are looking for two groups of people: one group of people who are experiencing some type of pain condition, and another group of people who are generally healthy and do not have any type of pain condition. All that we ask is that participants fill out some questionnaires related to health and mood, and complete some short processing tasks (very simple pen and paper tasks, and a couple of simple exercises on the computer, don’t need to know how to use a computer. . . . ) . . .

Would you be able to help with this? . . .

[Remember to screen . . . see “Pre-screen Interview” ]
Pre-screen Interview

Date: ______________________

1. Is English your first language?    ____ Yes          ____ No   (If “No” please do NOT continue)

2. Have you ever endured a concussion, brain injury, or head injury?    ____ Yes         ____ No
   (If “Yes” please do NOT continue)

3. Have you ever been diagnosed with a learning disability?                  ____ Yes         ____ No
   If so, please describe  __________________________________________________________
   ______________________________________________________________________________
   ______________________________________________________________________________

4. Have you ever been diagnosed with attention deficit disorder (ADD) or attention deficit
   hyperactivity disorder (ADHD)?           ____ Yes         ____ No

5. Do you have any type of neurological disease, psychiatric condition, or medical illness?
   ____ Yes    ____ No     If “Yes” please describe __________________________________________
   ______________________________________________________________________________
   ______________________________________________________________________________
   ______________________________________________________________________________

6. Do you have any other condition that could affect the speed or accuracy of your performance
   on written or computerized tasks (e.g., injury, handwriting difficulties, visual problems, etc.)?
   ____ Yes    ____ No     If “Yes” please describe __________________________________________
   ______________________________________________________________________________
   ______________________________________________________________________________
   ______________________________________________________________________________

Appointment:  Date _____________  Time _______________  Place _____________________
Location to meet: __________________________________________________

Please bring a list of all medications you are taking, including name, dosage, duration, purpose.
Thank You!

We appreciate your time and interest!

Please share this information with anyone who might be interested.

Please call or email for more information:

Mary Acraman
613-533-6000, ext. 75459
(Kingston)
613-394-4567
(Belleville/Trenton)
3mea2@queensu.ca

We need people with and without Chronic Pain

Help us learn more about Chronic Pain

Your help is greatly appreciated!
(and you could win $100!)

Queen's Psychology Pain Research Unit
Chronic Pain Study

Help us understand more about chronic pain
Chronic pain can be a debilitating condition and may affect many areas of a person’s life, such as physical functioning, employment, social activities, relationships, and general quality of life. We want to understand more about the processes involved in this condition.

What will we ask you to do?
All you will be asked to do will be to answer some short questionnaires regarding your health and mood, and complete some simple written and computerized tasks. You do not have to answer any questions you find objectionable or which make you feel uncomfortable.

Who can help?
You can help if:
☑ you are 18 years of age or older
☑ English is your first language
☑ you have never had a head injury
☑ you do not have any condition that would affect your performance on written or computerized tasks (e.g., handwriting difficulties, multiple sclerosis, Parkinson’s disease, etc.)

Completely Confidential
All information you provide will be kept confidential. Your name will not appear on any of the study answer sheets (we use Identification Numbers).

Completely Voluntary
Your participation is completely voluntary and you may withdraw at any time. If you are a person who heard about this study through a health care practitioner’s office (e.g., posters or handouts in waiting rooms of chiropractors, physiotherapists, registered massage therapists) your participation in this study, or withdrawal from the study, will not have any effect on the health care you receive.

Our Appreciation
We truly appreciate your help!
To show our thanks for your participation, your name (with your permission) will be entered in a

Draw for $100
To be held at completion of the study.

DEPARTMENT OF PSYCHOLOGY

Queens University

52 Arch Street
Humphrey Hall
Queen’s University
Kingston, Ontario K7L 3N6

Mary Acerson, Ph.D. Candidate
Phone: 613-533-6000, ext. 72540 (Kingston)
Phone: 613-354-4507 (Belleville/Trenton)
E-mail: jams2@queensu.ca
Thank You!

We appreciate your time and interest!

Please share this information with anyone who might be interested.

Please call or email for more information:

Mary Aceman
613-533-6000, ext. 75459
(Kingston)
613-394-4567
(Belleville/Trenton)

3mea2@queensu.ca

We need healthy people to participate in health research

We need your help!

Your help is greatly appreciated!
(and you could win $100!)

Queen's Psychology Research Unit
Health Psychology Research

What will we ask you to do?
All you will be asked to do will be to answer some short questionnaires regarding your health and mood, and complete some simple written and computerized tasks. You do not have to answer any questions you find objectionable or which make you feel uncomfortable.

Help us understand more
We need healthy people to act as a comparison group in our research regarding chronic pain and traumatic brain injury. Both of these conditions can be debilitating and may affect many areas of a person’s life, such as physical functioning, employment, social activities, relationships, and general quality of life. We want to understand more about the processes involved in these conditions.

Who can help?
You can help if:
- you are 16 years of age or older
- English is your first language
- you have never had a head injury
- you have never been diagnosed with a learning disability or attention deficit disorder (ADD or ADHD)
- you do not have any condition that would affect your performance on written or computerized tasks (e.g., handwriting difficulties, Multiple Sclerosis, Parkinson’s disease, etc.)

Our Appreciation
We truly appreciate your help!
To show our thanks for your participation, your name (with your permission) will be entered in a Draw for $100
To be held at completion of the study.

Completely confidential
All information you provide will be kept confidential. Your name will not appear on any of the study answer sheets (we use Identification Numbers).

Completely voluntary
Your participation is completely voluntary and you may withdraw at any time. If you are a person who heard about this study through a health care practitioner’s office (e.g., posters or handouts in waiting rooms of chiropractors, physiotherapists, registered massage therapists) your participation in this study, or withdrawal from the study, will not have any effect on the health care you receive.
Help us learn more about pain simply by filling out short questionnaires!

We need people with and without CHRONIC PAIN

Your help is greatly appreciated! (and you could win $100)

Please see handout for details!
Appendix B

Differences in Information Processing Among People with Traumatic Brain Injury, People with Chronic Pain, and Healthy Individuals

Letter of Information

This research is being conducted by Mary Acreman, Ph.D. Candidate in Clinical Psychology at Queen’s University, working with Dr. Dean Tripp, Associate Professor, Departments of Psychology, Anesthesiology, and Urology at Queen’s University, Kingston, Ontario.

This study is being conducted to help us better understand some of the difficulties faced by people with chronic pain, in particular, the effects their pain may have on specific thinking processes. Chronic pain, fatigue, and mood can all impact thought processes and when these symptoms are present in people who have endured a mild head injury, it can be difficult to determine whether or not a mild brain injury has occurred. Therefore, this study will assess differences in information processing among people who have endured a brain injury, people who experience chronic pain (who have never had a head injury), and healthy individuals (who have never had a head injury).

In this study you will be asked to complete demographic information (e.g., age, gender), brief questionnaires regarding your health, mood, medication and alcohol consumption, and short information processing tasks. Most items are completed using pen and paper, and four tasks present information on a computer screen and you are required to press a particular key on the keyboard to indicate your response. The time required to complete individual tasks and questionnaires ranges from approximately 2 to 10 minutes resulting in a total time of approximately 1 hour to complete all items. All information will be collected in a private, quiet room such as the Pain Laboratory in the Psychology Department at Queen’s University (for people in the Kingston area) or a reserved library/school room (e.g., at Loyalist College for people in the Belleville and Trenton areas).

There are no known physical, psychological, economic, or social risks associated with this study. You are not obliged to answer any questions you find objectionable or which make you feel uncomfortable. Your participation in this study is completely voluntary and you may withdraw at any time without any consequences. If you are a person with chronic pain who heard about this study through a health care practitioner’s office (e.g., posters or handouts in waiting rooms of chiropractors, physiotherapists, registered massage therapists) your participation in this study, or withdrawal from the study, will not have any effect on the health care you receive. If you are a Queen’s University student who is participating in this study for course credit, you will be awarded course credit whether or not you complete the study.

... 2
All participants are eligible to receive up to $5 to cover parking expenses while participating in this study and you will receive the $5 parking fee even if you choose to withdraw from the study. All participants are eligible (if they choose) to have their name placed in a draw for $100 and their name will remain in the draw even if the participant chooses to withdraw from the study. Two draws for $100 each (one draw for people with chronic pain, and one draw for healthy individuals without chronic pain) will be held at the completion of the study (completion date is expected to be no later than May 2008).

All of your responses will be kept confidential. All information you provide will be stored in a locked filing cabinet and on computer data files containing no personal identifiers, until the raw data is no longer required at which time it will be destroyed. Only researchers in the Pain Lab will have access to this data. To help us ensure confidentiality, please do not put your name on any of the research study answer sheets. The results of this study will be used to formulate a Ph.D. dissertation for the Queen’s Psychology Department. The data also may be presented in professional psychological journals, or at scientific conferences, but any such presentations will be of general findings and will never violate confidentiality. Should you be interested, we will send you a copy of the findings.

Please retain a copy of this letter for your reference. If you have any questions, complaints, or concerns about this research, please feel free to contact Mary Acreman at 3mea2@queensu.ca or (613) 533-6000, ext. 75459, or Dr. Dean Tripp at (613) 533-6955 or dean.tripp@queensu.ca. Should this not answer all of your questions, you may also contact Dr. Vern Quinsey, Head of the Department of Psychology at (613) 533-2492, or the Chair of the Queen's University General Research Ethics Board, Dr. Steve Leighton at (613) 533-6081.

Thank you very much for your participation in this study. Your time and interest are truly appreciated.

Mary Acreman  
Ph.D. Candidate  
Professor

Dr. Dean Tripp  
Associate
Appendix C

Differences in Information Processing Among People with Traumatic Brain Injury, People with Chronic Pain, and Healthy Individuals

Consent Form

Name (please print clearly): ____________________________

➢ I have read the Letter of Information and all my questions pertaining to this study have been answered satisfactorily.
➢ I understand that I will be participating in the project “Differences in Information Processing Among People with Traumatic Brain Injury, People with Chronic Pain, and Healthy Individuals”, and I have been informed that my involvement consists of completing several brief questionnaires and information processing tasks. Most items will be completed using pen and paper, while four tasks consist of simple computer exercises. I understand that the purpose of this study is to assess differences in information processing among people who experience chronic pain, people with a traumatic brain injury, and healthy individuals.
➢ I understand that my participation in this study is voluntary and that I may choose not to answer any question and to terminate my participation at any time. I understand that withdrawing from this study will have no adverse consequences of any sort.
➢ I understand that any data collected will be locked in file cabinets and every effort will be made to maintain the confidentiality of the data now and in the future.

I am aware that if I have any questions, concerns or complaints I can contact the project researcher, Mary Acreman at 3mea2@queensu.ca or (613) 533-6000, ext. 75459, Dr. Dean Tripp at (613) 533-6955 or dean.tripp@queensu.ca, Dr. Vern Quinsey, Head of the Department of Psychology at (613) 533-2492, or the Chair of the Queen's University General Research Ethics Board, Dr. Steve Leighton at (613) 533-6081.

I have read the above statements and freely consent to participate in this study:
Signature: ______________________________ Date: __________________

Please select one of the following options by initialling on the appropriate line:

____ Yes, I would like my name to be entered into a draw for $100 to be drawn at completion of this study.

If so, please provide: Mailing address __________________________________________
Email address __________________________________________
Telephone No. __________________________________________

____ No, do not enter my name in the draw for $100.
Differences in Information Processing Among People with Traumatic Brain Injury, People with Chronic Pain, and Healthy Individuals

Please complete the following information before you begin:

Today’s Date: ______________________

1. Is English your first language?   ____ Yes    ____ No (If “No” please do NOT continue)

2. Have you ever endured a concussion, brain injury, or head injury?   ____ Yes    ____ No (If “Yes” please do NOT continue)

3. Have you ever been diagnosed with a learning disability?   ____ Yes    ____ No
   If so, please describe __________________________________________________________
   ___________________________________________________________________________
   ___________________________________________________________________________

4. Have you ever been diagnosed with attention deficit disorder (ADD) or attention deficit hyperactivity disorder (ADHD)?   ____ Yes    ____ No

5. Do you have any type of neurological disease, psychiatric condition, or medical illness?   ____ Yes    ____ No
   If “Yes” please describe _____________________________________________________
   ___________________________________________________________________________
   ___________________________________________________________________________
   ___________________________________________________________________________

6. Do you have any other condition that could affect the speed or accuracy of your performance on written or computerized tasks (e.g., injury, handwriting difficulties, visual problems, etc.)?   ____ Yes    ____ No
   If “Yes” please describe _____________________________________________________
   ___________________________________________________________________________
   ___________________________________________________________________________
   ___________________________________________________________________________
Appendix E

Differences in Information Processing Among People with Traumatic Brain Injury, People with Chronic Pain, and Healthy Individuals

Debriefing Form

Chronic pain can be a debilitating condition and may affect many areas of a person’s life, such as physical functioning, employment, social activities, relationships, and general quality of life. When chronic pain is accompanied by other symptoms, such as fatigue, low mood, and/or anxiety, the difficulties are compounded. All of these symptoms can affect particular thinking processes, especially information processing. Therefore, our goal is to gain a greater understanding of the effects of chronic pain and its accompanying symptoms on information processing.

We expect the results of this study to be helpful in further understanding cognitive difficulties faced by some individuals with chronic pain, and also to potentially aid in the diagnosis of mild traumatic brain injury. When someone endures a mild head injury, they also may experience chronic pain, fatigue, low mood, and anxiety. Since chronic pain and its accompanying symptoms can affect thinking processes, it may be difficult to determine whether a mild brain injury has occurred. Therefore, we will be comparing the results of the information processing tasks among three groups of people: those who have endured a brain injury, those with chronic pain (who have never had a head injury), and healthy individuals (who have never had a head injury). In particular, we will assess whether different test scores in information processing among the three groups can potentially assist in the diagnosis of mild traumatic brain injury. We also will assess the impact of fatigue, low mood, and anxiety, on information processing, among people with chronic pain and healthy individuals to help determine whether these symptoms may play a significant role in cognitive difficulties.

Your participation in this study will help us reach the goals noted above. We truly appreciate your time and effort. Thank you!

If you are interested in this area of research, you may wish to read the following references:


If participating in this research has caused you to feel distressed, and you would like to talk to someone about your thoughts, please see your family doctor or contact one of the following:

<table>
<thead>
<tr>
<th>Kingston</th>
<th>Belleville</th>
</tr>
</thead>
<tbody>
<tr>
<td>Queen’s Student Counselling Service</td>
<td>613-533-2506</td>
</tr>
<tr>
<td>TALK Distress &amp; Information Line</td>
<td>613-544-1771</td>
</tr>
<tr>
<td>Canadian Mental Health Association</td>
<td>613-549-7027</td>
</tr>
<tr>
<td>Crisis Intervention Centre</td>
<td>613-549-7027</td>
</tr>
</tbody>
</table>

If you have any questions, complaints, or concerns about this research, please feel free to contact Mary Acreman at 3mea2@queensu.ca or (613) 533-6000, ext. 75459, or Dr. Dean Tripp at (613) 533-6955 or dean.tripp@queensu.ca. Should this not answer all of your questions, you may also contact Dr. Vern Quinsey, Head of the Department of Psychology at (613) 533-2492, or the Chair of the Queen's University General Research Ethics Board, Dr. Steve Leighton at (613) 533-6081.

Once again, thank you very much for your participation in this research!

Mary Acreman
Ph.D. Candidate

Dr. Dean Tripp
Associate Professor
Appendix F

Acreman Chronic Pain Research
Psychology Pain Unit, Queen’s University
Background Questionnaire

ID # _______________________

Background Questionnaire

1. Birthdate (dd/mm/yyyy): ______________
2. Age: __________
3. Gender: _____ Male         _____ Female
4. Number of years of formal education: ______ years
   (e.g., high school graduate = 12 years; 2 years college = 14 years;
   Bachelors Degree = 16 years; Masters Degree = 18 years)
5. Marital Status:     __ Married          __ Living w/someone         __Single
   __ Separated     __ Divorced                        __Widowed
6. List all medications you are currently taking:
   Medication Name             Dosage             #  times/day?      Taking for what?     For how long?
   ______________       ___________       ___       _____________      ___________  
   ______________       ___________       ___________       _____________      ___________  
   ______________       ___________       ___________       _____________      ___________  
   ______________       ___________       ___________       _____________      ___________  
7. List amount of alcohol usually consumed:
   One standard drink: Number per:   Day                     Week                    Month
   12 ozs of beer                        __________          __________          __________
   8 ozs of malt liquor                              __________          __________          __________
   5 ozs of wine                                               __________          __________
   1.5 ozs (a “shot”) of                               __________          __________          __________
   80-proof distilled spirits or       __________
   liquor (gin, rum, vodka, whiskey, etc.)
8. How long have you been drinking the amount of alcohol noted above?
   _____ Months          ______Years
9. Have you consumed any alcohol today?   ____ Yes       ____ No
   If “Yes”, please answer the following:
   Type of alcohol                        How many “standard drinks”?     How long ago?
   (e.g., beer, wine, etc.)              (see # 7 above)                     (minutes, hours)
   __________________                        __________________           __________________  
   __________________                        __________________           __________________  
   __________________                        __________________           __________________  
   __________________                        __________________           __________________

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Appendix G

Acreman Chronic Pain Research
Psychology Pain Unit, Queen’s University
Pain Questionnaire

ID # _____________________

Pain Questionnaire

Please describe your experience with pain. Here the word “pain” refers to experiences which are constant or often bothersome, not minor pains like a brief headache or sore muscles after exercising.

1. Do you suffer from pain? ___ Yes ___ No (If “No”, go to #18, page 4)

2. How long have you had the pain? #_______ Weeks #_______ Months #______ Years

3. How often do you have the pain? #________________ minutes/hours per day

#_________ days per week #________________ days/weeks per month

4. Overall, what percentage of time are you in pain? Please circle the approximate % of time:

% Time in pain = 0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

5. Temporal quality of your pain: Please circle all of the words below that describe your pain.

<table>
<thead>
<tr>
<th>Brief</th>
<th>Comes and goes</th>
<th>Continuous</th>
<th>Constant</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Always there</td>
<td>Never goes away</td>
<td>Appears and disappears</td>
</tr>
</tbody>
</table>

6. From what kind of pain do you suffer? Describe your pain: ____________________________

7. Rate how much the following words describe your usual pain. Indicate the severity of each pain experience word by shading “None”, “Mild”, “Moderate”, “Severe”.

<table>
<thead>
<tr>
<th></th>
<th>None</th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Throbbing</td>
<td>○₀</td>
<td>○₁</td>
<td>○₂</td>
<td>○₃</td>
</tr>
<tr>
<td>Shooting</td>
<td>○₀</td>
<td>○₁</td>
<td>○₂</td>
<td>○₃</td>
</tr>
<tr>
<td>Stabbing</td>
<td>○₀</td>
<td>○₁</td>
<td>○₂</td>
<td>○₃</td>
</tr>
<tr>
<td>Sharp</td>
<td>○₀</td>
<td>○₁</td>
<td>○₂</td>
<td>○₃</td>
</tr>
<tr>
<td>Cramping</td>
<td>○₀</td>
<td>○₁</td>
<td>○₂</td>
<td>○₃</td>
</tr>
<tr>
<td>Gnawing</td>
<td>○₀</td>
<td>○₁</td>
<td>○₂</td>
<td>○₃</td>
</tr>
<tr>
<td>Hot-Burning</td>
<td>○₀</td>
<td>○₁</td>
<td>○₂</td>
<td>○₃</td>
</tr>
<tr>
<td>Aching</td>
<td>○₀</td>
<td>○₁</td>
<td>○₂</td>
<td>○₃</td>
</tr>
<tr>
<td>Heavy</td>
<td>○₀</td>
<td>○₁</td>
<td>○₂</td>
<td>○₃</td>
</tr>
<tr>
<td>Tender</td>
<td>○₀</td>
<td>○₁</td>
<td>○₂</td>
<td>○₃</td>
</tr>
<tr>
<td>Splitting</td>
<td>○₀</td>
<td>○₁</td>
<td>○₂</td>
<td>○₃</td>
</tr>
<tr>
<td>Tiring-Exhausting</td>
<td>○₀</td>
<td>○₁</td>
<td>○₂</td>
<td>○₃</td>
</tr>
<tr>
<td>Sickening</td>
<td>○₀</td>
<td>○₁</td>
<td>○₂</td>
<td>○₃</td>
</tr>
<tr>
<td>Fearful</td>
<td>○₀</td>
<td>○₁</td>
<td>○₂</td>
<td>○₃</td>
</tr>
<tr>
<td>Punishing-Cruel</td>
<td>○₀</td>
<td>○₁</td>
<td>○₂</td>
<td>○₃</td>
</tr>
</tbody>
</table>
8. Write #1 next to your primary area of pain, and a #2, #3 etc. next to your secondary sites of pain.

- head/face/mouth
- neck
- shoulders/upper arms
- lower arms
- hands/fingers
- chest
- abdomen/stomach
- upper back
- mid-back
- low back
- upper legs
- lower legs
- feet
- pelvis
- buttocks
- hips
- anal area
- genital area
- other (specify): _______________

9. Using the “0 to 10” SCALE below, rate the usual strength or intensity of your pain for each area you marked above. Record a number rating on the line next to each area or site of your pain below.

No Pain | Worst Pain Imaginable
---|---
0 | 10

- head/face/mouth
- neck
- shoulders/upper arms
- lower arms
- hands/fingers
- chest
- abdomen/stomach
- upper back
- mid-back
- low back
- upper legs
- lower legs
- feet
- pelvis
- buttocks
- hips
- anal area
- genital area
- other (specify): _______________

10. What do you think is the primary cause for your pain? (write #1 next to the “primary cause, #2, #3, and so on, next to any secondary causes, and write in the specific cause/s if you can)

- motor vehicle accident
- a fall
- a lifting accident
- an assault
- moving wrong
- diabetes
- herniated disk
- cardiac disease
- arthritis: __________
- a chronic illness: __________
- cancer: __________
- pulmonary disease: __________
- an infectious disease: __________
- a repetitive strain injury: __________
- an inflammatory disease: __________
- a degenerative condition: __________
- a metabolic condition: __________
- unknown cause
- other known cause: __________

11. Please explain the causes for your pain that you have marked down above: _______________

________________________________________________________
12. Did the cause of your pain include a head injury or concussion?  __ Yes  __ No

13. What is/are your primary medical diagnosis or diagnoses for your pain condition?
__________________________________________________________________________________
__________________________________________________________________________________

14. Are you receiving any type of disability or worker’s compensation payments related to your pain condition?  __ Yes  __ No

15. Is an application planned for any type of disability or worker’s compensation payments related to your pain condition?  __ Yes  __ No

16. Are you involved in a lawsuit or legal proceedings related to your pain condition?  __ Yes  __ No

17. List below all medications you are currently taking for pain.

<table>
<thead>
<tr>
<th>Medication Name</th>
<th>Dosage</th>
<th># times/day?</th>
<th>Taking for what?</th>
<th>For how long?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
18. Please answer the following questions based on how you are feeling today:

Are you experiencing pain as described on the previous pages?  

Yes  No

Do you have minor pain today?  

Yes  No  If so, please indicate type of minor pain:

headache  sore muscles after exercising  other___________________________

Think of your current pain (during the last 24 hours). Rate how much the following words describe your pain. Indicate the severity of each pain experience word by shading “None”, “Mild”, “Moderate”, “Severe”.

<table>
<thead>
<tr>
<th></th>
<th>None</th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Throbbing</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Shooting</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Stabbing</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Sharp</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Cramping</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Gnawing</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Hot-Burning</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Aching</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Heavy</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Tender</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Splitting</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Tiring-Exhausting</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Sickening</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Fearful</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Punishing-Cruel</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

19. Shade a circle above the number that shows your PAIN:

Current Pain - now…  

<table>
<thead>
<tr>
<th></th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Pain</td>
<td></td>
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</tr>
<tr>
<td>Worst Possible Pain</td>
<td></td>
<td></td>
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<td></td>
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</tbody>
</table>

Pain at its least – past wk…  

<table>
<thead>
<tr>
<th></th>
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<th>3</th>
<th>4</th>
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<th>7</th>
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<th>9</th>
<th>10</th>
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<tbody>
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<td>No Pain</td>
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<td></td>
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<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Worst Possible Pain</td>
<td></td>
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<td></td>
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</table>

Worst Pain – past wk…  

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<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Worst Possible Pain</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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</tbody>
</table>

Average Pain – past wk…  

<table>
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<tr>
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<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Pain</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Worst Possible Pain</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

20. Shade in a descriptor below for your Current pain:

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>NO PAIN</td>
<td>3</td>
<td>DISTRESSING</td>
</tr>
<tr>
<td>1</td>
<td>MILD</td>
<td>4</td>
<td>HORRIBLE</td>
</tr>
<tr>
<td>2</td>
<td>DISCOMFORTING</td>
<td>5</td>
<td>EXCRUCIATING</td>
</tr>
</tbody>
</table>
Appendix H

**CES-D**

Circle the number of each statement, which best describes how often you felt or behaved this way – DURING THE PAST WEEK.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Rarely or none of the time (Less than 1 day)</th>
<th>Some or a little of the time (1-2 days)</th>
<th>Occasionally or a moderate amount of the time (3-4 days)</th>
<th>Most or all of the time (5-7 days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I was bothered by things that usually don’t bother me</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>2. I did not feel like eating; my appetite was poor</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>3. I felt that I could not shake off the blues even with help from my family or friends</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>4. I felt that I was just as good as other people</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>5. I had trouble keeping my mind on what I was doing</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>6. I felt depressed</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>7. I felt that everything I did was an effort</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>8. I felt hopeful about the future</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>9. I thought my life had been a failure</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>10. I felt fearful</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>11. My sleep was restless</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>12. I was happy</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>13. I talked less than usual</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>14. I felt lonely</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>15. People were unfriendly</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>16. I enjoyed life</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>17. I had crying spells</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>18. I felt sad</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>19. I felt that people disliked me</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>20. I could not get “going”</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>
Appendix I

STAI

PART 1

INSTRUCTIONS: A number of statements which people have used to describe themselves are given below. Read each statement and then circle the appropriate number to the right of the statement to indicate how you feel right now, that is, at this moment. There are no right or wrong answers. Do not spend too much time on any one statement but give the answer which seems to describe your present feelings best.

(1) Not at all; (2) Somewhat; (3) Moderately so; (4) Very much so

Right now, at this moment...

1. I feel calm................................................. 1 2 3 4
2. I feel secure............................................. 1 2 3 4
3. I am tense.............................................. 1 2 3 4
4. I feel strained......................................... 1 2 3 4
5. I am at ease........................................... 1 2 3 4
6. I feel upset........................................... 1 2 3 4
7. I am presently worrying over possible misfortunes.. 1 2 3 4
8. I feel satisfied......................................... 1 2 3 4
9. I feel frightened..................................... 1 2 3 4
10. I feel comfortable................................. 1 2 3 4
11. I feel self-confident.............................. 1 2 3 4
12. I feel nervous...................................... 1 2 3 4
13. I am jittery........................................... 1 2 3 4
14. I feel indecisive.................................... 1 2 3 4
15. I am relaxed......................................... 1 2 3 4
16. I feel content....................................... 1 2 3 4
<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>17.</td>
<td>I am worried.................................</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>18.</td>
<td>I feel confused...............................</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>19.</td>
<td>I feel steady...................................</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>20.</td>
<td>I feel pleasant..................................</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>
STAI
PART 2

INSTRUCTIONS: A number of statements which people have used to describe themselves are
given below. Read each statement and then circle the appropriate number to the right of the
statement to indicate how you generally feel.

(1) Not at all; (2) Somewhat; (3) Moderately so; (4) Very much so

Generally...

1. I feel pleasant................................................................. 1 2 3 4
2. I feel nervous and restless............................................... 1 2 3 4
3. I feel satisfied with myself............................................... 1 2 3 4
4. I wish I was as happy as others seem to be...................... 1 2 3 4
5. I feel like a failure......................................................... 1 2 3 4
6. I feel rested................................................................. 1 2 3 4
7. I am calm cool and collected........................................... 1 2 3 4
8. I feel that difficulties are piling up so that I cannot overcome them..... 1 2 3 4
9. I worry too much over something that doesn’t really matter........ 1 2 3 4
10. I am happy................................................................. 1 2 3 4
11. I have disturbing thoughts............................................. 1 2 3 4
12. I lack self-confidence................................................... 1 2 3 4
13. I feel secure............................................................... 1 2 3 4
14. I make decisions easily................................................. 1 2 3 4
15. I feel inadequate........................................................ 1 2 3 4
16. I am content............................................................. 1 2 3 4
17. Some unimportant thought runs through my mind and bothers me..... 1 2 3 4

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18. I take disappointments so keenly that I can’t put them out of my mind.  
19. I am a steady person.................................................................
20. I get in a state of turmoil as I think over my recent concerns & interests
Appendix J
ESFS

How likely are you to doze off or fall asleep in the following situations, in contrast to just feeling tired? Please shade in the appropriate circle for each item below:

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>Never doze off</th>
<th>High chance of dozing off</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Sitting and reading</td>
<td>O₀</td>
<td>O₁</td>
</tr>
<tr>
<td>2.</td>
<td>Watching TV</td>
<td>O₀</td>
<td>O₁</td>
</tr>
<tr>
<td>3.</td>
<td>Sitting inactive in a public place (e.g., theatre, meeting)</td>
<td>O₀</td>
<td>O₁</td>
</tr>
<tr>
<td>4.</td>
<td>As a passenger in a car for an hour when circumstances permit</td>
<td>O₀</td>
<td>O₁</td>
</tr>
<tr>
<td>5.</td>
<td>Sitting and talking to someone</td>
<td>O₀</td>
<td>O₁</td>
</tr>
<tr>
<td>6.</td>
<td>Sitting quietly after lunch without alcohol</td>
<td>O₀</td>
<td>O₁</td>
</tr>
</tbody>
</table>

Please shade in the appropriate circle for each item below:

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>Strongly disagree</th>
<th></th>
<th>Strongly agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.</td>
<td>Exercise brings on my fatigue</td>
<td>O₀</td>
<td>O₁</td>
<td>O₂</td>
</tr>
<tr>
<td>8.</td>
<td>I start things without difficulty but get weak as I go on</td>
<td>O₀</td>
<td>O₁</td>
<td>O₂</td>
</tr>
<tr>
<td>9.</td>
<td>I lack energy</td>
<td>O₀</td>
<td>O₁</td>
<td>O₂</td>
</tr>
</tbody>
</table>

Please shade in the appropriate circle to indicate:

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>No At All</th>
<th></th>
<th>Extremely</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.</td>
<td>How tired you feel now</td>
<td>O₀</td>
<td>O₁</td>
<td>O₂</td>
</tr>
<tr>
<td>11.</td>
<td>How fatigued you feel now</td>
<td>O₀</td>
<td>O₁</td>
<td>O₂</td>
</tr>
</tbody>
</table>