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Comparing WAIS-III profiles of traumatic brain injury and chronic pain.

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COMPARING WAIS-III PROFILES OF TRAUMATIC BRAIN INJURY AND CHRONIC PAIN

By

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Abstract

Traumatic brain injury (TBI) is a common neuropsychological phenomenon characterized by both behavioural and cognitive sequelae, the most common of which include working memory and information processing deficits. To improve its usefulness as a neuropsychological measure, the newest revision of the Wechsler Adult Intelligence Scale, the WAIS-III, developed specific tasks tapping these deficits (e.g., Symbol Search, Letter-Number Sequencing). Despite considerable research examining WAIS performance in TBI sufferers, previous research failed to compare TBI sufferers to other clinical groups with observed processing speed deficits, such as chronic pain sufferers. This study compared the WAIS-III profiles of both mild and moderate-severe TBI to chronic lower back pain (LBP).

Results showed no significant difference between the three groups on WAIS-III IQ or Index scores. Within-group analyses revealed that both TBI groups displayed significant processing speed deficits in comparison to other Index scores, whereas the LBP group did not show this pattern. Examination of Symbol Search raw scores revealed no significant group difference.

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Introduction

Traumatic brain injury (TBI) is one of the most common conditions seen in clinical neuropsychology (Snyder & Nussbaum, 1998). TBI kills approximately 11 000 people in Canada each year, and leads to chronic health changes that amount to an annual cost of three billion dollars to the health care system (Statistics Canada, 2001). In Ontario alone, approximately 19 000 individuals suffer a TBI, at an annual cost of approximately one billion dollars. Although TBI affects all ages, races, and genders, several demographic groups suffer traumatic injuries more often. Traumatic injuries represent the leading cause of death and disability in young adults in the United States and other industrialized countries (Snyder & Nussbaum, 1998). Specifically, young men are particularly susceptible to head injuries (Snyder & Nussbaum, 1998). TBI can vary in severity, in cerebral location, and in the associated cognitive and emotional disturbances.

Mild TBI (MTBI) can be defined as an injury to the head that involves little or no gross structural pathology. Specifically, there may be no skull fracture, no intracranial hematoma (rupture of blood vessels resulting in cerebral swelling), and no cerebral contusion (bruising) (Fisher, Ledbetter, Cohen, Marman, & Tulsky, 2000). Typically, the majority of symptoms (e.g., headache, dizziness, cognitive deficits) resulting from MTBI are acute in nature and resolve within weeks or months (Andary, et al., 1997). In contrast, moderate to severe TBI (M-S TBI) has been defined as a cerebral insult that may involve diagnosable cerebral contusion, laceration, hematoma, skull fracture, or a combination thereof (Fisher, et al., 2000). M-S TBI often leads to significant and potentially permanent cognitive and

behavioural sequelae, including impulsivity, problem-solving deficits, and irritability (Andary, et al., 1997).

Because of the wide range of cognitive difficulties that result from TBI, these deficits have generally been classified under several different taxonomies. Tate, Fenelon, and Manning (1991) labelled four areas of impairment: learning and memory; personality; speed of information processing; and a range of other basic neuropsychological functions, such as sensory and motor impairment. In contrast, Prigatano (1986) proposed six areas of dysfunction following TBI: attention and concentration; initiation and goal direction; judgment and perception; learning and memory; communication; and speed of information processing. Finally, others have theorized the presence of four primary areas of deficits: memory; attention; complex information processing; and processing speed (Johnstone, Hexum, & Ashkanazi, 1995). Although these taxonomies have proposed different areas of cognitive dysfunction, two domains consistently emerged: processing speed and memory. In fact, within a comprehensive neuropsychological test battery, speed of mental processing has been found to be the most significantly deficient after TBI (Johnstone, et al., 1995).

The concept of information processing speed originated from early studies involving reaction time. Although processing speed is more multifactorial than reaction time, the two terms have become synonymous in research. Reaction time tests have consistently revealed slowness in information processing following closed head injuries (Miller, 1970; Stuss, Stethem, Hugenholtz, Picton, Pivik, & Richard, 1989; Van Zomeren & Deelman, 1978; Van Zomeren & Van Den Burg, 1985). In addition, these deficits in reaction time/information processing occur during both the

acute and chronic stages of TBI. Individuals with severe TBI, when compared to normal controls, displayed significant slowness in information processing during the subacute stage; that is 1 to 6 months post-injury (Spikman, Van Zomeren, & Deelman, 1996). Unlike many of the other sequelae of TBI, information processing deficits persisted long after the initial injury. Previous studies found that 67% of individuals reported feelings of mental "slowness" at a 1-year follow-up and 33% of those individuals reported continued feelings of mental "slowness" 2 years following severe closed head injuries (Van Zomeren & Van Den Burg, 1985).

Information processing/reaction time deficits also occur in milder brain injuries. Slowing down of information processing has been demonstrated in patients with mild concussions, despite good prognoses (Gronwall & Wrightsom, 1974). However, similar to other cognitive phenomena, the degree of impairment has been found to be a function of injury severity. More severe injuries are correlated with worse performance on information processing tasks (Van Zomeren & Deelman, 1978). In addition, the influence of injury severity tends to be more obvious during more complex tasks of information processing. For instance, during simple reaction time tasks (i.e., one response for one stimulus), severely injured and mildly injured individuals only slightly differed in their performance, although both were significantly worse than normals (Van Zomeren & Deelman, 1978). As the complexity of the task increased (i.e., one stimulus, several possible responses), severely injured individuals exhibited significantly poorer performance than the mild TBI group (Van Zomeren & Deelman, 1978). Other studies also found that individuals with severe TBI displayed significantly worse performance on choice reaction time tasks in comparison to simple reaction time tasks (Miller, 1970).

Overall, reaction time and information processing deficits have been well established within the neuropsychological literature. These deficits are evident throughout different stages of recovery, differing severities, and among different tasks. However, the nature and extent of these deficits tend to change as a function of the severity of injury, time post-injury, and task complexity.

Information processing deficits can be particularly devastating since it is thought to be a crucial basic cognitive ability on which more complicated thought processes are based (Kyllonen, 1987). Kyllonen (1987) suggested that working memory, information processing speed, a declarative knowledge base, and procedural knowledge underlie the learning process. Thus, any deficit of processing speed or working memory may inhibit complex learning or problem solving abilities, hindering vocational or adaptive functioning. Therefore, the early detection and remediation of these deficits are crucial within the TBI population.

The Development of the WAIS-III and its use as a Neuropsychological Measure

Since individuals suffering from TBI exhibit a wide range of both subtle and more obvious cognitive deficits, a comprehensive neuropsychological assessment is often an important adjunct in addressing the clinical needs of this population. Although the use of individual test batteries differ among neuropsychologists, there is one test that has become a mainstay within adult test batteries: the Wechsler Adult Intelligence Scale (WAIS) and its revisions (WAIS-R, WAIS-III). Although not initially designed as a measure of brain integrity and dysfunction, the WAIS and its successors have become irreplaceable within neuropsychological evaluations due to their multi-faceted nature, their reasonably quick administration time, their excellent standardization, and their sound psychometric properties. In fact, the WAIS and its

revisions are the most widely used intelligence scales in the United States and Canada (Ardila, 1999).

The recent edition of the Wechsler measure of adult intelligence, the WAIS-III, was published in 1997 (The Psychological Corporation) in response to numerous critiques of its predecessor, the WAIS-R. Specifically, the authors addressed several psychometric, normative, and test construction concerns (The Psychological Corporation, 1997). First, to broaden the test's usefulness, the age range was extended to include persons from 16 to 89 years of age to accommodate the increasing life span of the population. In addition, the "floor" of each intelligence quotient (IQ) score was lowered to allow for greater discrimination among individuals who function at the lower end of the spectrum. As with previous editions, both the normative data and subtest items were updated in response to changing cultural and societal norms.

Second, three subtests were added to the WAIS-III in the effort of accomplishing two primary goals: to reduce the overall emphasis on timed performance and to isolate two other important domains of cognitive functioning. In response to criticism for the emphasis on timed performance (Axelrod, Fichtenberg, Liethen, Czarnota, & Stucky, 2001) the WAIS-III introduced the Matrix Reasoning (MR) subtest, in which the client is instructed to complete a pattern consisting of geometric figures and designs. From a choice of five items, the participant is asked to decide which one most appropriately "fits" or completes the pattern. This subtest was developed as a measure of visual perception of abstract stimuli (Kaufmann & Lichtenberger, 1998). However, unlike many other performance tasks, MR is not a timed subtest. Therefore, by replacing the Object Assembly subtest, which was

timed, the WAIS-III reduced the emphasis on processing speed within the Performance Scale. In turn, this allowed for a more comprehensive examination of an individual's performance within various areas of functioning without the results being possibly biased by overarching processing speed deficits.

Third, the WAIS-R was criticized for its limited usefulness in the evaluation of certain cognitive abilities (Ardila, 1999). In addition to the Full Scale IQ (FSIQ), Verbal IQ (VIQ), and Performance IQ (PIQ) inherent to the WAIS-R, it was suggested there were three underlying factors that were assessed by the subtests: Verbal Comprehension (VC), Perceptual Organization (PO), and Freedom from Distractibility (FFD) (Ardila, 1999). Despite the inclusion of domain IQ scores and factors, it was suggested the WAIS-R failed to test several key aspects of cognition adequately, such as processing speed and working memory. This critique became salient as the WAIS-R became a regularly used tool in the assessment of brain injury, in which both processing speed and working memory are known to suffer (Johnstone, et al., 1995).

In order to remedy this shortcoming, two subtests were added to the WAIS-III: Letter-Number Sequencing (LNS) and Symbol Search (SS). In LNS, the participant is read a list of both numbers and letters and is asked to repeat the numbers in order first followed by the letters in alphabetical order (Kaufmann & Lichtenberger, 1998). This subtest requires an individual to attend to and encode, mentally manipulate, and accurately recall items, thereby testing working memory. Symbol Search requires the subject to scan a set of five geometric figures on the right side of the page and compare them to two target figures on the left side of the page. The subject is to mark "yes" if one of the five figures matches one of the two target

shapes and "no" if no such match is found. Unlike Matrix Reasoning, this subtest is timed and the participants are instructed to respond as quickly as they can without making mistakes. In addition to the already existent Digit Symbol Coding, this subtest was developed as a measure of processing speed.

The factor structure of the WAIS-III was re-evaluated with these three new subtests (LNS, SS, MR) included. Although the WAIS-R was comprised of three IQ scores (FSIQ, PIQ, VIQ), research attempted to determine more specific cognitive domains (Ardila, 1999). From these findings, a three-factor paradigm was suggested (FFD, VC, and PO) (Ardila, 1999). This area of investigation contributed to the development the WAIS-III and its more specific cognitive domains or Index scores (The Psychological Corporation, 1997). Subsequently, the inherent two-factor structure (VIQ and PIQ) and the research-based three-factor model (VC, PO, and FFD) were re-examined. Subsequently, the two-factor structure of the WAIS-R (VIQ and PIQ) was supplemented with a four-factor structure in the WAIS-III, which included the Verbal Comprehension Index (VCI), the Perceptual Organizational Index (POI), the Working Memory Index (WMI) and the Processing Speed Index (PSI).

In sum, the WAIS-III is a multifaceted test composed of fourteen subtests (see Appendix A for description of each subtest): Vocabulary (V), Similarities (S), Information (I), Comprehension (CO), Arithmetic (A), Digit Span (DS), Letter-Number Sequencing (LNS), Picture Completion (PC), Block Design (BD), Matrix Reasoning (MR), Digit Symbol Copy (DSC), Symbol Search (SS), Picture Arrangement (PA), and Object Assembly (OA). From these fourteen subtests, eleven subtests (CO, OA, and PA not used) are used to create four Index scores: Verbal

Comprehension (V, S, and I), Perceptual Organization (BD, MR, PC), Working Memory (A, DS, LNS), and Processing Speed (DSC and SS). Both the Verbal IQ (VIQ) and Performance IQ (PIQ) scores are also calculated from the subtests, with the exception of Object Assembly, Letter Number Sequencing, and Symbol Search. However, in cases in which the administration of certain subtests is not possible, these three subtests can act as substitute scores in the calculation of the VIQ or PIQ. Therefore, Object Assembly is often not administered if all other subtests are administered. Finally, the Full Scale IQ (FSIQ) results from an individual's overall performance across both the VIQ and PIQ (see Appendix B for a complete hierarchical diagram of the WAIS-III).

Overall, the instrument has excellent psychometric properties, especially in its standardization and reliability (Kaufmann & Lichtenberger, 1998). Initial standardization revealed the average reliability coefficients of most of the WAIS-III subtests (except Picture Arrangement, Symbol Search, and Object Assembly) ranged from .82 to .93 (The Psychological Corporation, 1997). For the Vocabulary, Digit Span, Information, and Matrix Reasoning subtests, the coefficients were extremely high ($r > .90$). The coefficients for Arithmetic, Comprehension, Letter-Number Sequencing, Picture Completion, Digit Symbol-Coding, Similarities and Block Design ranged from .82 to .88. Symbol Search had an average test-retest coefficient of .77, which was relatively high (The Psychological Corporation, 1997).

Similarly, the average reliability coefficients for the WAIS-III IQ scales and Indexes ranged from .88 to .97 and were generally higher than those of the individual subtests. However, the Processing Speed Index exhibited the lowest reliability

coefficient (r = .88), which was expected because of the relatively small number of subtests comprising this index.

The WAIS-III has also demonstrated a good degree of both content and concurrent validity (The Psychological Corporation, 1997). In order to improve the WAIS-III's content validity from its predecessor, the WAIS-R, many measures were taken. Comprehensive literature reviews identified the problems with the content of the WAIS-R. Similarly, numerous neuropsychologists, clinical psychologists, and school psychologists reviewed the test during development. This resulted in several content changes in response to evolving social and cultural considerations.

The WAIS-III has also demonstrated excellent concurrent validity in comparison to many other well-known intelligence and achievement scales, including its predecessor the WAIS-R (The Psychological Corporation, 1997), the Stanford-Binet Intelligence Scale-Fourth Edition (SB-IV, Thorndike, Hagen, & Sattler, 1986), and the Wechsler Individual Achievement Test (WIAT). The correlation coefficients between the WAIS-III and WAIS-R for the VIQ, PIQ, and FSIQ scores were .94, .86, and .93 respectively, within an initial standardization sample of 192 individuals (The Psychological Corporation, 1997).

The WAIS-III has also displayed excellent psychometric properties within clinical samples. Specifically, within a group of individuals with TBI, internal consistency results were found to range from .81 to .96 (Zhu, Tulsky, Price, & Chen, 2001). In general, the internal consistency coefficients were higher for the verbal subtests than for the performance subtests, probably because the majority of the verbal subtests are dependent upon inherent or learned knowledge that remains relatively stable, even following a TBI. Finally, the WAIS-III has also exhibited a

good degree of sensitivity (i.e., the ability to classify impaired individuals as impaired). The Processing Speed Index appeared to be the most sensitive, whereas the Verbal Comprehension Index was the least sensitive to TBI (Taylor & Heaton, 2001).

In summary, the WAIS-III was a marked improvement over its predecessor as it demonstrated excellent psychometric properties and was also designed to assess the major areas of deficits observed in individuals with TBI (i.e., memory, processing speed, abstract reasoning).

Research Examining TBI and WAIS Performance

There has been extensive research pertaining to the WAIS versions and TBI. However, the majority of research articles have focused on the comparison of the WAIS scores across varying severities of TBI or comparing individuals with TBI to the normal population. Crawford, Johnson, Mychalkiw, and Moore (1997) compared WAIS-R scores of individuals with closed head injuries (CHI) to normals matched for sex, age, and race. The researchers found significant differences at all levels of evaluation. The CHI group displayed lower scores on all three IQ scales. Not only were scores on the PIQ of the CHI group significantly lower than that of the normal group, but they were also lower than VIQ scores within the CHI group itself. In addition, there were significant differences within the factor scores. Namely, the FFD factor score was markedly lower in the CHI group when compared to both the normal group's FFD factor, and to the CHI group's other factor scores. The PO factor also showed marked impairment, whereas the VC Factor did not show any significant difference from the control group. Finally, upon examination of the individual subtests, the researchers found that Digit Span (DS), a test of working memory,

exhibited the largest deficit after CHI. From these results, the researchers concluded that following TBI, perceptual and attentional skills were more impaired than verbal skills or knowledge-based skills. However, this study made no distinction between varying severities of injury. Specifically, it is probable that the majority of cases were moderate-severe in nature as all participants required inpatient care.

The examination of intersubtest scatter within the WAIS-R as a possible indicator of brain trauma has also been investigated. Upon the creation of the WAIS-R, Wechsler (1981) claimed that a large VIQ-PIQ discrepancy or a marked degree of intersubtest scatter were indicative of brain damage, a claim that provoked debate. Ryan, Paolo, and Smith (1992) examined individuals with TBI and concluded that the interpretation of abnormal scatter as a pathognomonic sign of TBI was unwarranted. Similarly, Kraiuhin, Shores, and Roberts (1996) examined the frequency with which an abnormal VIQ-PIQ difference and inter-index scatter occurred within a sample of persons with a history of TBI. Severity of injury was determined by length of post-traumatic amnesia, yet all TBI individuals were then collapsed into one group and compared to normals. There were no comparisons among differing severities. They found Wechsler's claim to be unsupported since they failed to find any significant pattern of intersubtest scatter or index pattern. However, they did note that although not statistically significant, there was a VIQ-PIQ discrepancy among those with TBI as VIQ scores were higher.

Due to its recent inception, the WAIS-III has yet to receive as much research attention as its predecessor. However, several studies have examined WAIS-III profiles of individuals with TBI. During initial standardization, 22 patients with M-S TBI displayed significantly lower scores on all WAIS-III IQ and Index scores than a

group of normals and a group of individuals with MTBI (The Psychological Corporation, 1997).

Since the initial standardization, researchers have examined the validity of those earlier findings. Donders, Tulsky, and Zhu (2001) examined the clinical utility of the new subtests in the evaluation of TBI sequelae. They found that of the 14 subtests within the WAIS-III, only four (Picture Completion, Letter-Number Sequencing, Digit Symbol Coding and Symbol Search) were significantly different among the control group and individuals with MTBI, as well as individuals with MTBI and those with M-S TBI. Furthermore, Symbol Search was the sole reliable predictor in distinguishing between MTBI and M-S TBI, although its sensitivity was only 63%. Of the three new subtests, LNS and SS were both affected by injury severity, whereas Matrix Reasoning did not demonstrate sensitivity to TBI. These findings support the notion that decreased processing speed is one of the most common consequences of brain injury, as both subtests within the PSI (DSC and SS) were sensitive to TBI whereas MR, an untimed task, was not.

Hawkins (1998) examined the usefulness of the WAIS-III as a neuropsychological assessment measure. He was interested in determining whether there were profile commonalities or "red flags" of brain impairment. Although patients were unlikely to demonstrate a VIQ-PIQ difference (Hawkins, Plenh, & Borgaro, 2002), he found that PSI appeared to be the most sensitive to brain dysfunction. Moreover, he proposed a specific profile that he predicted to be indicative of TBI. Namely, the PSI would always be the lowest score, followed by the VCI, WMI, and POI in increasing order. However, the latter three constituted a relatively flat profile in which there was no significant difference in performance.

From these findings, Hawkins proposed that a large PSI- VCI discrepancy could be used as a screening measure for brain dysfunction following cerebral insults. However, within these studies, moderate-severe cases were used (Hawkins, et al., 2002) or severity was not specified (Hawkins, 1998).

In response to Hawkins' hypothesis, Axelrod, et al. (2001) examined 46 individuals with recent TBI (both mild and moderate severity). Within each individual, they found the PSI to be significantly lower than the other three Index scores while the WMI was the next lowest, followed by POI and VCI. The profiles were not congruent with those observed by Hawkins (1998). Based on their findings, Axelrod and colleagues (2001) concluded that Index scores were differentially sensitive to brain injury and that, although some low Index scores may be typical of the disorder, the profile patterns lacked sufficient specificity to "rule in" TBI. Instead, the authors suggested that this information may contribute to differential diagnoses by identifying atypical differences across Index scores to "rule out" TBI (e.g., suspected cases containing large differences between WMI and VCI, which do not differ significantly in TBI patients). However, the researchers did not distinguish between mild and moderate TBI and collapsed the data, thus ignoring any possible differences between these groups.

Similar to the research examining its predecessor, research investigating the relationship between the WAIS-III and TBI has predominantly focussed on the comparison between individuals with varying degrees of injury severity and its effect on WAIS-III performance. Fisher et al. (2000) compared individuals with M-S TBI to those with MTBI and normal controls. Overall, they found no significant difference between patients with MTBI and the control group on any of the WAIS-III measures.

However, the PSI did exhibit the largest effect size as it was the most robust in discriminating between the control group and M-S TBI. The WMI presented a similar, but nonsignificant pattern, as the control group attained higher scores than those with MTBI, who in turn achieved higher results than those with M-S TBI. From these results, the researchers concluded that no WAIS-III IQ or Index score would be effective in discriminating between normal controls and those with MTBI. However, it is possible that researchers' inability to find consistent performance profiles in individuals with TBI may be due to some of the downfalls of the WAIS-III itself.

For example, the primary criticism of the aforementioned research and of the development of the WAIS-III, has been the lack of attention paid to potential extraneous factors that may affect an individual's performance. Within the WAIS-III, scores are corrected for age, but not education. This is questionable as it has been repeatedly found that the most important variable affecting psychological and neuropsychological test performance is education, not age (Anastasi, 1988; Ostrosky, Ardila, & Rosselli, 1998). Approximately two-thirds of the standardization sample for the WAIS-III had twelve or more years of education. Numerous research studies have only examined individuals with TBI who attained more than 12 years of education (e.g., Axelrod, et al., 2001), or completely failed to include education information altogether (e.g., Fisher, et al., 2000; Hawkins, et al., 2002). Thus, the use of the WAIS-III as a measure sensitive to brain injury remains questionable with persons of lower educational levels (i.e., less than 12 years).

In examining the potential effect of education level on WAIS-III performance, Donders, et al. (2001) hypothesized that in patients with TBI, education would

explain a significant degree of variance in test scores. They found level of education explained additional variance in scores, over and above that accounted for by various injury severity parameters, and was the only factor that explained a significant amount of the variance. Therefore, the authors concluded it was important to consider level of education in the context of TBI patients while assessing cognitive deficits.

Other potential confounding factors in the relationship between TBI and neuropsychological functions have also remained overlooked. The contribution of comorbid factors such as depression, anxiety, and pain have been ignored. Specifically, the contribution of pain symptoms to neuropsychological performance has been consistently disregarded. A significant proportion of patients who sustain a TBI experience chronic pain (CP) due to associated physical injuries (Lahz & Bryant, 1996). Previous research has found that up to 95% of individuals with MTBI complain of pain that is of sufficient magnitude to interfere with their daily living activities (Uomoto & Esselman, 1993).

Some have suggested that chronic pain patients show striking similarities to those with mild closed head injuries (Andary, et al., 1997; Schnurr & MacDonald, 1995). Namely, signs and symptoms overlap substantially among patients with diagnoses of TBI and CP, including decreased concentration and memory, increased fatigue and sleep disturbances, impaired vocational performance and social relations, as well as increased anxiety and depression (Andary, et al., 1997). This overlap has led some researchers to suspect that pain and its related deficits may largely account for the cognitive complaints in many or most cases of post-concussive syndrome or MTBI (e.g., Hart, Martelli, & Zasler, 2000; Martelli, Grayson, & Zasler, 1999;

Nicholson, 2000). Vernon-Wilkinson and Tuokko (1993) examined 122 patients with head injury and divided them into groups with and without pain. Although the pain patients had less severe head injuries in terms of both Glasgow Coma Scale (GCS) scores and post-traumatic amnesia, they exhibited poorer performance on many neuropsychological tests.

In contrast, other studies have found little support that pain-related factors are detrimental to neurocognitive test performance (Alfano, Asmundson, Larsen, & Allerdings, 1999). Bell, Primeau, Sweet, and Lofland (1999) compared groups with MTBI, CP and migraine headache. They found that both of the pain groups performed significantly better on most measures of the WAIS-R. Although subjects in the MTBI group reported pain, their performance could not be solely attributed to this pain because the TBI group still performed significantly worse than either pain group. The inconsistencies within previous research suggests that the issue remains unresolved. Therefore, research examining the contribution of pain within TBI patients' cognitive functioning remains relevant.

Chronic Pain and Neuropsychological Findings

Chronic pain has been defined as "pain that persists long after injury (i.e., greater than six months) and is more likely to be characterized by: a) relatively ambiguous neuroanatomic pathways mediating somatic effects; b) transmission of information that may perpetuate protective responses of limited adaptive value, especially to the extent that there is a lack of underlying tissue damage and/or decreases in, or avoidance of, activity inhibiting rehabilitation; c) a protracted course of medication use and minimally effective medical services and; d) marked

behavioural and emotional changes, including restrictions in daily living activities" (p. 131, Hart, Martelli, & Zasler, 2000).

Although chronic pain occurs throughout various locations within the body, one of the most frequently reported locations of chronic pain is the lower back (Hoffman, Meier, & Council, 2002). In fact, back injuries follow only arthritis in the leading causes of chronic pain (Hoffman, et al., 2002). The prevalence of chronic lower back pain (LBP) has been reported between 9% and 35% (Harman, Pivik, D'Eon, Wilson, Swenson, & Matsunaga, 2002) and the costs associated per year have been estimated to surpass $125 billion, including medical costs, missed workdays, and worker's compensation (Hoffman, et al., 2002). LBP tends to occur more often in women and older individuals (Andersson, 1999).

Symptoms of chronic pain, regardless of location or cause, are known to include paraesthesia (an abnormal tingling or pricking sensation), chronic fatigue, irritability, decreased libido, somatic preoccupation, anxiety, depression, insomnia, and cognitive disturbances (Schnurr & MacDonald, 1995).

Cognitive deficits have been observed in many chronic pain conditions, including cancer (Sjogren, Olsen, Thomson, & Dalberg, 2000), musculoskeletal patients (Kewman, 1989), and fibromyalgia (Hart, et al., 2000). Eccleston (1994) found that patients with higher degrees of pain (with no history of brain injury) showed more deficits on attention-demanding tasks than patients with lower degrees of pain and pain-free control groups. In addition to attentional deficits, one of the most common subjective complaints of chronic pain patients is memory disturbances, often observed as episodes of forgetfulness or difficulty finishing tasks (McCracken & Iverson, 2001).

However, one of the most common observable deficits in individuals with chronic pain has been decreased processing speed. Sletvold, Stiles, and Landro (1995) found deficits on tests requiring attention, rapid information processing, and psychomotor speed in patients with fibromyalgia. Specifically, patients performed significantly worse than normal controls on the Digit Symbol subtest of the WAIS-R. Similarly, Grigsby, Rosenberg, and Busenbark (1995) reported that pain patients displayed deficits in reaction time relative to normals and mild-moderate TBI. The pain group also showed mild difficulties compared to normal controls on simple motor speed tasks (i.e., finger tapping).

Despite research suggesting that chronic pain can affect cognitive processes as much as, if not more, than traumatic brain injury, and that pain can accompany up to 95% of MTBI cases, there has been very little research comparing these two conditions in terms of neuropsychological functioning. As aforementioned, in studies that have consistently attributed cognitive deficits to brain injury, pain has seldom, or never been considered a possible confound. The majority of TBI studies have only used normal control groups for comparison and none has used chronic pain patients.

In sum, previous research examining cognitive deficits following TBI, especially those employing the WAIS-III, have predominantly ignored the potential contribution of several confounding factors. First, most studies have either only compared TBI groups of varying severities, or compared a collapsed sample of TBI individuals of varying severities to normal control groups. Very rarely have researchers compared varying degrees of TBI to other clinical samples. Chronic pain samples can provide particular insight into post-injury manifestations as they share many symptoms with those of TBI. Second, many studies examining the WAIS-III

have failed to include education level as a potential extraneous factor, despite research arguing for its importance in predicting neuropsychological functioning (e.g., Anastasi, 1988).

The Present Study

In response to these considerations, the present study will compare the WAIS-III profiles of three groups of individuals: those with MTBI, those with M-S TBI, and those with known chronic pain (lower back pain, LBP) and no history of brain injury. Only patients with lower back pain exclusively will be included to eliminate the possible confound of upper body motor impairment. Since previous research has shown that groups with both MTBI and M-S TBI exhibit deficits in processing speed, it is predicted that within both TBI groups, significant deficits in the Processing Speed Index and its subtests (Digit Symbol Coding and Symbol Search) will be observed in comparison to the other Indexes and subtests. Since previous research (e.g., Fisher, et al., 2000) has consistently found M-S TBI to produce more substantial cognitive deficits than MTBI, it is hypothesized that this pattern will again emerge in this study. Lastly, it is hypothesized that the processing speed of individuals with LBP will not significantly differ with the results of individuals with MTBI, again consistent with the previously cited research (e.g., Sletvold, et al., 1995).

Since previous research has primarily included collapsed samples of TBI severity (e.g., Axelrod, et al., 2001; Hawkins, 1998), this present study will also provide comparisons of WAIS-III performance between LBP and a collapsed TBI group (i.e., both MTBI and M-S TBI) in order to address the generalizability of the present study to past studies. Similarly, within-group comparisons will also be

examined in the collapsed TBI group to determine whether the profile exhibited supports previous findings.

Since previous studies have found that education level is a significant factor in the interpretation of WAIS-III scores (Donders, et al., 2001), it will also be included in the analysis. Within the two TBI groups, chronicity will also be analyzed to determine whether there are significant differences between the two groups which may confound the results as previous research has consistently found that time since injury is one of the most important factors contributing to an individual's post-injury cognitive functioning, especially information processing speed (Van Zomeren & Deelman, 1978).

Finally, the present study will begin to examine the composition of processing speed deficits. Previous research has found Symbol Search to be the most sensitive and reliable predictor of TBI (Donders, et al., 2001), perhaps making it the most valid measure of processing speed within the WAIS-III for a TBI population. Very little research has examined the composition of Symbol Search performance. Specifically, the administration of the Symbol Search requires incorrect answers to be subtracted from correct responses in order to produce a final score. However, no research has investigated whether a low score on Symbol Search results from slower processing speed (i.e., simply completing fewer items within the time limit) or from some degree of impulsivity (i.e., answering quickly but inaccurately). For these aforementioned reasons, the present study will also examine the composition of Symbol Search raw scores in an attempt to delineate the relative contribution of slower processing speed and impulsivity.

Method

Participants

This study was composed of three groups: 1) individuals who suffered a mild TBI (MTBI); 2) individuals who suffered a moderate-severe TBI (M-S TBI), and 3) individuals who experienced chronic lower back pain (LBP) at the time of their cognitive assessment.

The exclusion criteria for all groups were the presence of substance abuse (i.e., self-reported past treatment for any of type of substance abuse or dependence) , self-reported premorbid learning disabilities, previously diagnosed major psychiatric disorders (e.g., bipolar disorder, major depressive disorder), epileptic seizures within a year prior to testing, physical disabilities that would prevent use of the dominant hand (e.g., paraplegia), and English as a second language. Only individuals between the ages of 16 and 59 years were considered eligible for this study to minimize the confounding effect of age.

Twenty-nine individuals who sustained a TBI were included in this study. There were 17 individuals in the MTBI group (8 male, 9 female; M_{age} = 36.41 years, SD = 10.97 years) and 12 individuals in the M-S TBI group (10 male, 2 female; M_{age} = 31.67 years, SD = 12.23 years). A larger proportion of males were present in the M-S TBI group, consistent with the demographic gender characteristics of this population (i.e., Snyder & Nussbaum, 1998). The TBI were from various causes, such as motor vehicle accidents, workplace accidents, and assaults. Severity of TBI was determined by using various sources of information, such as Glasgow Coma Scale scores (based on criteria regarding verbal responses, eye opening, and motor responses; as cited in Snyder & Nussbaum, 1998), length of unconsciousness, and

length of post-traumatic amnesia, depending on what information was available. The degree of severity was determined using the following criteria (Snyder & Nussbaum, 1998):

Table 1

Classification of TBI severity

Severity of Injury	**Glasgow Coma Scale (GCS)**	**Post-Traumatic Amnesia (PTA)**	**Loss of Consciousness (LOC)**
Mild	Greater than or equal to 13	Less than one hour	Less than or equal to 30 minutes
Moderate-Severe	Less than or equal to 12	Greater than one hour	Greater than 30 minutes

This lack of a unitary measure of severity resulted from both the archival nature of the data and the varying sources of information as case files were from a regional brain injury program and the private practices of two clinical psychologists.

The LBP group was composed of 26 individuals (21 male, 5 female; M_{age} = 40.77 years, SD = 7.94 years) suffering from chronic lower back pain. The presence of chronic lower back pain was determined by both required chronicity (i.e., at least 6 months) and self-report which included subjective ratings of everyday pain level. History of causative injury was determined by both self-report as well as accompanying medical files if included. The subjects' pain resulted from varying causes and injuries [e.g., spinal lumbar (L4, L5, S1 vertebrae) injuries, heavy lifting, falls, etc.]. Case files were from the private practice of a clinical psychologist in which information was part of psycho-vocational assessment.

In addition to the general exclusion criteria aforementioned, individuals were only included in the chronic pain group in the absence of any head injury, whether at the time of the back injury or premorbidly.

Procedure

This study used archival data collected from the private practices of two clinicians and from the Windsor Regional Hospital Acquired Brain Injury Program. All participants were clients of these establishments and were referred for psychovocational or neuropsychological assessment. During collection of the data, all efforts were made to ensure complete confidentiality (i.e., no identifying information included, files remained on site, etc.). Files were coded and all identifying information removed prior to being released to the researcher.

The dependent measures examined in this study were derived from the Wechsler Adult Intelligence Scale- Third Edition (WAIS-III). Specifically, both IQ (i.e., FSIQ, PIQ, and VIQ) and Index scores (i.e., VCI, POI, WMI, and PSI) were examined between each group. In addition, 13 subtests (excluding Object Assembly) were examined: Vocabulary (V), Similarities (S), Information (I), Comprehension (CO), Arithmetic (A), Digit Span (DS), Letter-Number Sequencing (LNS), Picture Completion (PC), Block Design (BD), Matrix Reasoning (MR), Digit Symbol Copy (DSC), Symbol Search (SS), and Picture Arrangement (PA). Finally, the raw scores (i.e., number of incorrect and correct responses) of the SS subtest were analyzed.

Analyses

The questions posed in the study were organized into three sections. The first set of analyses compared the three groups within the major cognitive domains assessed by the WAIS-III. One-way Analysis of Variance (ANOVA) tests compared

IQ scores, Index scores, and subtest scores among the three groups. For each of these analyses, Hochberg post hoc tests adjusted for unequal sample sizes during pairwise comparisons. Between groups comparisons (i.e., One-way ANOVAs) were also completed to determine whether significant differences existed between the three groups on potentially confounding variables, such as education, age, medication use, and time since injury (only for the two TBI groups). For these analyses, Tukey HSD post hocs were employed. Gender comparisons were not conducted due to small sample sizes. Finally, Independent Samples t-tests compared the LBP group to the collapsed TBI group to investigate the generalizability of previous research.

The second set of questions and analyses focused on the within-group comparison of WAIS-III profiles. Again, Within-Group Analysis of Variance (ANOVA) tests determined whether significant differences existed between scores at any levels (i.e., IQ scores, Index scores, subtest scores). The significant IQ and Index scores were examined with Bonferroni post hoc tests that implemented an adjusted significance level based on the number of comparisons ($p = .008$). Due to the large number of pairwise comparisons available at the subtest level, Tukey LSD post hocs were used since the Bonferroni adjustment caused the significance level to be too small ($p = 6.4 \text{ X } 10^{-3}$). These analyses were completed for each of the TBI groups, the LBP group, and the collapsed TBI group.

The final set of analyses involved the between-groups comparison of Symbol Search scores. One-way ANOVAs compared differences between the TBI groups and the LBP group on the number of correct and incorrect responses to determine whether significantly different response patterns emerged. Due to the high frequency of errorless performances in the samples, an Independent Samples Chi-Square test

also compared SS performance between the three groups. An alpha level of .05 was used for all statistical tests to determine significance.

Results

Approximately 200 TBI cases and 200 LBP cases were examined, and reduced, based on the aforementioned exclusion criteria. In the end, 26 LBP cases, 17 MTBI cases, and 12 M-S TBI cases were included for analysis.

Analysis 1: Between-Group Comparisons of the WAIS-III

To determine whether significant differences existed between the three groups on any of the dependent measures derived from the WAIS-III (i.e., IQ scores, Index scores, subtest scores), a series of One-way ANOVAs were conducted. Prior to these analyses, ANOVAs were also conducted on all potential confounding variables, including age, education, medication use and time since injury (only for the TBI groups). These analyses determined whether any of the variables required further inclusion within group comparisons as significant covariates. Finally, a series of T-tests compared the LBP group to a collapsed TBI group, containing both the mild and moderate-severe cases. This analysis allowed for comparison to previous research that only used collapsed TBI groups.

One-way ANOVAs were conducted to examine the differences between the three groups in terms of age, education, time since injury, and WAIS-III FSIQ (see Table 2). Overall significant differences were found between the groups on average age, $F(2, 52) = 3.57, p < .05$, and education, $F(2, 50) = 3.63, p < .05$. Post hoc analyses (i.e., Tukey HSD) revealed that the M-S TBI group was significantly older than the LBP group ($p < .05$). In regards to education level, post hoc tests (Tukey HSD) found the MTBI group had a significantly higher mean education level than the LBP group ($p < .05$). However, this analysis failed to meet the homogeneity of variance assumption, $F(2, 50) = 4.44, p < .05$).

An independent sample t-test examined the difference between the two TBI groups in terms of the time post-injury in weeks. No significant difference was found, $t(26) = -1.10$, $p = .28$, between the MTBI group and the M-S TBI. The MTBI group's time since injury ranged from 8 weeks to 216 weeks (i.e., approximately 4.5 years), whereas the M-S TBI group's time since injury ranged from 8 weeks to 280 weeks (i.e., approximately 6 years).

Table 2

Means and standard deviations for demographic information.

Measure	LBP	MTBI	M-S TBI
N Total	26	17	12
Men	21	8	10
Women	5	9	2
Age	40.77 (7.93)	36.41 (10.97)	31.67 (12.22)
Education	10.92 (1.62)	12.60 (2.53)	11.58 (1.62)
Weeks Post-Injury		43.88 (53.84)	77.27 (104.61)
FSIQ	93.50 (9.20)	95.83 (15.91)	96.42 (14.15)

Note: Standard Deviations appear in parentheses

For the present study, medication use was coded using a dichotomous scale as follows: 0 = no use or occasional use of medication resulting in little or no cognitive side effects (e.g., occasional use of Tylenol #3) according to the Compendium of Pharmaceuticals and Specialties- 34th Edition (Canadian Pharmacists Association, 1999); and 1 = regular use of medication (mostly prescribed) resulting in possible

cognitive side effects. Medications varied in purposes, including anti-depressants (e.g., sertraline, amytriptyline), muscle relaxants (e.g., Talwin), non-steroidal anti-inflammatory drugs (e.g., ibuprofen, naproxyn), opoiod analgesics (e.g., Percocet, morphine, codeine), and general analgesics (e.g., Aspirin, Tylenol). Independent Samples Chi-Square analyses (i.e., Kruskal-Wallis test) revealed no significant group difference in the frequency of medication users, $\chi^2(2, N = 53) = 2.30, p = .32$ (see Table 3).

Table 3

Frequency of Medication use.

Group	*n*	Medications
LBP		Tylenol 3 (7); Percocet (4); Naproxyn (3); Vioxx;
None/Occasional	9	Amytriptiline; Regular Strength Tylenol; Extra
Regular	15	Strength Tylenol; Arthrotec; Morphine; Talwin; Ibuprofen; Aspirin; Advil; Motrin; Norflex; Flexeril; Darvon; muscle relaxant not otherwise specified
MTBI		Dilantin (2); Alprazolam (2); Acibututol;
None/Occasional	10	Amytripiline; Estraderm; Nizatidine; Tylenol 3;
Regular	7	Naproxyn; Nortriptyline; Estrodial; Diovan; pain medication not otherwise specified; anti-depressant not otherwise specified
M-S TBI		Zantac (2); Regular Strength Tylenol (2);
None/Occasional	7	Clonazepam; Dilantin; Adivan; Colace;
Regular	5	Naproxyn; Serax; Sertraline; Extra Strength Tylenol; anti-depressant not otherwise specified

Note: Values in parentheses indicate number of individuals who reported use; no value in parentheses equivalent to one individual

One-way ANOVAs compared the three groups at all levels of WAIS-III performance. No significant difference was found between the three groups on any of the three IQ scores (see Table 4).

Table 4

One-way ANOVA comparisons of IQ scores among the three groups.

Measure	*M*	*SD*	*n*	*F*	*df*	*p*
FSIQ				.29	2,52	.75
LBP	93.50	9.20	26			
MTBI	95.82	15.92	17			
M-S TBI	96.42	14.15	12			
PIQ				.08	2,52	.93
LBP	94.85	9.12	26			
MTBI	94.06	15.99	17			
M-S TBI	96.00	16.33	12			
VIQ				.71	2,52	.50
LBP	93.19	8.95	26			
MTBI	97.35	15.24	17			
M-S TBI	96.67	13.27	12			

Note: FSIQ = Full Scale Intelligence Quotient; PIQ = Performance Intelligence Quotient; VIQ = Verbal Intelligence Quotient

One-way ANOVAs comparing the three groups on the Index scores also revealed no significant difference (see Table 5). Unexpectedly, there was no group difference on either the WMI or PSI.

Despite no overall IQ or Index score difference, there were several significant differences between the three groups on individual subtest scores (see Table 6). One-way ANOVA tests revealed a significant difference among the three groups on the Vocabulary subtest. Post hoc analyses (Hochberg for unequal sample sizes) revealed significant differences as the LBP group attained a lower average score than the MTBI group ($p < .05$). A significant difference also existed on the mean Digit Span subtest scores, as Hochberg post hoc tests revealed a significant difference between the LBP group and the MTBI group ($p < .05$). However, in contrast to Vocabulary

score, the LBP achieved a significantly higher average score on this measure than the MTBI group.

Table 5

One-way ANOVA comparisons of Index scores among the three groups.

Measure	*M*	*SD*	*n*	*F*	*df*	*p*
VCI				1.54	2,52	.22
LBP	91.23	9.17	26			
MTBI	97.53	16.15	17			
M-S TBI	95.75	10.75	12			
POI				.21	2,52	.81
LBP	96.84	9.55	26			
MTBI	95.82	16.16	17			
M-S TBI	99.00	15.21	12			
WMI				.31	2,52	.73
LBP	96.23	12.37	26			
MTBI	93.18	14.35	17			
M-S TBI	94.33	10.82	12			
PSI				1.60	2,52	.21
LBP	92.46	11.05	26			
MTBI	87.35	14.28	17			
M-S TBI	85.50	12.66	12			

Note: VCI = Verbal Comprehension Index; POI = Perceptual Organization Index; WMI = Working Memory Index; PSI = Processing Speed Index

Table 6

One-way ANOVA comparisons of subtest scores among the three groups.

Measure	*M*	*SD*	*n*	*F*	*df*	*p*
Vocabulary				3.73	2, 52	.03
LBP	8.19	1.90	26			
MTBI	10.06	2.86	17			
M-S TBI	9.83	2.72	12			

Table 6 (cont'd)

Measure	*M*	*SD*	*n*	*F*	*df*	*p*
Similarities				.04	2, 52	.96
LBP	8.96	1.99	26			
MTBI	9.18	3.45	17			
M-S TBI	9.08	2.19	12			
Information				1.12	2, 52	.33
LBP	8.19	2.33	26			
MTBI	9.41	3.16	17			
M-S TBI	8.83	2.41	12			
Comprehension				3.08	2, 52	.06
LBP	9.50	1.68	26			
MTBI	11.47	3.02	17			
M-S TBI	10.17	3.33	12			
Arithmetic				.91	2, 52	.41
LBP	8.77	2.08	26			
MTBI	9.47	3.48	17			
M-S TBI	10.08	3.42	12			
DS				3.82	2, 52	.03
LBP	10.19	2.73	26			
MTBI	8.00	2.37	17			
M-S TBI	9.25	2.34	12			
LNS				1.43	2, 52	.25
LBP	9.27	2.34	26			
MTBI	9.35	2.78	17			
M-S TBI	8.00	1.65	12			
PA				.34	2, 52	.71
LBP	9.54	2.60	26			
MTBI	10.24	3.54	17			
M-S TBI	10.25	3.67	12			
PC				1.07	2, 52	.35
LBP	9.50	2.14	26			
MTBI	8.24	3.25	17			
M-S TBI	8.92	3.29	12			

Table 6 (cont'd)

Measure	*M*	*SD*	*n*	*F*	*df*	*p*
BD				.14	2, 51	.87
LBP	9.23	1.82	26			
MTBI	9.59	2.76	17			
M-S TBI	9.55	3.01	11			
MR				.80	2, 51	.46
LBP	10.31	2.28	26			
MTBI	10.06	3.23	17			
M-S TBI	11.36	3.11	11			
DSC				1.62	2, 52	.21
LBP	8.42	2.39	26			
MTBI	7.41	2.76	17			
M-S TBI	6.92	2.84	12			
SS				1.92	2, 52	.16
LBP	9.15	1.99	26			
MTBI	7.88	3.31	17			
M-S TBI	7.67	2.57	12			

Note: DS = Digit Span; LNS = Letter Number Sequencing; PA = Picture Arrangement; PC = Picture Completion; BD = Block Design; MR = Matrix Reasoning; DSC = Digit Symbol Coding; SS = Symbol Search

Since education levels were significantly different between the MTBI and LBP groups, matched-education comparisons were conducted in order to determine the extent to which education contributed to between-group differences. Matches among the three groups based on education level was available for only nine cases. Consistent with the unmatched between-group comparisons, there was no significant group difference on the IQ scores or Index scores.

The utilization of education-matched groups eliminated the previously significant group differences among the subtest scores. There was no longer

significant group difference on Vocabulary, $F(2, 24) = .42$, $p = .66$, or Digit Span, $F(2, 24) = 1.98$, $p = .16$.

T-tests compared the LBP to the collapsed TBI group (see Table 7). Again, no significant differences existed between the TBI and LBP groups on IQ and Index scores.

Table 7

T-test comparisons of LBP and Collapsed TBI on IQ and Index scores.

Measure	*M*	*SD*	*n*	*t*	*df*	*p*
FSIQ				-.78	47.20*	.44
LBP	93.50	9.20	26			
TBI	96.07	14.95	29			
PIQ				-.01	45.52*	.99
LBP	94.85	9.12	26			
TBI	94.86	15.87	29			
VIQ				-1.22	47.78*	.23
LBP	93.19	8.95	26			
TBI	97.07	14.21	29			
VCI				-1.72	53	.09
LBP	91.23	9.17	26			
TBI	96.79	13.97	29			
POI				-.09	47.13*	.93
LBP	96.85	9.55	26			
TBI	97.14	15.58	29			
WMI				.76	53	.45
LBP	96.23	12.37	26			
TBI	93.66	12.80	29			
PSI				1.76	53	.08
LBP	92.46	11.05	26			
TBI	86.59	13.43	29			

Note: * = adjusted degrees of freedom due to unequal variances

Table 8

T-test comparisons of LBP and Collapsed TBI groups on subtest scores.

Measure	*M*	*SD*	*n*	*t*	*df*	*p*
Vocabulary				-2.75	53	.01
LBP	8.19	1.90	26			
TBI	9.97	2.76	29			
Similarities				-.26	49.39*	.79
LBP	8.96	1.99	26			
TBI	9.14	2.95	29			
Information				-1.39	53	.17
LBP	8.19	2.33	26			
TBI	9.17	2.84	29			
Comprehension				-2.13	43.56*	.04
LBP	9.50	1.68	26			
TBI	10.93	3.16	29			
Arithmetic				-1.27	47.04*	.21
LBP	8.77	2.08	26			
TBI	9.72	3.41	29			
Digit Span				2.42	53	.02
LBP	10.19	2.73	26			
TBI	8.52	2.40	29			
LNS				.74	53	.47
LBP	9.27	2.34	26			
TBI	8.79	2.44	29			
PA				-.83	53	.41
LBP	9.54	2.60	26			
TBI	10.24	3.53	29			
PC						
LBP				1.34	49.02*	.19
TBI	9.50	2.14	26			
	8.52	3.23	29			

Table 8 (cont'd)

Measure	*M*	*SD*	*n*	*t*	*df*	*p*
BD				-.53	46.62*	.60
LBP	9.23	1.82	26			
TBI	9.57	2.81	28			
MR				-.35	52	.73
LBP	10.31	2.28	26			
TBI	10.57	3.19	28			
DSC				1.74	53	.09
LBP	8.42	2.39	26			
TBI	7.21	2.76	29			
SS				1.97	53	.06
LBP	9.15	1.99	26			
TBI	7.79	2.98	29			

Note: * = adjusted degrees of freedom due to unequal variances

The LBP and collapsed TBI group differed significantly on several mean subtest scores. The TBI group's average Vocabulary and Comprehension scores were significantly higher than the LBP groups. The LBP group's mean Digit Span score was significantly higher than the TBI group. Although the LBP group displayed higher mean scores on both Digit Symbol Coding and Symbol Search, the results did not reach significance.

Overall, the results of Analysis 1 revealed no significant between-group difference on any of the WAIS-III IQ or Index scores, and only a pair of differences on subtest scores, which disappeared as the groups were matched for education level. These results were inconsistent with the hypothesis that the M-S TBI group would demonstrate significantly worse performance on most measures, particularly PSI and WMI, in comparison to both the MTBI and LBP group. In contrast, the comparable

performance of the MTBI and LBP groups was consistent with the hypothesis. With the TBI groups collapsed, differences between the LBP and TBI groups remained insignificant.

Analysis 2: Within-Group Comparisons on the WAIS-III

To determine whether significant differences existed on any of the dependent variables derived from the WAIS-III within each group, a series of Within-Group ANOVAs was completed. Specifically, for each of the three groups, comparisons were made between IQ scores, Index scores, and subtest scores, respectively.

Within the LBP group, Within-Group ANOVAs revealed several significant differences among the WAIS-III scores (see Table 9). The Within-Group ANOVAs for the IQ scores and for the subtest scores revealed a violation of the assumption of sphericity and, therefore, adjusted degrees of freedom were used (i.e., Greenhouse-Geisser epsilon). Overall, there was no significant difference between the three IQ scores. However, significant differences existed within the LBP group on the Index scores. Bonferroni post hoc analyses revealed that the mean VCI score was significantly lower than the mean POI score ($p < .01$). No significant difference existed between the PSI and the other Index scores. This pattern failed to support the hypothesis, which postulated that the PSI would be lower than the other three Index scores. However, with the exception of the VCI scores, the LBP group displayed a similar profile of scores as the MTBI group (i.e., PSI, WMI, POI).

Within-Group ANOVA also revealed an overall main effect for the 13 subtest scores, $F(6.26, 156.46) = 3.64$, $p < .01$ (see Appendix C for means and standard deviations). Tukey LSD post hoc tests ($p = .05$) revealed numerous differences between the mean subtest scores of the PSI and remaining subtests. Digit Symbol

Coding scores were, on average, significantly lower than the Digit Span ($p < .01$) and Matrix Reasoning ($p < .01$) scores. The average Symbol Search score was significantly lower than the Matrix Reasoning score ($p < 05$). Unexpectedly, the mean Symbol Search score was significantly higher than the mean Digit Symbol Coding score ($p < 05$).

Table 9

Within-Group ANOVA comparisons of LBP group's IQ and Index scores.

Measure	*M*	*SD*	*n*	*F*	*df*	*p*
IQ scores				1.66	1.11, 27.84*	.21
FSIQ	93.50	9.20	26			
VIQ	93.19	8.95	26			
PIQ	94.85	9.12	26			
Index scores				2.98	3, 75	.04
VCI	91.23	9.17	26			
POI	96.85	9.55	26			
WMI	96.23	12.37	26			
PSI	92.46	11.05	26			

Note: *adjusted degrees of freedom using Greenhouse-Geisser Epsilon $r = .522$

Within the MTBI group, the same series of Within-Group ANOVAs determined the presence of any differences among the WAIS-III dependent measures (see Table 10). Analysis of the IQ scores revealed a failure to meet the assumption of sphericity, thus the Greenhouse-Geisser adjustment for degrees of freedom was implemented. Overall, there was no significant difference between the three IQ scores among individuals with MTBI.

There was a significant difference observed between the Index scores. Specifically, Bonferroni pairwise comparisons revealed that the mean PSI score was significantly lower than the mean VCI score ($p < .01$). In sum, the profile within the

MTBI group revealed the PSI as the lowest score, followed by the WMI, POI and the VCI, as hypothesized. However, the latter three Indexes did not significantly differ, forming a relatively flat profile.

Table 10

Within-Group ANOVA comparing MTBI group's IQ and Index scores.

Measure	*M*	*SD*	*n*	*F*	*df*	*p*
IQ scores				2.06	1.04, 16.70*	.17
FSIQ	95.82	15.92	17			
VIQ	97.35	15.24	17			
PIQ	94.06	15.99	17			
Index scores				4.47	3,48	.008
VCI	97.53	16.15	17			
POI	95.82	16.16	17			
WMI	93.18	14.35	17			
PSI	87.35	14.28	17			

Note: *adjusted degrees of freedom using Greenhouse-Geisser epsilon $r = .522$

Overall significant differences between the 13 subtests were found, $F(12, 192) = 4.74$, $p < .001$ (see Appendix D for means and standard deviations). The mean Digit Symbol Coding score was significantly lower than most other mean subtest scores, including Vocabulary ($p < .01$), Similarities ($p < .01$), Information ($p < .05$), Comprehension ($p < .001$), Arithmetic ($p < .05$), Letter-Number Sequencing ($p < .05$), Picture Arrangment ($p < .01$), Block Design ($p < .05$), and Matrix Reasoning ($p < .05$). The mean Symbol Search score was significantly lower than mean scores on Vocabulary ($p < .01$), Similarities ($p < .05$), Information ($p < .05$), Comprehension ($p < .01$), Arithmetic ($p < .05$), Picture Arrangement ($p < .001$), Block Design ($p < .05$), and Matrix Reasoning ($p < .01$).

A series of Within-Group ANOVAs was completed to investigate the differences in WAIS-III scores within individuals with M-S TBI (see Table 11). Similar to both the LBP and MTBI groups, no significant difference existed among the three IQ scores. Again, due to the failure to meet the sphericity assumption, an adjustment of the degrees of freedom was necessary to allow for further analysis. As expected, there were significant differences between the four Index scores. Bonferroni post hoc tests revealed that the mean PSI score was significantly lower than the mean POI score ($p < .01$). The PSI score was also lower than both the WMI and the VCI scores, yet the results failed to reach significance ($p = .06$, and $p = .11$, respectively).

Table 11

Within-Group ANOVA comparing the M-S TBI group's IQ and Index scores.

Measure	*M*	*SD*	*n*	*F*	*df*	*p*
IQ scores				.03	1.02, 11.26*	.87
FSIQ	96.42	14.15	12			
VIQ	96.67	13.27	12			
PIQ	96.00	16.33	12			
Index scores				7.16	2.03, 22.36*	.004
VCI	95.75	10.75	12			
POI	99.00	15.21	12			
WMI	94.33	10.82	12			
PSI	85.50	12.66	12			

Note: *adjusted degrees of freedom using Greenhouse-Geisser $r = .512$ and $r = .678$, respectively

Examination of the subtests revealed an overall significant difference, $F(7, 63) = 3.65$, $p < .01$ (see Appendix E for means and standard deviations). The mean Digit Symbol Coding score was significantly lower than mean scores on

Vocabulary ($p < .05$), Similarities ($p < .05$), Comprehension ($p < .01$), Arithmetic ($p < .01$), Digit Span ($p < .05$), Picture Arrangement ($p < .001$), Block Design ($p < .01$), and Matrix Reasoning ($p < .001$). The mean Symbol Search score was significantly lower than the mean scores on Comprehension ($p < .05$), Arithmetic ($p < .05$), Picture Arrangement ($p < .05$),Block Design ($p < .001$), and Matrix Reasoning ($p < .01$).

Finally, Within-Group ANOVAs compared IQ, Index, and subtest scores for the collapsed TBI group (see Table 12). There was no significant difference between any of the IQ scores. There were significant differences between the four Index scores. Bonferroni post hocs revealed that the average PSI score was significantly lower than each of the other three average Index scores. The other three Index scores did not significantly differ from each other.

Table 12

Within-Group ANOVA comparing the collapsed TBI group's IQ and Index scores.

Measure	*M*	*SD*	*n*	*F*	*df*	*p*
IQ scores				1.15	1.03, 28.92*	.30
FSIQ	96.07	14.95	29			
VIQ	97.07	14.21	29			
PIQ	94.86	15.87	29			
Index scores				10.44	3, 84	.00
VCI	96.79	13.97	29			
POI	97.14	15.58	29			
WMI	93.66	12.80	29			
PSI	86.59	13.43	29			

Note: * = adjusted degrees of freedom using Greenhouse-Geisser Epsilon of $r = .516$

Comparisons of the subtests revealed significant differences, $F(6.82, 190.86) = 7.37$, $p < .001$ (see Table 13). The mean DSC score was significantly lower than all other mean subtest scores, except Symbol Search: Vocabulary ($p < .001$), Similarities

($p < .001$), Information ($p < .01$), Comprehension ($p < .001$), Arithmetic ($p < .001$), Digit Span ($p < .05$), Letter-Number Sequencing ($p < .01$), Picture Arrangement ($p < .001$), Picture Completion ($p < .05$), Block Design ($p < .001$), and Matrix Reasoning ($p < .001$). SS was significantly lower than Vocabulary ($p < .001$), Similarities ($p < .01$), Information ($p < .05$), Comprehension ($p < .001$), Arithmetic ($p < .01$), Picture Arrangement ($p < .001$), Block Design ($p < .001$), and Matrix Reasoning ($p < .001$).

Table 13

Means and standard deviations of subtest scores for the collapsed TBI group ($n = 29$).

Measure	*M*	*SD*
Vocabulary	9.97	2.76
Similarities	9.14	2.95
Information	9.17	2.84
Comprehension	10.93	3.16
Arithmetic	9.72	3.41
Digit Span	8.52	2.40
Letter Number Sequencing	8.79	2.44
Picture Arrangement	10.24	3.53
Picture Completion	8.52	3.23
Block Design	9.59	2.76
Matrix Reasoning	10.55	3.13
Digit Symbol Coding	7.21	2.76
Symbol Search	7.79	2.98

Overall, the results of Analysis 2 revealed significant within-group differences. The TBI groups displayed significantly lower mean PSI scores in comparison to the other Indexes, although the exact patterns differed. In both groups, the other three Index scores did not significantly differ, forming a relatively flat profile. This pattern continued in the mean subtest scores, as both of the subtests comprising the PSI were significantly lower than many other subtests, especially subtests involving verbal and general knowledge, such as Vocabulary and Comprehension. When collapsed, the TBI group displayed a significantly lower mean PSI score in comparison to the other Index scores. Again, both the DSC and SS subtests revealed significantly lower mean scores than the majority of remaining subtests. In contrast, the LBP group did not display any significant PSI weakness, as only the average VCI score was significantly lower. However, the PSI scores were similar to the VCI scores and lower than both the POI and WMI. Examination of PSI subtests revealed several significant differences, yet these results were not as extensive as the TBI groups.

Analysis 3: Between-Group Comparisons of Symbol Search Performance

To determine whether there were significant differences between the three groups in the composition of Symbol Search scores, two analyses were conducted. First, two One-way ANOVAs compared both the correct and incorrect responses between the three groups (see Table 14). There was no significant difference between the three groups on either the mean number of correct responses or the mean number of errors.

Table 14

One-way ANOVA comparisons of Symbol Search (SS) scores.

Measure	*M*	*SD*	*n*	*F*	*df*	*p*
SS Correct				1.75	2, 52	.18
LBP	30.15	6.52	26			
MTBI	26.94	8.96	17			
M-S TBI	25.30	8.55	10			
SS Errors				.88	2, 52	.42
LBP	1.00	1.41	26			
MTBI	1.29	2.39	17			
M-S TBI	.40	.51	10			

Due to the relatively large number of errorless performances, which hindered the validity of mean-based statistical analysis of errors, a second comparison of SS errors investigated the occurrence of errors across groups. A Chi-Square Independent Samples test (i.e., Kruskal-Willis) determined whether the three groups significantly differed in the occurrence of errors. For this test, errors were coded dichotomously (no errors = 0, one or more errors = 1). Consistent with the AVONA results, there was no significant group difference, indicating that the groups performed similarly in the number of targets correctly identified and in the number of errors committed, $\chi^2 = 1.00$, $p = .61$.

Overall, Analysis 3 revealed no significant difference between the three groups regarding the composition of the SS scores. Specifically, the three groups did not demonstrate any difference in the mean number of correct or incorrect responses.

Discussion

The present study attempted to further the understanding of the usefulness of the WAIS-III as a neuropsychological measure by examining its sensitivity to TBI and its cognitive sequelae (i.e., processing speed deficits). WAIS-III profiles of differing TBI severities, as well as another well-established clinical population (chronic lower back pain), were examined. Previous research (e.g., Fisher, et al., 2000; The Psychological Corporation, 1997) has only focused on comparing differing TBI severities on cognitive measures, including the WAIS-III. These studies have consistently found processing speed to be significantly impaired in individuals who have suffered a TBI, regardless of severity (Fisher, et al., 2000). Although no studies have directly examined WAIS-III profiles in individuals with chronic pain, there have been several studies that have observed processing speed deficits within this population (Grigsby, et al., 1995; Sletvold, et al., 1995).

Between-Groups Comparisons of WAIS-III Profiles

It was hypothesized that although the three groups would demonstrate specific deficits, the M-S TBI group would exhibit significantly more impaired performance in comparison to the other two groups, especially on processing speed tasks, which has been found to be a sensitive measure of TBI (Donders, et al., 2001; Hawkins, 1998). Furthermore, it was hypothesized that the MTBI and LBP groups would not significantly differ in their performance on most WAIS-III measures, including the Processing Speed Index.

Results of the study did not support this hypothesis. However, some results were consistent with predictions. The LBP and MTBI groups did not differ on most measures (i.e., IQ scores, Index scores, most subtest scores), as expected. However,

contrary to expectations, the M-S TBI group showed no significant difference on any of the measures, including IQ scores, Index scores, and subtest scores, when compared to the other groups. The only significant differences found among the three groups were between the LBP and MTBI groups on two subtests (i.e., Vocabulary, Digit Span). The difference between the two groups on mean Vocabulary score was unexpected as Vocabulary is one of the least sensitive to traumatic brain injury (Kaufmann & Lichtenberger, 1998).

Since these two groups differed significantly in education level, further analyses were used with education-matched samples. When matched, the groups no longer differed. These results suggests that the observed differences on Vocabulary are likely attributable to education differences. However, it is unclear why Digit Span differences also diminished when education was matched as the LBP group attained higher scores on this measure. This result could simply be a result of statistical limitations, including a small sample size.

The M-S TBI group's failure to display significantly worse performance than the MTBI group on the WAIS-III was inconsistent with past literature. Many studies have consistently found significant differences in WAIS-III performance between MTBI and M-S TBI (Donders, et al., 2001; Fisher, et al., 2000), including the initial standardization of the WAIS-III itself (The Psychological Corporation, 1997). Particularly surprising was the lack of processing speed differences between the two groups. Previous research has consistently stated that processing speed deficits are among the most noticeable following M-S TBI (e.g., Donders, et al., 2001). Numerous studies have found significant differences between the PSI scores of individuals with M-S TBI and those with MTBI, even in the absence of other

differences (Donders, et al., 2001; Fisher, et al., 2000; Martin, Donders, & Thompson, 2000; The Psychological Corporation, 1997). Donders et al. (2001) found that of the 14 subtests within the WAIS-III, only four subtests were significantly different between individuals with MTBI and M-S TBI. Of these four subtests, both subtests within the PSI (i.e., DSC and SS) were included and Symbol Search was the only subtest that distinguished between MTBI and M-S TBI groups.

There was no significant difference among the two TBI groups and the LBP group on the PSI score or either of its subtests (DSC, SS) in the current study. Several explanations, regarding both the characteristics of the current sample and other potentially confounding variables, may contribute to these divergent findings. First, although time since injury within the two TBI groups did not reach statistical significance, small sample sizes and heterogeneous variances limit the validity of this analysis. Examination of the means revealed a difference of approximately 33 weeks. On average, the M-S TBI group was assessed approximately 19 months after injury, compared to 11 months for the MTBI group. Although the M-S TBI group initially suffered from more severe brain trauma, they had more time to recover or compensate for their injuries than the MTBI group.

However, this argument remains questionable since equivalent time since injury between differing severities is representative of different stages of recovery (Snyder & Nussbaum, 1998). Thus, chronicity comparisons between different severities of TBI are misleading. Most deficits following MTBI tend to fully remit within 6 months (Axelrod, et al., 2001; Snyder & Nussbaum, 1998). Deficits following M-S TBI usually take between 1 1/2 to 2 years to remit, if ever (Snyder & Nussbaum, 1998). Therefore, an individual assessed at 8 months post-injury would

be at vastly different stages of recovery depending on the severity of the injury. For an individual with a MTBI, cognitive assessment at 8 months follow-up would likely reveal a return to premorbid functioning. An individual with M-S TBI would display more extensive cognitive impairment at an 8-month post-injury assessment. Therefore, despite identical time since injury, different severities play a large role in determining cognitive outcome.

Second, although injury severity affects cognitive outcome (Donders, et al., 2001, Fisher, et al., 2000; Snyder & Nussbaum, 1998), the various classification systems to determining severity remain crude. Problems with unreliable classification of TBI severity could also explain lack of between-group differences in the present study. Most classification systems (e.g., Glasgow Coma Scale, loss of consciousness, and length of post-traumatic amnesia) are crude measures based on immediate, physiological criteria. For instance, the GCS is based on criteria including verbal responses, eye opening, and simple motor responses (Snyder & Nussbaum, 1998).

There has been much controversy surrounding the predictive validity of these classification measures. In general, PTA has been found to be a more reliable predictor of post-injury cognitive performance (as measured by tasks such as the WAIS-R, Wechsler Memory Scale-Revised, Stroop test, and the Trail Making test), in comparison to GSC scores (Ropacki, 2001). Bishara, Partridge, Godfrey, Hamish, and Knight (1992) found that duration of PTA and GCS scores on admission to hospital were both strongly correlated with outcome (measured by the Glasgow Outcome Scale). However, duration of PTA was the only significant predictor of outcome measures.

Both the GCS and LOC classification measures have not displayed as strong predictive abilities. In a group of MTBI individuals, differing GCS scores were not significantly related to several indices of neuropsychological status, including neurobehavioural signs and symptoms, psychological distress, functional and psychosocial outcome, and rate of return to work (McCullagh, Oucherlony, Protzner, Blair, & Feinstein, 2001). Similarly, Hanlon and colleagues found no difference in neuropsychological status or vocational outcome between patients who had and those who had not suffered brief loss of consciousness (Hanlon, Demery, Martinovich, & Kelly, 1999). In contrast, acute injury characteristics such as mechanism of injury (e.g., acceleration/deceleration versus blunt force trauma) and type of injury (i.e., motor vehicle accidents, fall, assault, sports/recreation) both exhibited significant relationships with outcome measures (Hanlon, et al., 1999).

In sum, inconsistency among classification measures in the present study, as well as equivocal results regarding predictive validity of cognitive functioning may have contributed to the lack of between-group differences in the present study.

The third population characteristic that may contribute to the lack of performance differences, particularly between the LBP and M-S TBI groups, is referral bias. The cases gathered for the LBP group were from psychovocational assessments. The potential problem arising from this difference is the purpose of psychovocational assessments themselves. The majority of the LBP cases used in this study involved individuals who injured their backs during strenuous activities (e.g., heavy lifting, quick turns, etc.). Therefore, it is probable that they required new vocational placements or duties since the majority of their jobs involved some type of manual labour that they could no longer perform. It is likely that their premorbid

vocational placements were highly related to their premorbid cognitive functioning (Snyder & Nussbaum, 1998). If this were the case, the lack of difference between the M-S TBI group and the LBP group may be partly attributable to a disparity in premorbid cognitive functioning. However, independent means by which to estimate premorbid levels of cognitive functioning were unavailable to test this possibility, thus no compelling inferences are possible.

To clarify this divergence from previous studies, some explanations regarding population differences must also be ruled out. For instance, although analyses revealed that the M-S TBI group was significantly younger than the LBP group, it is improbable that this age difference contributed to the equalization of the two groups' performance, since the WAIS-III scoring system adjusts for age differences. Similarly, no differences existed among the groups on reliance on medication, so it is not likely that medication use affected performance.

In addition to population characteristics included in the current study, there are also several potentially confounding factors that may help explain the lack of performance differences between the three groups. As noted above, chronic pain and brain injury exhibit a large number of overlapping symptoms. Specifically, several non-neurological sequelae of both chronic pain and brain injury affect cognitive functioning.

The first of these consequences, are depressive symptoms. Depressive symptoms are common sequelae of both TBI and CP, with estimates ranging from 21 to 50% for TBI (McCleary, et al., 1998) and 21 to 80% for CP (France, Houpt, Skott, Krishnan, & Varia, 1986). Within TBI samples, the frequency of depression remains relatively stable over time. Earlier studies reported that more than 50% of severely

head injured patients displayed depressed moods 3, 6, and 12 months following injury (McKinley, Brooks, Bund, Martinage, & Marshall, 1981). Similarly, Jorge and colleagues (1993) followed 66 patients over the course of one year and found that 26% met the criteria for major depression immediately following injury, and 17% remained depressed at a 1-year follow-up session (Jorge, Robinson, Ardnt, Starkstein, Forrester, & Geisler, 1993).

Depression can cause many symptoms, including cognitive ones that greatly overlap with those seen in both TBI and CP (Bay, Hagerty, Williams, Kirsch, & Gillespie, 2002). According to the American Psychiatric Association (2000), recognized symptoms required for diagnosis of depression include psychomotor retardation or slowing of mental processes. Other cognitive symptoms known to accompany depressive symptoms include decreased attention, memory, and visual-spatial and visual-motor skills, all of which overlap substantially with those seen in TBI and CP (Veiel, 1997).

The most salient deficits seen in depressed individuals and pertinent to the present study are the observed reaction time/processing speed deficits. Many studies have found slower reaction times in depressed samples with differences ranging from 1.1 to 2.4 standard deviations below the average (Veiel, 1997). People with depressed moods have reported delayed information processing speed as one of the most common and noticeable cognitive impairment (Brand & Jolles, 1987). Some researchers have suggested the severity of some neuropsychological functions in individuals with depressive symptoms are comparable to those either observed in M-S TBI approximately one year following injury (Veiel, 1997) or acute MTBI (Busch & Alpern, 1998).

In the TBI groups, the prevalence of depressive symptoms changes as a function of injury severity (Busch & Alpern, 1998). Alexander (1992) compared MTBI and severe TBI (STBI) and found that depressive complaints occurred in 30% of MTBI patients, as opposed to only 19% STBI patients. Similarly, Busch and Alpern (1998) compared MTBI and STBI groups and found that the two groups significantly differed in the prevalence of major depression or dysthymia (according to the DSM-II criteria) despite no significant differences in premorbid psychological history. Specifically, 87% of the MTBI group displayed diagnosable depressive symptoms, whereas only 31% of the STBI group demonstrated similar symptoms. These previous findings may prove useful in explaining the between group results of the current study. The cognitive differences between the two severities of TBI may have been masked by a greater occurrence of depressive symptoms in the MTBI group. Although the two groups performed equivalently, their performances may be attributable to different factors.

Another overarching variable that may have contributed to the lack of group differences in WAIS-III test scores are sleep disturbances. Similar to depressive symptoms, sleep disturbances are common sequelae of both TBI and CP and are capable of producing many of the same cognitive impairments, including processing speed deficits (Schnurr & MacDonald, 1995; Thaxton & Myers, 2002). During post-acute TBI, disordered sleep and insomnia complaints are frequent, with prevalence estimates ranging from 27% to 50% or higher (Beetar, Guilmette, & Sparadeo, 1996). Again similar to the depressive symptoms, sleep disturbances can become chronic problems within TBI populations. Previous research comparing an acute TBI group (i.e., 3 to 5 months post-injury) to a chronic TBI group (i.e., 2 to 3 years post injury)

found sleep complaints at 73% and 52%, respectively (Cohen, Oksenberg, Snir, Stern, & Groswasser, 1992).

Sleep disturbances manifest differently within different TBI populations. Beetar and colleagues (1996) examined sleep disturbances in groups with TBI (both mild and moderate-severe) and non-TBI neurological conditions. Furthermore, the researchers divided these groups into patients with and without significant pain. They found 58% of the TBI group reported insomnia complaints, as opposed to less than 33% of the non-TBI group. When comparing the two TBI groups, there were more than twice as many insomnia complaints reported by individuals with MTBI, in comparison to individuals with M-S TBI. Finally, the report of pain in both TBI and non-TBI groups was associated with a twofold increase in the number of sleep complaints, including problems falling asleep, maintaining sleep, and overall insomnia (Beetar, et al., 1996). From these results, the authors concluded that pain likely played a significant role in disrupting sleep. This conclusion was further supported by the observation that the MTBI group reported more pain and more sleep disturbances than the M-S TBI group.

The findings of Beetar et al. (1996) suggest another important area of potential confound in the present study. It is possible that the equivalent cognitive performance among the three groups is partially attributable to the experience of pain itself. Pain remains a significant problem in many cases where integrity of neuropsychological functioning is assessed, as research has revealed frequent pain complaints within TBI populations (Uomoto & Esselman, 1993). Following TBI, particularly MTBI, headache is the primary physical discomfort reported (Nicholson, et al., 2001). Up to 95% of individuals with MTBI reported pain of a sufficient

magnitude to interfere with their daily functioning, whereas only 22% of individuals with M-S TBI within the same study reported similar degrees of discomfort (Uomoto & Esselman, 1993).

Much controversy remains over the effect pain has on cognitive functioning. Whereas some studies have suggested that pain explains a significant degree of variance in cognitive performance, even more so than TBI severity (Vernon-Wilkinson & Tuokko, 1993), others have found little support that pain-related factors are detrimental to neurocognitive test performance (Alfano, et al., 1999). Because of this controversy, the role of pain remains relevant to studies examining cognitive performance within TBI populations.

Unfortunately, due to the retrospective and archival nature of the data, there was no information on pain complaints from either of the two TBI groups. It is possible that, similar to the pattern hypothesized for both depressive and sleep disturbances, pain symptoms contributed to the equality of WAIS-III performance seen between the three groups. Since previous studies have observed that MTBI individuals experience more pain than those with M-S TBI, the CP and MTBI groups' performances may be attributable to uninvestigated pain difficulties. However, without further information into the physical complaints of the TBI groups, the role of pain cannot be tested.

In conclusion, the present study did not find any significant between-group difference on the WAIS-III scales, a finding that was unexpected given previous research that had consistently found differences between MTBI and M-S TBI groups. These results were not explained by differences in age or medication use among the three groups. However, time since injury, limitations of the classification measures,

and referral bias may have influenced the results. Similarly, potentially confounding variables could have contributed to the absence of group differences. In the MTBI and CP groups, the possibility of more frequent depressive symptoms, sleep disturbances, and pain complaints, may have hindered performance to the point of equating that of the M-S TBI group.

Within-Group Comparisons of WAIS-III Profiles

Individuals who have suffered a TBI, regardless of severity display processing speed deficits following injuries (Hawkins, 1998). Similarly, chronic pain patients exhibit marked impairments in their speed of information processing or reaction times, in comparison to other more resilient abilities, such as general knowledge or verbal abilities (Nicholson, et al., 2001). In accordance with these studies, the second hypothesis of this study postulated that in each group, WAIS-III profiles would reveal significantly poorer performance on the PSI and its subtests, in comparison to the other Indexes and subtests.

The results of the study did not support the hypothesis. However, several patterns were consistent with predictions. There was no significant VIQ-PIQ discrepancy observed within these groups. This pattern was inconsistent with previous claims by Wechsler and succeeding WAIS-III developers. In 1981, Wechsler claimed that a large VIQ-PIQ discrepancy was indicative of brain damage. Similarly, while assessing the WAIS-R, Crawford et al. (1997) found that individuals with closed head injuries displayed significant lower PIQ scores in comparison to VIQ scores, as well as PIQ scores of normals. Finally, in the initial standardization of the WAIS-III, M-S TBI individuals displayed significantly lower scores on all IQ and

Index scores than both MTBI and normals, and significantly higher VIQ scores when compared to PIQ scores (The Psychological Corporation, 1997).

These patterns have been recently criticized as numerous studies have not found significant discrepancy between the IQ scores on the WAIS-III (e.g., Axelrod, et al., 2001; Fisher, et al., 2000; Hawkins, 1998; Hawkins, et al., 2002). However, in those studies, as well as the present one, a consistent and important profile emerged. Regardless of injury severity (i.e. MTBI, M-S TBI, collapsed), PSI was the only measure sensitive to TBI. No other measure (i.e., the three IQ scores, VIQ-PIQ discrepancy, or the other three Index scores) exhibited sensitivity to this population. Even the WMI, which is thought to measure an area of cognitive deficit in TBI populations, failed to show any sensitivity. Although the profiles differed slightly between the MTBI and M-S TBI groups, the differences were negligible and did not reach significance in any of the TBI groups.

The collapsed TBI group demonstrated significantly lower PSI scores compared to all the other Index scores. This pattern was stronger than the MTBI and M-S TBI groups in which the PSI was significantly lower than only one of the Index scores (VCI and POI, respectively). These results support the notion that regardless of severity, the PSI is the most sensitive to TBI-related deficits. Furthermore, these results are consistent with past research that has cited processing speed deficits as one of the most evident, and resilient deficits following TBI, regardless of severity (Gronwall & Wrightsom, 1974; Johnstone, et al., 1995; Van Zomeren & Deelman, 1978).

In contrast to both the TBI groups, the LBP group did not demonstrate the hypothesized PSI sensitivity, as the group's lowest Index score was the VCI, not the

PSI. It is possible that the lower VCI score is associated with the lower education levels within the LBP group. The mean education level of the LBP group was approximately 11 years, whereas most of the standardization samples for the WAIS-III had at least 12 years of education (The Psychological Corporation, 1997). With the exception of the VCI, the remaining three Indexes created the same pattern (i.e., PSI, WMI, and POI) as the one seen in the MTBI group, as hypothesized.

In conclusion, within-group analyses of WAIS-III measures did not support the hypothesis, although some results were consistent with predictions. In all three TBI groups, global measures of cognitive functioning, as measured by the IQ scores in the WAIS-III, failed to reveal any cognitive impairment. However, the PSI demonstrated significant sensitivity to the TBI populations and the resultant processing speed deficits. The remaining Index scores, including the WMI, did not differ from each other and failed to exhibit sensitivity to TBI.

In contrast, the LBP group did not display a similar WAIS-III profile as its lowest score was the VCI. However, education level may have played a role in this pattern. Furthermore, with the exception of the VCI, the remaining three Indexes (PSI, WMI, and POI) created the same profile as the MTBI group, although the profile failed to reach significance. Overall, the within-groups comparison replicated and extended previous claims that the PSI is the most sensitive measure within the WAIS-III to both TBI and other clinical populations. In both LBP and TBI groups, none of the other global measures (i.e., IQ scores, remaining Index scores) displayed any sensitivity to the cognitive deficits in these groups.

Between-Group Comparisons of Symbol Search Performance

One of the most sensitive measures to TBI within the WAIS-III is Symbol Search (Donders, et al., 2001; Hawkins, 1998; The Psychological Corporation, 1997). However, previous research has failed to examine the composition of Symbol Search scores. Impaired performance on this subtest can be achieved through either a slower, yet accurate pattern of responding, or a faster, less accurate approach. The pattern of responding can provide information regarding the sequelae of TBI. Quick, yet inaccurate responding may be indicative of impulsivity, whereas slower, yet accurate responding is more likely to be indicative of processing speed deficits.

To investigate this research question, correct and incorrect responses in the three groups were examined. A high number of incorrect responses would suggest impulsive responding. The results suggest that although the overall Symbol Search scores were below average (particularly for the two TBI groups), the lower scores were attributable to slower processing speed in the majority of cases within all three groups. In fact, only a small number of individuals committed any errors at all, and even fewer committed more than one error.

There were no significant differences between the three groups on any of the Symbol Search measures. Although the LBP group achieved a better overall score than the TBI groups, this difference failed to reach significance. Similarly, no group differences existed on either the number of correct or incorrect responses.

In sum, the results of the analyses supported the validity of the Symbol Search subtest as a measure of processing speed by eliminating an alternate explanation of poor performance in these samples, that of impulsive responding.

Implications

The results of this study have many implications within theoretical, research, and clinical realms. Theoretically, this study has provided support for previous taxonomies (e.g., Johnstone, et al., 1995; Prigatano, 1986; Tate, et al., 1991) that have included processing speed as a primary area of weakness within TBI populations. Furthermore, these findings have been expanded to include chronic pain patients, as they displayed processing speed performance similar to individuals with varying degrees of TBI. Significant within-group analyses supported previous studies that named the PSI as the most sensitive measure of TBI within the WAIS-III.

The similar profiles attained by the two TBI groups suggest that future research examining TBI should include other sequelae, including depression, pain, and sleep disturbances, as they can have detrimental effects on cognitive performance. Although the test performance was similar within the mild and moderate-severe TBI groups, the factors contributing to the performance may differ. This study has also provided a foundation for future research investigating CP and its relationship to standardized intelligence test performance.

Perhaps the most important implications of the present study are those within the clinical field. First, the results of this study suggest that clinicians using the WAIS-III within a neuropsychological assessment should routinely administer the "optional" Symbol Search subtest so the PSI is calculated, and because it is possibly the most sensitive measure to TBI. Second, automatic attribution of post-TBI cognitive symptoms to the pathophysiology of TBI is contraindicated since pain may affect cognitive functioning in a similar way as TBI, as seen the present study's CP population. Other factors, such as sleep disturbances and/or depressive symptoms

may also be involved in impaired cognitive performance in TBI populations. Finally, the results of this study suggest a need to differentiate between TBI with pain versus either TBI or CP in isolation to maximize treatment/remediation approaches.

Limitations of the Present Study

Several limitations within the present study may have influenced the results. Due to the clinical nature of the data, as well as the exclusion criteria, the sample size was limited. The small sample sizes may have impeded the power of the statistical analyses. Furthermore, small sample sizes within each group precluded any analyses of potential gender influences.

Due to the archival nature of the data, there were several limitations on the information collected for each individual. First, because the individuals who had suffered a TBI sought medical attention through different sources, severity evaluations were not uniform. This may have hindered the reliability of the severity classification. Even if the classification measures were consistent in the groups, the validity of these measures remain equivocal (Hanlon, et al., 1999; McCullagh, et al., 2001).

Second, although chronicity was not statistically different between the MTBI and M-S TBI groups, the difference was approximately 8 months, which in terms of the natural course of TBI, is clinically significant. Furthermore, the stages of recovery represented by similar chronicity would differ greatly. The present study had an average time since injury of approximately 11 months for the MTBI group, and approximately 19 months for the M-S TBI group. The natural course of MTBI suggests that cognitive functioning recovers fully by 6 months post-injury (Snyder & Nussbaum, 1998). Therefore, assessment 10 months post-injury would not be

expected to reveal any deficits in comparison to premorbid functioning. Conversely, the natural course of M-S TBI suggests that recovery usually reaches a plateau at about two years post-injury (Snyder & Nussbaum, 1998). Therefore, some of the patients in this study may have still been in the stages of recovery. Although the time since injury did not differ between the two groups, it is probable that it represented significantly different stages of recovery, and different cognitive abilities as well.

Third, exclusion criteria were primarily based on self-report. Particularly problematic is the reliance on self-reports for diagnosis of premorbid learning disorders, substance abuse, or psychiatric disturbances. Due to the older age of the some of the participants, diagnosis of a learning disorder would not have been feasible while they attended school, and thus would have remained undetected into their adult lives. Similar self-report biases existed for substance abuse and psychiatric disorders. However, to minimize these problems, the exclusion criteria were adjusted to limit potential self-report biases. Recognition of substance abuse was restricted to those individuals who had attended treatment for substance abuse in their past, as this information was readily available in the files and did not require any type of inference on behalf of the client. Similarly, psychiatric disturbances were operationalized as any premorbid diagnosis of a major psychiatric disorder (e.g., Major Depression, Bipolar Disorder, etc.). However, even with these adjustments, it is possible that the prevalence of premorbid substance abuse or psychiatric disturbances were underestimated within this sample.

Fourth, the archival nature of the project precluded the examination of several confounding variables, such as pain complaints or sleep disturbances. Within the TBI groups, no distinction was available between injuries of a focal (i.e., affecting

primarily one area of the brain) versus diffuse (i.e., global impairment) nature. Since the mechanisms of these injuries differ, the deficits that arise, as well as the neuropsychological outcome, also differ quite dramatically (Hanlon, et al., 1999). Therefore, it would be possible that the cognitive manifestations of each, when examined by the WAIS-III, would display observable differences.

Finally, this study included no normal control group. Despite analyses revealing similar performance of the TBI and LBP groups on most measures of the WAIS-III, conclusions regarding absolute performance are not possible. However, qualitative examination of the standardized scores would suggest that there were significant areas of impairment (e.g., on Digit Symbol Coding, Symbol Search).

Directions for Future Research

Future research should focus on the replication and expansion of these findings. First, larger sample sizes would increase the power of statistical analyses and provide further support for or against the present findings. Diverse populations would be helpful as individuals of different race, gender, and socio-economic status would further expand the generalizability of these results. The use of a normal control group would provide a more accurate picture of WAIS-III performance in both TBI and LBP populations by determining whether these groups display absolute weaknesses in performance.

Inclusion of other variables (i.e., sleep, depressive symptoms) would provide a more comprehensive depiction of the factors involved in WAIS-III performance, and cognitive impairment in general, within TBI and CP populations. Research examining WAIS-III performance of severity-matched individuals who differ in depressive or sleep symptoms would also broaden current knowledge. Studies

comparing individuals who have suffered a TBI of varying natures (i.e., focal versus diffuse, penetrating versus closed head) would also provide expansion of these studies in that it could perhaps determine whether different mechanisms of injury result in different WAIS-III profiles regardless of severity. Future studies should avoid absolute comparisons of chronicity among varying degrees of TBI severity. MTBI and M-S TBI groups assessed at 6 months post-injury would exhibit different cognitive profiles. Instead, relative comparisons would be beneficial, perhaps focussing on acute (i.e., 1 month for MTBI versus 3 months for M-S TBI) and chronic (i.e., 4-6 months for MTBI versus 18-24 months for M-S TBI) neuropsychological status.

The results of this study showed that individuals with chronic pain displayed similar cognitive profiles as those with mild or moderate-severe TBI. Therefore, future studies should examine the relationship of pain complaints in TBI populations to cognitive performance, especially processing speed. A study comparing TBI with pain, TBI without pain, and chronic pain could possibly elucidate differences not observed in the present study.

Finally, to improve the WAIS-III usefulness as a neuropsychological measure, future studies should compare WAIS-III performance within impaired populations (i.e., TBI, CP) to other developed neuropsychological measures. This area of research would be particularly helpful for processing speed tasks, as the WAIS-III measures are relatively new and only include processing speed of visual symbols. Also, the subtests of the PSI (DSC and SS) are not simple reaction time tasks, but are multifaceted tasks, composed of many neuropsychological constructs, such as attention, fine motor skills, and ability to learn new tasks (The Psychological

Corporation, 1997). Within certain neuropsychological populations, processing speed deficits may manifest differently depending on the nature of the tasks (e.g., visual versus verbal; oral versus motor; automatic versus novel). Thus, future research would be helpful in determining whether the WAIS-III provides a comprehensive depiction of an individuals' overall processing speed, rather than their processing speed within specific contexts, or concomitant cognitive deficits, such as attention or fine motor skills. The predictive validity of the PSI should also be investigated by evaluating its relationship with outcome measures, such as vocational return and rehabilitative success.

Conclusions

The primary purpose of the present study was to investigate the usefulness of the WAIS-III as a neuropsychological measure by examining its sensitivity to two clinical populations, TBI and CP. The results suggested that the newly developed PSI and its subtests provide a sensitive measure of information processing speed across different populations. Thus, the WAIS-III should be included within the context of a comprehensive neuropsychological assessment as it can provide valuable information regarding the cognitive abilities of an individual. However, future research remains important to a better understanding of this area, which will improve theory, research, and practice.

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Appendix A

Descriptions of the WAIS-III Subtests

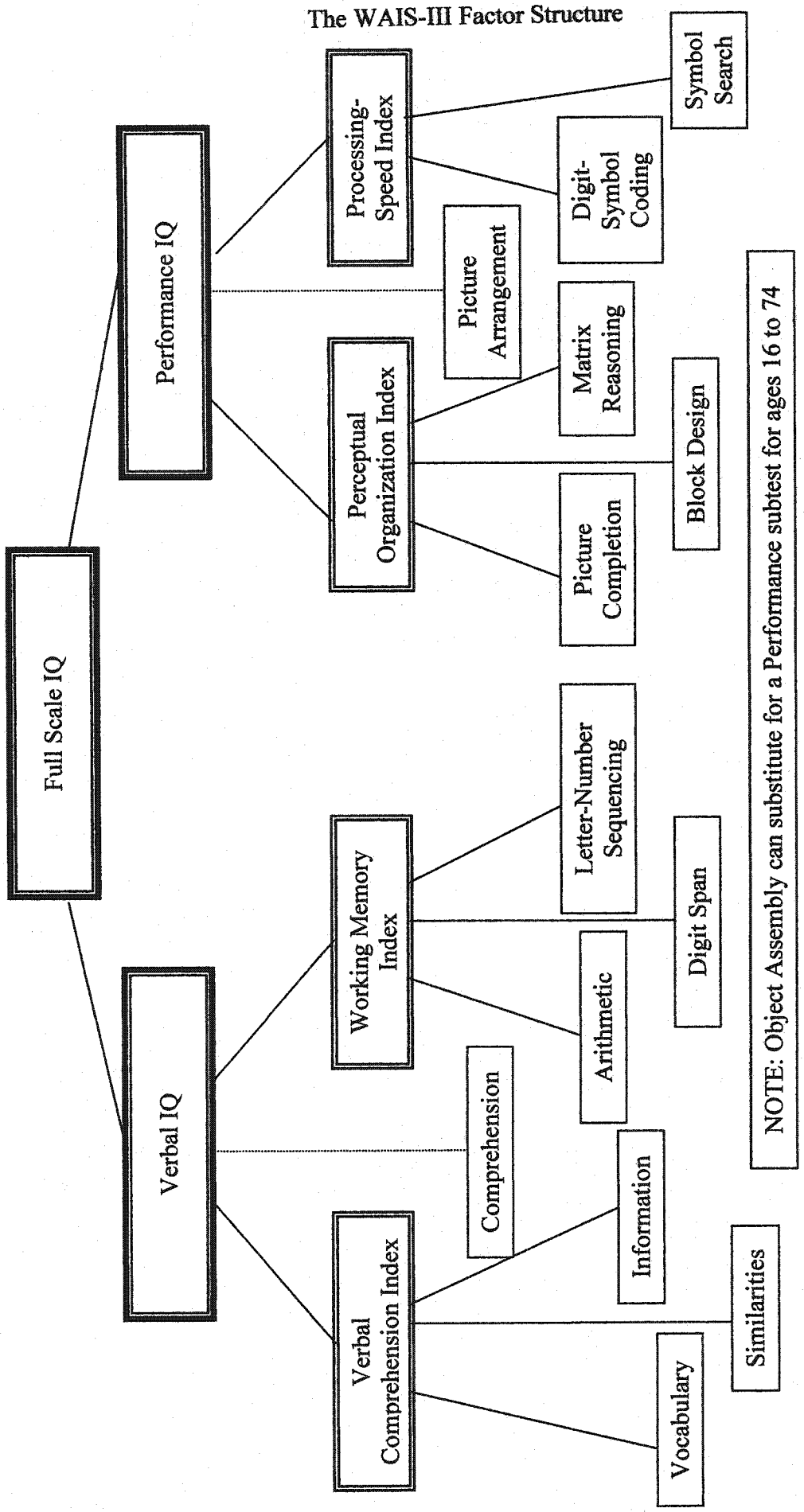
Subtest	Description	Measures
Vocabulary	The examinee must define visually presented words.	Language development, word knowledge
Similarities	The examinee must identify similarities between pairs of objects or concepts.	Logical abstract reasoning, verbal concept formation
Information	The examinee must answer questions regarding general knowledge about the world (e.g., geography, history, science)	General factual knowledge, semantic knowledge retained from prior learning
Comprehension	The examinee is required to demonstrate judgement and opinion related to everyday problems or concerns.	Practical knowledge, knowledge of conventional standards of behaviour, skills at evaluating past experience
Arithmetic	The examinee must complete mental computations to questions presented in a "story problem" format.	Computational skill, concentration and attention, numerical reasoning, working and auditory memory
Digit Span	The examinee repeats a fixed random series of numbers of increasing length both forward and backward	Immediate rote recall, ability to shift thought patterns (backward only), attention and concentration
Letter Number Sequencing	The examinee must repeat and re-organize (i.e., numbers in numerical order and letters in alphabetical order) a series of numbers and letters of increasing length.	Working memory, sequential processing, facility with overlearned sequences
Picture Completion	The examinee must identify some important missing visual component in each of a series of pictures.	Visual alertness, accuracy in differentiating essential from nonessential details, visual recognition
Block Design	The examinee must organize a set of red and white blocks to match the patterns in a booklet.	Spatial visualization, visual-motor coordination, analysis of whole into its parts
Matrix Reasoning	The examinee must choose from alternatives the piece that would best complete a visual matrix	Nonverbal problem solving, analogic reasoning, spatial visualization

Picture Arrangement	The examinee must rearrange a set of cards depicting sequential, nonverbal interactions presented out of order.	Anticipation of consequences, time concepts and temporal sequencing, planning abilities, visual organization
Digit Symbol Coding	The examinee must perceptually pair symbols with corresponding digits followed by rapidly (timed) transcribing the symbols with the corresponding digits.	Psychomotor speed, visual short-term memory, paper-pencil skills, clerical speed and accuracy
Symbol Search	The examinee must scan each line of symbols for the presence or absence of designated targets, which differ from line to line.	Speed of visual search, speed of information processing, visual acuity
Object Assembly	The examinee must complete jigsaw-type puzzles.	Understanding the relationship between parts, synthesis, visuomotor organization

(Kaufmann & Lichtenberger, 1999)

Appendix B

The WAIS-III Factor Structure



Appendix C

Means and standard deviations of subtest scores for LBP group within-group ANOVA.

Measure	*M*	*SD*	*n*
Vocabulary	8.19	1.90	26
Similarities	8.96	1.99	26
Information	8.19	2.33	26
Comprehension	9.50	1.68	26
Arithmetic	8.77	2.08	26
Digit Span	10.19	2.73	26
Letter Number Sequencing	9.27	2.34	26
Picture Arrangement	9.54	2.60	26
Picture Completion	9.50	2.14	26
Block Design	9.23	1.82	26
Matrix Reasoning	10.31	2.28	26
Digit Symbol Coding	8.42	2.39	26
Symbol Search	9.15	1.99	26

Appendix D

Means and standard deviations of subtest scores for the MTBI group within-group ANOVA.

Measure	*M*	*SD*	*N*
Vocabulary	10.06	2.86	17
Similarities	9.18	3.45	17
Information	9.41	3.16	17
Comprehension	11.47	3.02	17
Arithmetic	9.47	3.48	17
Digit Span	8.00	2.37	17
Letter Number Sequencing	9.35	2.78	17
Picture Arrangement	10.24	3.54	17
Picture Completion	8.24	3.25	17
Block Design	9.59	2.76	17
Matrix Reasoning	10.06	3.23	17
Digit Symbol Coding	7.41	2.76	17
Symbol Search	7.88	3.31	17

Appendix E

Means and standard deviations of subtest scores for M-S TBI group within-group ANOVA.

Measure	*M*	*SD*	*N*
Vocabulary	9.83	2.72	12
Similarities	9.08	2.19	12
Information	8.83	2.41	12
Comprehension	10.17	3.33	12
Arithmetic	10.08	3.42	12
Digit Span	9.25	2.34	12
Letter Number Sequencing	8.00	1.65	12
Picture Arrangement	10.25	3.67	12
Picture Completion	8.92	3.29	12
Block Design	9.55	3.01	11
Matrix Reasoning	11.36	3.11	11
Digit Symbol Coding	6.92	2.84	12
Symbol Search	7.67	2.57	12

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