NEUROPSYCHOLOGICAL, EMOTIONAL, PERSONALITY AND PAIN PROFILES IN LITIGATING WHIPLASH PATIENTS: PRELIMINARY EVIDENCE FOR DIFFERENTIATION INTO SUB-GROUPS BASED ON PRESENCE AND LEVEL OF CERVICAL INJURY

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Neuropsychological, Emotional, Personality and Pain Profiles in Litigating Whiplash Patients: Preliminary Evidence for Differentiation into Sub-Groups Based on Presence and Level of Cervical Injury.

by

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Abstract.

Neuropsychological, affective, personality, and physical consequences of post-concussion syndrome following an indirect blow to the head sustained through rapid acceleration/deceleration forces causing hyperextension/hyperflexion (whiplash) injury were investigated. A mild traumatic brain injury comparison group (MTBI) was used. All but one patient was involved in litigation at the time of their assessment. Whiplash patients were divided into three groups based on presence and level of cervical injury. Patients with upper cervical spine injury were classified as the cervicoencephalic syndrome group (CES); lower cervical spine injury, the lower cervical spine syndrome (LCSS) group; and patients without structural damage, the 'no objective evidence of pathology' (NOEP) group. The study sought to substantiate this differential diagnosis.

Whiplash patients experienced fewer and less severe cognitive compromise than MTBI patients. In general, they were not memory impaired as was the MTBI group. The higher the level of neck injury, the greater the propensity for impaired attentional functions and speed of information processing. This may be attributable to proximity of brainstem structures. Results provide preliminary support for the differentiation of whiplash patients into separate groups based on presence and level of cervical injury as proposed by Radanov *et al.* (1992).

The NOEP group performed better overall than any of the other groups on attentional measures and speed of information processing. This supports the belief that their injuries are less severe.

A predictable pattern emerged whereby as perceived pain intensity and interference due to physical discomfort increased, ability to control pain and activity levels decreased, and patients were more susceptible to depression. This pattern was most apparent in the CES group and tended in the same direction in the NOEP group. In contrast, as perceived control of pain and activity levels increased, pain intensity and interference decreased, with less susceptibility to depression. This was most obvious in the head injured group and tended in the same direction in the LCSS group. Cognitive deficits following whiplash and MTBI were independent of levels of pain and coping responses to physical discomfort; emotional disturbance; and personality traits. That these patterns were not predictive of neuropsychological profiles suggests that they are based on different etiological origins.

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INTRODUCTION

1.1 Post Concussion Syndrome Following Mild Traumatic Brain Injury

Post-concussion syndrome (PCS) typically refers to a constellation of symptoms following a direct blow to the head (Szmanski and Linn, 1992). Studies on the physical effects of intracranial brain movement have also demonstrated that PCS can occur in individuals subjected to extreme acceleration forces in motor vehicle accidents (MVA's) without direct impact to the head and in the absence of loss of consciousness (LOC) (Batjer, Cole Kopitnik and Purdy, 1992; Sweeney 1992). Taylor, Cox and Mailis (1996) suggest that whiplash can represent one of the mildest forms of head injury. Sweeney (1992) also asserts that victims of non-impact acceleration forces often meet diagnostic criteria for mild head injury. Although this suggests that the symptoms have a primarily organic etiology, it has been argued that the syndrome also has psychological origins (Mariadas, Chitra, Gangadhar and Hegde 1989; Putnam, Millis and Adams 1996).

1.1.1 Definitions

Several classification schemes have been designed to determine head injury severity based on initial and changing neurological findings over time. Although these criteria vary to some degree, salient classification features include: a transient loss or alteration of consciousness following trauma to the head with resultant post-traumatic amnesia (PTA) which does not exceed 20 minutes around the injury event; Glasgow Coma Scale score (GCS) of 13 to 15; and hospitalization of less than 48 hours (Davidoff, Kessler, Laibstain and Mark 1988; Putnam *et al.* 1996). The American Congress of Rehabilitation Medicine confers the term "mild traumatic brain injury" on patients who report feeling dazed or stunned following an accident and includes a whiplash injury, even when GCS ratings are perfect and no obvious loss of consciousness (LOC) has occurred (Taylor *et al.* 1996). It has been estimated that up to 50% of patients who suffer mild head injuries experience cognitive disturbances in a few days to weeks following the initial insult (Joseph 1990). These cognitive effects usually return to normal approximately three months post-injury (Stuss, Ely, Hugenholtz, Richard, LaRochelle, Poirier and Bell 1985). Although variable in degree and duration, post-concussion symptoms may persist in a subgroup of patients for extended periods of months to years after the event (Levin, Eisenberg and Benton 1991; Yarnell and Rossie 1988). This is long after the expected recovery time (Binder 1986; Taylor *et al.* 1996).

There are three major types of post-concussional symptoms associated with mild head injury that evolve in the initial hours following trauma (Anderson 1995). The first symptom group includes physical complaints such as headache, fatigue, insomnia, dizziness, hyperacusis, photophobia and alcohol intolerance. The second group of symptoms involve affective or emotional changes characterized by increased irritability and low frustration tolerance, anger and generalized anxiety. Dysphoria or depression, as well as aspontaneity and reduced initiative are also common. Finally, sufferers of mild head injury complain of persistent cognitive sequelae. These include impaired attention and concentration, memory problems, slowed reaction time, and diminished rate of information processing, as well as mental inertia.

Cognitive and neurobehavioral sequelae of the post-concussive syndrome (PCS) following mild head injury persists in a subgroup of patients beyond time limitations anticipated based on the original severity of impact (Hugenholtz, Stuss, Stethem and Richard 1988). Although the contention that persisting sequelae which occur after mild head injury are insupportable, the possibility of selective vulnerability of some patients should be considered to differentiate those who are at risk for long-term consequences from those who are not. The level of disruption in patients who experience persistent complaints can lead to vocational disability (Blankenship 1988; Hurt 1991); interpersonal discord (Bohnen and Jolles 1992); as well as to psychopathology including anxiety and depression. Whether these symptoms are of primarily physiogenic or psychogenic etiology continues to be debated (Bohnen and Jolles 1992; Putnam *et al.* 1996). This controversy is partially fuelled by the dis-proportionality of symptoms to the original insult as well as to the absence of identifiable central nervous system lesions on standard neuro-imaging techniques (Schwartz, Barth, Dane, Drenan, DeGood and Rowlingson 1987; Anderson 1995). The presence of confounding effects such as litigation in many of the afflicted patients has led to the diagnosis of malingering, compensation neurosis, or secondary gain (Mckinlay, Brooks and Bond 1983; Schwartz *et al.* 1987; Youngjohn *et al.* 1995).

Until recently people who sustained mild head injury remained largely neglected by the medical profession except for the provision of acute treatment with discharge from the emergency room. Although they now receive increased assessment, almost no emphasis is placed on follow-up intervention either medically or psychologically until their condition has become more chronic (Bohnen and Jolles 1992).

1.2 Cerebral Symptoms Caused by Hyperextension/Hyperflexion Injury to the Neck.

Hyperextension/hyperflexion injury to the neck, commonly referred to as a whiplash injury, can be sufficient to cause cerebral symptoms similar to those following mild head injury. This can occur in the absence of an apparent direct physical impact to the head (Yarnell and Rossie 1988; Sweeney 1992). These types of injuries are particularly numerous in patients who experience rapid acceleration/deceleration forces to the neck through a whiplash mechanism such as that encountered in motor vehicle accidents (Chapman-Smith 1988). The presence of minor brain trauma, sustained through a whiplash mechanism, has been postulated based on the similarity of symptoms following whiplash with those of Post Concussive Syndrome (PCS) following mild traumatic brain injury (Teasell *et al.* 1993). While there is some credible evidence of an organic etiology for post-traumatic symptoms following concussion, its presence after uncomplicated whiplash remains more questionable due to lack of evidence (Teasell *et al.* 1993; Radonov *et al.* 1993).

Pioneer work on neurophysiological change following concussion demonstrated permanent, traumatically-generated damage characterised by microscopic capillary hemorrhages and neural lesions as well as reduced cerebral blood flow (Oppenheimer 1968). This early work is often cited to support the view that concussion falls on a continuum and represents a mild form of diffuse brain injury. Oppenheimer (1968) further proposed that these neurophysiological changes reflect disruption to bilateral anterior and cortical-subcortical connections. Although the prognosis of whiplash patients is variable, it has been estimated that symptoms persist for at least six months in more than a quarter of afflicted patients (Spitzer, Skovron, Salmi, Cassidy, Duranceau, Suissa 1995).

Rapid acceleration forces to the head causes brain tissue to accelerate at a different rate than bone due to differential densities between the two. Differences also exist between white (pathways) and gray (cell bodies) matter regions. This creates a gradient that results in shearing forces on brain tissue (Bigler 1990). Ommaya and Gennarelli (1974) proposed that the whiplash mechanism involves inertial impulse loading that results in localized involvement of limbic and fronto-orbito-temporal cortices as well as in the brainstem and upper cervical spinal cord (Sweeney 1992). These regions demonstrated increased susceptibility to damage due to maximal centripetal, structural and tissue density (Binder 1986). The strain involved following such acceleration-deceleration forces cause not only a shearing of axons but a resultant degeneration over time of neural tracts in the brainstem (Joseph 1990). The effects of the shear/strain mechanism begin at the surface of the brain in mild cases and extend inward to involve the diencephalic - mesencephalic core following more severe trauma (Ommaya and Gennarelli 1974). It has been suggested that concussion symptoms likely result from "structural or electrical interference with ascending reticular pathways" (Mesulam 1985).

Extreme or rapid extension of the head may cause decreased blood flow to the brain by compressing the vertebral arteries which supply the brainstem, cerebellum, occipital lobe and hippocampal region of the temporal lobe (Joseph 1990). The internal carotid artery exposed in the neck is also vulnerable to injury under conditions of rapid extension or rotation that can contribute to further trauma. Although speculative, it has been postulated that the cause and effect of cerebral ischemia after trauma creates neuronal abnormalities in the cranial-spinal junction that leads to altered cerebral blood flow (Joseph 1990). Prolongation of vasoconstriction and vasomotor dysregulation has been hypothesised as another of the possible mechanisms which might contribute to the persistence of PCS (Binder 1986).

In an investigation of electroencephalograms (EEG) of post-whiplashed monkeys, King Liu, Chandran, Heath and Unterharnscheidt (1984) found electrophysiological disturbances in the brain particularly in the hippocampal region. They considered the growth and development of this trauma-induced hippocampal spiking to be a subclinical form of post-traumatic epilepsy (King Liu *et al.* 1984). When subcortical EEG changes did take place, normal or mild abnormal tracings were obtained from scalp EEGs. When the whiplashed animals developed abnormalities, they occurred at least six weeks post-whiplash.

Since then cognitive deficits involving attentional functions were demonstrated in whiplashed patients even without a speculated mild traumatic brain injury (Radonov *et al.* 1992). These deficits were considered secondary to headache caused by cervical pathology. Schwartz *et al.* (1987) however, caution against the misattribution of cognitive problems to pain. In a prospective study, Radonov *et al.* (1993) found a direct relationship with ongoing symptomatology following whiplash with factors linked to trauma, age, presence of previous head injury and, in particular, reduced cognitive acuity as a result of the injury. Psychosocial factors, personality traits and negative affect were not determinants of the development or duration of symptoms following cervical strain.

1.3 Incidence and Economic Impact

A cohort study conducted by a Quebec task force was struck to investigate various aspects of whiplash associated disorders (WAD). The source population for this epidemiological study was comprised of all people who suffered a whiplash injury in a MVA in 1987 in Quebec and who submitted a claim through the provincial insurance service. The study found the population-based annual incidence rate of compensated insurance claims for whiplash injury was 70 per 100,00 inhabitants. This resulted in more than 18 million dollars paid out to 4757 patients. Over 70% of this money accounted for payment for replacement of lost regular income. The study revealed that the incidence of claims was notably higher in females than males across different age groups. It was speculated that this was attributable to the fact that given the same head size, men have more neck musculature than women, making them less prone to suffering whiplash injury (1995). It was also proposed that women may be more inclined to seek compensation than men. In addition, regional variation in incidence of claims existed which appeared to be correlated with population density and the number of commuters in each region.

Although research is limited, and time estimates for recovery are variable, it is established that post-concussion symptoms following either a direct or indirect blow to the head such as a whiplash injury can linger in a subgroup of patients for long periods. Symptoms can last from months to years or even indefinitely. The economic toll of these residual problems can delay or prohibit resumption of work, wreak havoc in personal lives, generate stress reactions and contribute to ongoing discomfort. This situation is critical given that approximately fifty percent of people who suffer mild traumatic brain injury are at risk of developing post-concussive symptoms (Joseph 1990). Eighty-one percent of head injuries are classified as mild. This translates into an incidence rate of 131 per 100,000 individuals or 35,000 Canadians per year. The nonspecific nature of those symptoms associated with mild traumatic brain injury make them difficult to quantify or to document objectively.

Compared to other trauma-related injuries, soft tissue injury of the cervical spine is disproportionately associated with litigation. Whiplash injury is common among motor vehicle occupants following collision. The incidence rate varies greatly in different parts of the world with the annual estimated rate as high as 106 per 100,000 in Australia (Spitzer *et al.* 1995). Bannister and Gargan (1993) state that 56% of cases presenting to the Accident Board in Victoria Australia over a six month period who suffered such injury are involved in litigation. In Quebec, whiplash represents the most common type of injury for which claims have been filed with the local insurance service. In British Columbia and Saskatchewan, both provinces with single payer motor vehicle insurance programs ("No-fault"), 68% and 85% of their respective claims are paid to whiplash patients (Spitzer *et al.* 1995). This represents a substantial financial burden for the insurance system.

Approximately 6.5 million motor vehicle accidents occurred in the United States in 1994, of which 3.2 million resulted in injuries. Eighteen percent of these accidents involved rear-end collisions that caused injury to an estimated 500,000 people. These rear-end impacts result in a higher incidence of whiplash associated disorders than any other type of injury (Brault, Wheeler, Siegmund and Brault 1998).

Taylor *et al.* (1996) projected an annual hospitalization cost for Americans in excess of $1 billion following whiplash injury. A similar extrapolation from 1981 projected a cost estimate for hospitalized mild head injured patients at slightly over $900 million annually (Kraus and Nourjah 1989). Added to this figure is the cost of future medical consultations, future lost earnings and treatment costs. It has been estimated that 53% of whiplash patients take more than four weeks to recover. One year after the event, 2.9% remained unable to return to work. Given the variability in time frame for recovery, these costs can be projected from weeks to years in any individual case. Since the peak incidence rate of whiplash injury occurs in the 20-54 year old age range (Spitzer *et al.* 1995), it predominantly affects a group of working people for whom lost wages can become a very costly factor in compensation.

Statistics cited from New York University suggest that the rate of post-concussion symptoms remains at approximately 10% at the end of a year. About 11% of people employed before their injury are out of work at one year follow-up. Kay, Newman, Cavallo, Ezrachi and Resnick (1992) in using a conservative estimate of 5% of patients with residual dysfunction following mild head injury, estimated 67,000 people are rendered dysfunctional by whiplash on an annual basis. Teasell (1993) stated that less than 10% of whiplash injured patients develop chronic ongoing pain. However, they estimated 40-70% of patients retain some degree of intermittent discomfort or "nuisance" symptoms which fluctuate from being distracting to occasionally intolerable. Given that at six months post-injury the person's condition is considered chronic and prognosis for further recovery is guarded (Teasell 1993), these types of injuries are cumulative in the population (Kay 1992).

According to some accounts, neuropsychological investigation can be used in the absence of other supporting medical documentation to detect subtle changes in cognitive functions following such injuries (Gentilini, Nichelli and Schoenhuber 1989; Stuss *et al.* 1985; Shapiro and Roth 1993; Anderson 1995). Neuropsychological findings can also be used to make recommendations regarding eventual return to employment or supported employment. These issues, which are becoming increasingly important from a medical-legal perspective, have also affected personal injury claims in Newfoundland. Claims incorporating neuropsychological evidence incur increased costs through such consultations. Higher compensation awards are typically offered when allegations of mild brain damage following whiplash is suggested (Taylor *et al.* 1996).

There is an ongoing need to investigate the contribution of neuropsychological and psychological factors in the etiology, maintenance and perpetuation of symptoms associated with whiplash.

1.4 Post Concussion Symptoms

1.4.1 Physical Sequelae

Chronic, recurrent post-traumatic headaches, the most commonly reported physical complaint following minor head trauma can have a major disruptive effect for prolonged periods in individuals who have otherwise recovered (Bennett 1988). The economic impact of chronic headaches is significant in prevention of return to work. The incidence of cervico-genic headaches in victims of cervical whiplash ranges from 50 to 87 % in the acute phase to 14 to 61 % in later stages (Radonov *et al.* 1992). Although the pathogenesis of these headaches remains imprecise, they are usually unilateral, localised to the occipitocervical region, and can last for hours. They may be associated with phono or photophobia, nausea, vomiting, irritability, vertigo, blurred vision, tearing and conjunctival redness as well as hypoesthesia in the posterior region of the scalp (Spitzer *et al.* 1995).

Irritation of the dura mater or the dural sac has been correlated with paravertebral spasm along multiple levels of the cervical spine with severe limitation of movement of the herniated disc. Sudden increase in pressure such as that elicited by coughing or effort may then trigger severe cervical pain. This has been proposed as the mechanism by which a C1 to C3 injury results in pain in the suboccipital and temporal regions as well as in the periauricular region (Spitzer *et al.* 1995).

For years patients who complained of head pain following mild head trauma were considered neurotics who either exaggerated or contrived their complaints for secondary gain. Though still incompletely understood it is becoming increasingly recognized that head pain is real and that early management is critical to prevent the establishment of chronic pain patterns (Larkin 1992).

Other primary physical complaints associated with both the post-concussion syndrome as well as whiplash injury involves visual and acoustic hyperaesthesia (Bohnen, Twijnstra, Wijnen and Jolles 1992; Bagby 1992), as well as dizziness, insomnia, fatigue and reduced tolerance to alcohol (Anderson 1995; Davidoff *et al.* 1988).

The multiplicity of symptoms associated with the postconcussion syndrome has lead to difficulty in conceptualization and quantification of complaints (Levin, High, Goethe, Sisson, Overall *et al* 1987). This is worsened by the interaction of the various symptoms involved. It is particularly apparent in patients who suffer pain over a prolonged period of time. Kewman, Vaishampayan, Zald and Han (1991) established that cognitive impairments in memory and attention can exist in patients who suffer musculoskeletal pain. Shapiro, Teasell and Steenhuis (1993) cite Kewman's research to support the view that cognitive complaints in whiplash patients is attributable to pain and does not reflect mild traumatic brain injury. However, Kewman and colleagues themselves speculated undiagnosed organic brain dysfunction as well as low education level to be two contributing, confounding variables to their finding of cognitive impairment in pain patients. They also suggested that these deficits, in combination with other factors including psychological distress to pain, adversely influenced cognitive status. Shapiro *et al.* (1993) contend that most clinicians who work with chronic pain patients have observed that complaints of cognitive difficulty, particularly in memory and concentration, are quite prevalent.

Although the attribution of cognitive deficits in whiplash patients to mild brain injury has been advanced by some researchers, others contend that cognitive complaints are prevalent in chronic pain patients (Shapiro, Teasell and Steenhuis 1993). It has been suggested that people who suffer pain are distracted by sensory pain input which interferes with cognitive functions such as memory. Although the possibility that chronic pain, in association with emotional disturbance, can have a negative impact on cognitive status cannot be denied, few empirical studies exist formally assessing neuropsychological functions in pain patients. The studies that are available fail to compare results to clinically meaningful norms or standards (Kewman *et al.* 1991).

Two studies that did assess the relationship between cognitive deficits in pain patients relied on brief screening tools or few tests which limited interpretation of results (Kewman *et al.* 1991; Schwartz *et al.* 1987). In Kewman's study, although 32% of the musculoskeletal pain patients were impaired on the cognitive screening tool they utilized, the correlation between pain and cognitive impairment was reduced to insignificant when psychological distress was accounted for. The authors suggest that although cognitive dysfunction is frequent in chronic pain patients, chi square analysis did not support a statistically significant correlation between these two factors. They recommend use of a more thorough comprehensive neuropsychological battery, including more standardized measures of emotional distress, to more clearly define the relationship of cognitive compromise in pain patients (Kewman *et al.* 1991).

Consistent findings were reported by Schwartz *et al.* (1987) who compared cognitive performance in chronic pain patients with and without a history of head /neck injury. Measures used in their study to assess cognitive functions included the Trail Making Test (TMT), the Paced Auditory Serial Addition Test (PASAT), as well as a measure of verbal fluency. No mean differences were found between the groups on any of these tests. However cognitive impairment ratings, based on the pattern of performance between the three tests, were highly significant when education was accounted for. The neck/head injured group was clearly more cognitively compromised compared with a predominantly low back pain population. Sixty-eight percent of the patients with a history of traumatic head or neck injury were impaired compared with only twenty-six percent of patients with chronic pain syndromes.

The relationship between pain severity and emotional response to it warrants further discussion. Kleinke (1991) hypothesised the interaction between chronic pain and depression may be mediated by such factors as appraisals of life interference due to physical discomfort as well as by perceived control of pain. It has been shown that convictions of no control and helplessness are more highly correlated with the perception of pain and disability than actual disease-related variables (Flor, Birbaumer and Turk 1990).

Closely related to perceived control is an individual's sense of self-efficacy. This refers to the conviction that one can successfully contend with a given situation and that situational demands will not exceed the ability to cope with them (Dolce 1987). Self-efficacy appears to play a significant role in the understanding of chronic pain. The higher the perceived sense of control, the lower the level of emotional arousal in stressful situations, all of which have been correlated with changes in heart rate, blood pressure and serum catecholamine levels (Dolce 1987).

Active coping strategies, wherein patients take responsibility for their own pain management, have been associated with lower levels of subjective reports of pain severity, reduced depression and less functional disability (Turner and Clancy 1986; Jensen, Turner, Romano and Karoly 1991). In contrast to active strategies, passive strategies such as reliance on the medical system or medication use, have been associated with increased pain severity, depression and functional disability. Pain, which occurs during activity may precipitate anxiety-related sympathetic activation with resultant increased muscle tension. Long periods of immobility will lead to muscular atrophy as well as a reduction in the ability of the muscles to restore and maintain stability (Flor *et al.* 1990). Pain patients often restrict their general activity level, including isolated body movements in the affected region, for fear of pain. This results in increased muscle tension with no stress release mechanism so that muscles remain constricted resulting in heightened physical discomfort.

Depressed chronic pain patients have been consistently found to be less active than non-depressed controls (Haythornwaite, Sieber and Kerns 1992). Reduced activity for fear of pain has a direct effect on endogenous opiate release which may contribute to a maintenance or perpetuation of both physical discomfort and depression. A two to fivefold increase in plasma concentrations of endorphins have been reported following such physical activity as running or swimming (Daniel, Martin and Carter 1992). Activity may therefore play a potentially powerful therapeutic role in chronic pain management. There is strong support for the proposal that physical activity induces endorphin-mediated mood changes tending away from tension, anger, fatigue and depression. The analgesic, behavioural and cardiovascular effects of exercise, mediated by endorphinergic mechanisms, favours a greater sense of well-being (Thoren *et al.* 1990).

Empirical research measuring cognitive functions is sparse in patients suffering mild head and neck injury and virtually nonexistent in other chronic pain populations. It is therefore impossible to determine the relationship or etiological significance between cognitive deficits and pain in whiplash patients given limited research in this area.

1.4.2 Cognitive Sequelae

Together with physical complaints the incidence of cognitive deficits in patients suffering post-concussion symptoms is high. Schwartz *et al.* (1987) suggested that most of these patients focus predominantly on their pain and themselves attribute emotional, behavioural and cognitive sequelae to secondary effects of pain. Despite this it has been speculated that vocational and social disruption may be a direct result of organically based cognitive deficits.

Stuss *et al.* (1983) suggested that mental deficits may persist in mild head injured patients even when the patient is otherwise considered to have made a good recovery. They characterized residual deficits, primarily in divided attention, as a "limitation of the damaged brain in information processing capacity, either in terms of speed of processing or in terms of the amount of information that can be handled simultaneously" (Stuss *et al.* 1985). Other cognitive deficits experienced involved memory processes especially following a timed delay.

In a later study various parameters of attention vulnerable to the detrimental effects of head injury, regardless of severity, including those deficits experienced by concussed patients were further clarified (Stuss, Stethem, Hugenholtz, Picton, Pivik and Richard 1989). They maintained that such patients exhibit a deficit in complex attentional functions including divided attention. This they defined as the slowed conscious control of information processing coupled with an inability to contend with multiple pieces of information rapidly and easily. Impaired focussed and sustained attention was also apparent and limited the patients' ability to meet task demands. This resulted in inconsistency in maintaining an optimal level of performance over time. Although not well investigated, the pathophysiology underlying these deficits has been postulated to reflect a disruption in frontal-limbic-reticular activating system-brainstem control of attentional processes (Stuss *et al.* 1985).

Without positive results using neuroimaging techniques documenting that concussion or mild traumatic brain injury has occurred, the value and sensitivity of neuropsychological evaluation has become recognized as providing clinical or functional evidence of organic brain dysfunction through disruption of cognitive functions (Guilmette and Matazow 1992). However the subtle nature of residual neuropsychological deficits necessitates that assessment procedures be sensitive enough to detect them. The need for psychometric testing within the context of a multidisciplinary assessment and treatment approach for whiplash patients was more recently advocated by a Quebec task force studying whiplash associated disorders (WAD) (Spitzer *et al.* 1995). Positive neuropsychological findings incorporated into research and clinical protocols can provide meaningful information on altered cognitive status. It can therefore help to determine the severity of the consequences of the injury. Results can also be used to facilitate return to previous vocational and lifestyle pursuits.

1.4.3 Emotional Sequelae

Affective consequences of post-concussion syndrome are common and include emotional lability and disinhibition (Davidoff *et al.* 1988) as well as anxiety, irritability and depression (Levine 1988; Anderson 1995). Some feel that the evolution of these symptoms is a reaction to physical and cognitive effects of the injury. O'Hara, (1988) suggested such factors as lack of information to the patient to explain symptoms;

overlooked evidence of minor head trauma; or unsuccessful, premature return to work resulting in a failure experience and reduced self-esteem all contribute to psychopathology. Such emotional reactions typically involve anxiety, irritability and depression.

Schoenhuber and Gentilini (1988) prospectively studied a group of mild head injured patients for neuropsychiatric complications. They found 77% of the patients studied showed an increased susceptibility to depression but they found no evidence of elevated state or trait anxiety using the Spielberger index (STAI). They attributed this latter finding to inadequate sensitivity in the STAI to differentiate the two aspects of anxiety. They strongly recommend screening for depression in all patients suffering mild traumatic brain injury given its high incidence.

The lack of correspondence between subjective complaints and severity of head injury and the persistence of symptoms, together with these emotional factors, has been used to support the contention that post concussion symptoms are primarily of psychological or motivational etiology. Indeed some clinicians conceive of post concussion symptoms solely as a manifestation of a post-traumatic stress disorder (PTSD) (Davidoff *et al.* 1988). However essential to the diagnosis of post-traumatic stress disorder is the existence of intrusive ideas, as well as feelings or dreams about the trauma. This is characterized by the persistent re-experiencing of the traumatic event (DSM IV 1994). These symptoms are not typically present in mild head injured patients (Binder 1986). Spitzer *et al.* (1995) corroborate that PTSD, which typically occurs following exposure to an unusually high-risk traumatic event causing temporary psychological destabilisation, does not hold true for whiplash patients. Orsillo and McCaffrey (1992) point out that symptoms in patients who experience even a brief period of post-traumatic amnesia (PTA) such as that which occurs following mild traumatic brain injury are more likely attributable to post-concussion symptoms, since the amnesia would preclude vivid recollection of the traumatic event critical to the diagnosis of PTSD. This argues against the anxiety theory accounting for all ongoing complaints following whiplash. However the importance of differential diagnosis between post-concussion symptoms and post-traumatic stress disorder given the considerable degree of overlap between somatic, cognitive and affective symptoms should not be minimized.

Despite the ubiquity of emotional disturbance in patients suffering post concussion symptoms and the attribution by proponents of the organic school of thought of cognitive deficits to structural brain damage, the pathogenesis of emotional consequences remains almost exclusively attributed to psychological factors which develop secondary to the actual physical injury. This attribution may be premature given the association of personality change following significant head injury (Prigatano 1992) to structural brain lesions (Mattson and Levin 1990; Stuss, Gow and Hetherington 1992). Speed (1993) further contends that there is considerable evidence to support the belief that mood changes following cervical strain or whiplash not only play a permanent role in the continuation of post-traumatic symptoms, but are directly related to the site of brain injury.

There is considerable overlap in emotional sequelae associated with post concussion syndrome with brain damage of various other etiologies including head injury, stroke, multiple sclerosis, or epilepsy (Roberts, Gorman, Lee, Hines, Richardson, Riggle 1992; and Varney, Hines, Bailey and Roberts 1992). Commonly reported emotional concomitants of brain damage involve irritability, agitation, anger, abrupt episodic dyscontrol, emotional lability, anxiety, aspontaneity, reduced initiative, easy fatigue and depression. (Prigatano 1992). These symptoms have typically been associated with fronto-temporal-limbic structures all of which are thought to modulate emotions. It seems not inconceivable therefore that emotional concomitants associated with post-concussion syndrome may be at least partially related to the site of cerebral damage and not solely reactionary to cognitive and physical change.

Derryberry *et al.* (1992) caution against analysing one functional system or brain structure in detail or of hypothesizing that a deficit in a specific region can explain a clinical disorder given the "formidably complex" interdependence of the proposed levels of processing involved in emotional representation. Nevertheless, knowledge on neural substrates of emotions continues to advance. The evolutionary circuitry underlying emotions is considered to extend from the brainstem to the limbic system and from paralimbic regions to cortical structures (Derryberry and Tucker 1992). The network represents a hierarchal distribution of neural systems with an integration of information from the multiple levels of input involved. Emotional expression is commonly ascribed to the limbic system primarily because of its involvement in somatic and autonomic activity

(Orsillo and McCaffrey 1992). Although definitive statements cannot be made on neural mediation of affective symptoms, some evidence exists which may be useful, when supplemented with cognitive and physical information, in further elucidating the etiology of post concussion symptoms following hyperextension injury to the neck.

Few studies have investigated the possible neurological substrates of generalized anxiety disorder (GAD). In view of the paucity of studies, a single unifying perspective on the neuropsychology of anxiety has not been postulated. However it has been hypothesized that patients with GAD experience a diminution of attentional capacity to external stimuli representing an information processing deficit. Further research in this area would contribute to a better understanding of underlying neural substrates and the possible mechanism of action of post concussion symptoms. This is especially noteworthy in view of the overlap of symptoms including impaired efficiency of information processing coupled with increased anxiety common to both anxiety and concussed patients.

In reviewing electrophysiological and neuroimaging results, Orsillo and McCaffrey (1992) found the consistent emergence of involvement of temporal lobe regions in the mediation of anxiety. The authors recommend that further electrophysiological and brain-imaging assessment should be augmented by neuropsychological assessment of memory processes to confirm the presence or absence of temporal lobe dysfunction in anxiety-disordered patients. They speculate that anxiety resulting from CNS damage may result from focal neurological disruption or may present as an anxiety disorder according to DSM IV classification. Thus, similar or adjacent neural pathways may underlie both cognitive deficits and affective dysfunction. Damage to regions involving brainstem and temporal lobe structures have been postulated to mediate both anxiety and PCS. This consistency supports the contention that some degree of affective dysfunction associated with post concussion syndrome may be structurally based.

Patients with whiplash injury have been shown to be more depressed and anxious than healthy controls (Lee *et al.* 1993). It has also been shown that depression and high pain ratings were greater in patients with a longer history of pain (Lee *et al.* 1993). These findings have led to the suggestion that psychological disturbances are a secondary reaction associated with pain in whiplash patients and are not a primary feature of the diagnosis. Further, the longer the disruption to normal routines, the greater the likelihood of developing psychological reactions. It has been recognised that the presence of anxio-depressive factors may influence the perception of a patient following whiplash injury and thereby perpetuate the emotional response to pain. This, in turn can exacerbate the painful experience itself (Spitzer *et al.* 1995).

The presence of cognitive deficits due to cerebral dysfunction in patients with a history of head or neck injury and who experience pain can cause and in turn be amplified by reactive psycho-social distress (Schwartz *et al.* 1987). Further, the stress associated with cognitive compromise may precipitate the development of a feedback loop causing increased muscle tension which can aggravate physical discomfort generated by muscular skeletal problems. Increased muscle tension, also critical to the diagnosis of anxiety may be erroneously attributed to psychological distress without due regard for etiological factors which may have contributed to its development.

Psychological sequelae including depression and anxiety, commonly reported in PCS patients following both whiplash and head injury, can have a potentially adverse effect on long-term outcome. That incidence rates of depression associated with traumatic brain injury vary greatly with ranges as wide as 10 to 77 percent (Rosenthal *et al.* 1998) recognises the impact in terms of the number of patients suffering psychological distress. Rosenthal *et al.* (1998) attributed some of the variability in these depression ratings to lack of control for severity of head injury in the populations studied as well as to different methods used to diagnose the severity of the depression. Before lingering deficits associated with PCS following either mild traumatic brain injury or whiplash are attributed to brain damage, the contribution of these factors, which can have a deleterious effect on cognitive functions, should be considered. Shapiro (1993) recommends that decrements in cognitive status should be greater than expected as a consequence of co-existing affective symptoms or pain.

Historically, depression and anxiety following head injury was thought to reflect a psychological reaction to the injury. Merskey (1993) suggested that concentration difficulties following mild traumatic brain injury may be due to the effects of depression. Fox, Lees-Haley, Earnest and Dolezal-Wood (1995) point out that many complaints associated with PCS are common to a variety of psychological and medical conditions.

They suggest that given the considerable degree of overlap between psychological symptoms associated with depression and anxiety and those experienced by patients with other neurological disorders such as forgetfulness and reduced concentration, it seems more logical to attribute cognitive deficits to a psychological reaction to the injury. In addition, it has been suggested that the development of psychological disturbance following acceleration injury is fostered by the medical system in feedback given to patients in the acute phase of illness. Early after injury, patients are often told their symptoms should resolve in three to six months. This message becomes counter-therapeutic for the select group of patients who do not recover as anticipated within this time-frame (Mersky 1993). When patients continue to have lingering symptoms, they begin to feel there is some reason for their lack of recovery and that they may be somehow to blame for not following recommendations. These concerns can precipitate psychological distress.

Neuropsychological deficits in clinically depressed patients typically cluster around three major areas of impairment. These include slowed psychomotor speed; attention and motivational functions including difficulty performing tasks requiring sustained effort and concentration; and learning and memory (Sweet and Westergaard 1997). Learning and memory deficits have been further characterised and include impaired intentional memory; difficulty learning new and unfamiliar types of associations; as well as difficulty with free recall. In contrast, incidental recall and recognition of information tends to be better preserved in depressed patients (Sweet and Westergaard 1997).

Findings of memory impairment in depressed patients, however, are certainly not conclusive as a number of studies have failed to find memory problems in clinically depressed patients (Newman and Sweet 1992). This may be attributed to the degree of depressive symptomatology present since some studies have found a correlation between severity of depression and neuropsychological test performance. Typically severely depressed psychiatric in-patients perform more poorly than mildly to moderately depressed out-patients (Newman and Sweet 1992). Clearly the impact on neuropsychological test performance in patients with a primary diagnosis of depression is not well understood and can lead to confusion when interpreting cognitive test results. Future research should attempt to more clearly delineate the influence of reactive depression as well as feelings of dysphoria in both neurological and pain patients on neuropsychological findings to discern the etiology of cognitive compromise experienced.

As with depression, the impact of anxiety on neuropsychological test performance is often far from clear. It has been accepted that patients who are highly anxious in general, as measured by high trait anxiety, are compromised on cognitive testing. Anxiety reduces the amount of available central executive capacity which, when directed to such activities as worry, leaves less capacity to focus attention on other cognitive processes (Shapiro *et al.* 1993). However in their review, Orsillo and McCaffrey (1992) suggest that anxiety does not significantly affect test performance, specifically in PTSD patients who are clearly not severely compromised on neuropsychological testing compared to normative data. These authors also emphasize that although approximately 25 % of traumatic brain injury survivors, regardless of severity, suffer from increased anxiety or tension, only 10 % display a level of anxiety or depression considered clinically significant. The distinction between the presence of anxiety symptoms that do not meet DSM-IV diagnostic criteria versus patients who do meet these criteria is, therefore critical (Orsillo and McCaffrey 1992).

Cognitively, similar to depression, new learning potential as well as concentration deficits have been associated with anxiety. In a review of lingering polysymptomatic complaints of mild traumatic brain injury, Putnam *et al.* (1996) emphasize that state anxiety has been associated with cognitive impairment affecting working memory capacity. They therefore attribute lingering deficits experienced following mild brain damage to secondary changes associated with anxiety.

More recently, however, neurological techniques have confirmed neuroanatomic and neurochemical correlates of both depression and anxiety following brain injury which has helped to dispel the attribution of psychological disturbance in PCS solely to secondary reaction to the injury. In his review, Rosenthal *et al.* (1998) cites evidence that head injured patients with major depression showed lesions of the left dorso-lateral frontal region and/or had lesions in the left basal ganglia. In fact they suggest that damage to the left basal ganglia may be critical to the development of depression.

Research investigating neurochemical correlates of depression have focussed on the biogenic amine system given its widespread distribution throughout the brain (Rosenthal *et al.* 1998). Specifically, noradrenergic and serotonergic projections from the brainstem enter the cortex via the frontal pole. Collateral projections are then sent throughout the neocortex. Given the propensity for damage to the frontal pole following acceleration injuries, it has been suggested that even a small lesion in this area could cause potential widespread disruption to cortical aminergic function. Despite these observations, Rosenthal *et al.* (1998) asserts that knowledge on the neurobiological correlates of depression following brain injury is limited and therefore few conclusions can be drawn.

As with depression, neuroanatomical theories have been advanced to account for anxiety-related symptoms which are most apparent in patients suffering chronic panic attacks. It has been proposed that a hierarchial progression of abnormal brainstem function may explain autonomic symptomatology typical of anxiety. That is, overactivation of specific brainstem nuclei involved in the control of respiration (nucleus solitarius), heart rate (nucleus ambiguus), bronchial constriction (nucleus ambiguus) and balance (vestibular nucleus) may occur. This activation, followed by overactivation of midbrain limbic structures including posterior hypothalamic nuclei, mesial temporal lobe, amygdala, hippocampus and orbital frontal lobes (Orsillo and McCaffrey 1992), may contribute affective coloration and thereby the maintenance of anxiety symptoms.

Rosenthal *et al.* (1998) caution that dichotomizing depression in terms of primary and secondary disorders may be "grossly oversimplified" since both forms of depression can occur concurrently. They propose that depression which occurs in the acute phase of head injury may be subserved by neurophysiological processes associated with the injury. In contrast, late onset depression is more likely attributable to psychological factors. Anxiety in patients suffering CNS trauma may also be due to focal neurological disruption, may reflect subclinical levels, or may present as a DSM-IV disorder (Orsillo and McCaffrey 1992). Therefore anxiety may also reflect actual structural damage, psychological response to trauma and residual cognitive and physical effects thereof, or a combination of both.

In addition to emotional changes associated with post concussion syndrome following whiplash or head injury, it has been argued that personality variables of long-standing origin influence whether or not patients suffer lingering symptoms. In their review article, Putnam *et al.* (1996) emphasise the existence of a common personality type in traumatic brain injured patients characterised by a negativistic pattern with passive-aggressive traits as measured by the Millon Behavioral Health Inventory. These authors cite several papers in which it has been argued that neuroticism is a stable, pervasive personality characteristic which is highly associated with self-report of physical symptoms. Youngjohn *et al.* (1995) also believe that personality traits influence the persistence of post concussion symptoms. In their study of 55 patients suffering ongoing complaints of PCS following mild traumatic brain injury, elevations were apparent on the somatisation index of the MMPI-2. They use this finding to support the hypothesis that persisting symptoms of PCS are likely functional in many patients and therefore not of organic etiology (Youngjohn *et al.* 1995). The idea that premorbid characterological factors contribute to the maintenance of PCS has not, however, been universally accepted (Robertson, Rath, Fournet, Zelhart and Estes 1994; Gimse, Bjorgen, Tjell, Tyssedal and Bo 1997). Putnam *et al.* (1996) do acknowledge that the role of personality variables has not been adequately addressed in clinical neuropsychological studies.

1.4.4 Symptom Interaction

One of the few attempts to examine the relationship between physical complaints including head and neck pain and cognitive dysfunction in whiplash patients was undertaken by a group of Swiss researchers (Radonov *et al.* 1992; 1993). They suggested that whiplash patients as a whole could be subdivided into two groups based on level of cervical injury. Patients who suffered injury to the upper spine complained of fatigue, dizziness, reduced concentration, and disturbed adaptation to light intensity. In addition to slowed rate of information processing, these patients exhibited impaired divided attention. These symptoms were classified as a "cervicoencephalic syndrome" (CES). Patients with lower cervical spine injury (LCSS) suffered predominantly cervical and cervicobrachial pain. They experienced no loss of consciousness at the time of trauma. Although cognitive testing using the Paced Auditory Serial Addition Test (PASAT) revealed impaired divided attention in patients suffering CES, this was not present in the

LCSS group. As with CES patients, LCSS patients were impaired with respect to speed of information processing.

Each group therefore demonstrated a unique symptom-complex involving cognitive deficits. Based on these findings, the authors recommended the classification of whiplash patients into more precise subgroups be vigorously tested using objective clinical data. To date, only limited positive findings using conventional radiographic diagnostic procedures are available to support this view (Gimse *et al.* 1997). In Radonov's 1992 study, only 20 of the 45 whiplash patients studied showed observable lesions of the cervical spine. Of these, 5 had damage in the upper cervical region while 15 sustained injury in the mid to lower cervical region. Fifty-six percent of the whiplash patients showed 'no objective evidence of pathology' (NOEP) on standard radiological or medical investigation.

In an attempt to differentiate the effects of pain on cognitive status, Schwartz *et al.* (1987) studied a group of chronic pain patients with and without a history of head or neck trauma sustained in rear-end motor vehicle collisions. They found a higher incidence of cognitive disturbance characterized by impaired sustained attention and reduced rapid problem-solving ability in the former group of patients. They emphasized several key points including the finding that the incidence and duration of subtle cognitive deficits in this population is greater than previously recognized. In addition cognitive deficits combined with pain results in more significant disruption in life functioning than would result from pain alone. Finally although deficits were subtle, they generated enormous difficulty in functioning especially in occupations involving time or performance pressure, presented unpredictable demands or required intact attention-switching capacity.

Wood, Novack and Long (1984) proposed that cognitive deficits, likely of neurogenic origin following concussion may result in the development of emotional problems which in turn may increase existing cognitive deficits in a cyclic fashion. They emphasised that post-concussion symptoms are most troublesome at times of increased environmental stress. The contribution of depression in interfering with optimal neuropsychological test performance has been documented (Fogel 1985). Effects of affective dysfunction are particularly relevant in terms of slowed rate of information processing and may therefore accentuate cognitive deficits of focal cerebral origin. Mild head injured patients experience increased difficulty whenever environmental demands exceed their cognitive capacity to effectively deal with the demand resulting in easy fatiguability. Stress reactions and mood disturbances thus generated can further compromise cognitive acuity causing a heightening and maintenance of both affective and cognitive symptoms through an interactive cycle (Bohnen and Jolles 1992).

The prevalence and etiology of anxiety and depression following mild traumatic brain injury, in addition to the lack of correlation between frequency and intensity of affective disturbance to severity of injury remains poorly understood. Prigatano (1992) emphasised that patients unable to cope with environmental demands they previously handled with ease are more susceptible to becoming overwhelmed emotionally. When confronted with limitations imposed by cognitive or physical deficits, enhanced sensitivity to distress occurs. This represents a reactionary state closely interconnected with underlying neuropsychological deficits.

Investigators in the field of mild traumatic brain injury have suggested that future research address the multiplicity of factors which may be involved in the perpetuation of ongoing symptomatology. Kay *et al.* (1992) recommend that the question of whether patients suffering trauma, depression, or pain have similar deficits experienced by mild traumatic brain injury patients be examined. Research looking at inter-correlations of these factors has not yet been undertaken. Lack of information regarding personality traits and coping styles further contributes to difficulty navigating through the quagmire of etiological factors in the long-term maintenance of post-concussion sequelae. Future research should attempt to unravel the interplay between organic and reactive or psychological factors which can interfere with an individuals ability to recover or compensate for ongoing symptoms toward the path of functional recovery. This requires an integration of neuropsychological, physical and emotional data.

1.5 Pathogenesis of Post Concussion Symptoms:

1.5.1 Neuropsychological Mechanism of Action

The etiopathology of affective symptoms of post concussive syndrome can gain insight from research in the area of epilepsy. In fact several lines of evidence suggest a neurobiological similarity between complex partial seizures and anxiety disorder (Nichell and Uhde 1991). Anxiety is often reported by epileptic patients and is thought to be the most common emotional component of partial seizures arising from the temporal lobe

(Nichell and Uhde 1991). It is likely that changes in limbic system function underlie many of the symptoms common to both anxiety patients suffering panic attacks and partial seizure patients. Nichell and Uhde cite research documenting the association between sclerotic or other hippocampal change and partial seizures in support of this contention (Sutula 1990).

In addition to anxiety, the incidence of depression is greater in epileptic patients than in other patient populations including other chronic illness groups. This increased risk was associated with a plethora of psychosocial factors concomitant with epilepsy (Mendez and Grau 1991). These include, among others, the unpredictable nature of epileptic attacks (Strauss and Wada 1991; Herman and Whitman 1992) and medication side effects. However depression may well represent an increased risk to developing psychopathology peculiar to epileptic patients and not other chronic illness groups based on neural susceptibility (Adamec 1990).

Patients who suffer minor closed head injury can exhibit underlying neuroelectrical abnormalities (Varney *et al.* 1992). Symptoms such as memory gaps, confusional spells or olfactory hallucinations in closed head injured patients commonly occur in association with theta burst activity. EEG abnormalities in these minor head injured patients correlate with similar findings in patients suffering multiple, partial seizure-like symptoms. Varney *et al.* (1992) emphasise that whether theta bursts represent underlying seizure activity or some other neurophysiological disturbance, they respond well clinically when treated with anti-convulsants. In a further study, Verduyn, Hilt, Roberts and Roberts (1992) differentiated between multiple partial seizure-like symptoms experienced by both minor head injured patients and clearly epileptic patients. They found that unlike patients with classic complex partial seizure disorders, the symptoms of head-injured patients did not occur in stereotyped sequences. In addition, in contrast with neuro-imaging and EEG findings which were essentially normal in mild head injured patients, results from neuropsychological investigation often revealed evidence of both static and episodic cognitive dysfunction. Specifically, the neuropsychological profile revealed that although intellectual capacity was not routinely depressed, excessive intra-subtest scatter was present on the eleven different measures comprising intellectual assessment using the Weschler Adult Intelligence Scale - Revised (WAIS-R). This was consistent with subjective complaints of cognitive impairment. In addition, mild to moderate memory disturbance, impaired attentional processes and evidence of frontal lobe involvement manifested by altered executive functions were typical following mild traumatic brain injury.

With respect to physical parameters, thirteen of the fifteen patients involved in the Verduyn *et al.* study endorsed moderate to severe headaches or cephalic pain which was the primary reason most patients sought medical consultation. Affective changes included chronic dysphoria and anxiety. They also exhibited abrupt temper outbursts characterized as grossly disproportionate to eliciting environmental stimuli.

Speculation that this constellation of changes in minor head injured patients is a manifestation of multiple, partial, seizure-like symptoms is a recently introduced notion which remains a theoretical debate. The absence of unequivocal EEG abnormalities using surface electrodes as well as the lack of stereotyped motor automatisms in mild head injured or concussed patients would argue against the possibility. However, it has been demonstrated that scalp electrodes are not as sensitive as intracerebral electrodes in detecting electrical activity in the depths of the brain. Roberts *et al.* (1992), among others, have shown that select patients with normal surface EEG recordings may suffer frequent abnormal electrical discharges in the limbic system. The sensitivity of implanted electrodes was necessary to detect these discharges. These changes correlated with cognitive disruption. Therefore subclinical electrophysiological disturbance is associated with neuropsychological dysfunction.

King Liu *et al.* (1984) provides an experimental model to explain how subclinical electrophysiological discharges can develop in humans suffering hyperextension/hyperflexion injuries to the neck. They suggest a broadened conceptualization viewing epilepsy along a biological continuum specific to etiological factors based on individual patients' case history. Berkovic, Andermann, Andermann and Gloor (1987) further supports the possible significance of subclinical seizures which can originate following head injury sustained in motor vehicle accidents. Sperling and O'Connor, (1990) studied the relevance of subclinical seizures with respect to prognostic significance. They found that seizures impaired cognition characterized by fluctuation in mental performance. In addition, it was speculated that subclinical seizures might produce permanent neuronal change and thus more long-lasting cognitive blunting. These neural changes may represent subtle electrophysiological brain dysregulation which produces clinically significant neurobehavioral correlates.

Eighty percent of the mild head injured patients in the Verduyn *et al.* study made at least moderate improvement of clinical symptoms when treated with anticonvulsants (Verduyn *et al.* 1992; Hayes, Lyeth and Jenkens 1989) . This supports the notion that post concussion symptoms may represent a variation of an epileptogenesis in some patients. This notion, together with the clinical significance associated with subclinical seizures, may represent a mechanism by which the persistence of symptoms associated with post-concussion syndrome represents underlying electrophysiological changes. These changes may be analogous in kind, though not necessarily in degree, to those observed in complex partial seizure patients.

The existence of a neurobehavioral syndrome called "epilepsy spectrum disorder" involving multiple cognitive, affective and psychosensory phenomena was further substantiated by Roberts *et al.* (1992). They defined the syndrome with multiple, partial seizure-like symptoms in the context of persistent dysphoria and emotional lability. To elucidate parameters of the syndrome, Roberts *et al.* (1992) studied a group of patients with a history of injury considered significant enough to produce cerebral damage or dysfunction. Patients included in the group endorsed at least seven of a possible thirty-five partial seizure-like symptoms. Affective symptoms reported included mood complaints such as chronic dysphoria, ego-dystonic temper outbursts or fear that they were "going crazy". Subjective cognitive disturbances included memory gaps or brief confusional spells. Physically, they complained of atypical headache or cephalic pain. The author compared these epilepsy spectrum disordered (ESD) patients with normal controls and complex partial seizure (CPS) patients.

Results revealed a significant degree of overlap in the qualitative aspect of symptom endorsement between the ESD and CPS groups. However quantitative differences, in which the ESD patients endorsed significantly more episodic phenomena than the CPS group, were found. These differences supported the contention that the two syndromes represent distinct clinical entities (Roberts *et al.* 1992). The typical ESD patient reported too many symptoms to be diagnosed as suffering a conventional simple partial or complex partial seizure disorder.

Despite experiencing a broader array of seizure-like symptoms, ESD patients produced a lower frequency of clearly epileptiform surface EEG abnormality than CPS patients. Some patients who suffer persistent post-concussive symptoms following mild traumatic brain injury or whiplash may represent patients in this ESD group.

1.5.2 The Kindling Model.

Limbic pathways are particularly vulnerable to activation with high-frequency trains of stimulation that evoke brief electrographic and behavioral seizures. These have many features of complex partial seizures. Repeated activation with trains of stimulation results in progressive behavioral and electrographic seizures. These eventually evolve into spontaneous seizures and a permanent epileptic state. This phenomena is referred to as the "kindling" response (Sutula *et al.* 1990; Goddard *et al.* 1969). Certain areas of the brain including the anterior and mesial temporal lobes are more susceptible to developing epileptic activity than other brain regions (Joseph 1990).

Roberts *et al.* (1992) explained the apparent inconsistency between electrophysiological characteristics of ESD patients and their subjective experience of multiple cognitive, affective and psychosensory phenomena on the basis of partial kindling. Verduyn *et al.* (1992) also invoked partial kindling as a putative mechanism by which electrophysiological dysfunction, without gross structural change, could ultimately culminate in a "functional" brain lesion.

Through animal research on partial kindling, Adamec (1990) proposed that this experimental model could account for the manifestation of affective or behavioral change independent of motor convulsive epileptogenesis. Adamec suggested that the scarring associated with post-traumatic epilepsy is an insufficient condition, in isolation for the development of a seizure disorder. Rather cerebral damage was considered to create a kindling stimulus. This can precipitate seizures because neural pathways from the damaged focal area have been permanently changed. Adamec postulated through kindling data obtained from cats, that limbic seizures produce changes in brain function that enhance anxiety. If clinical parallels can be drawn in humans, then limbic seizures may predispose these patients to emotional problems including anxiety. Moreover, it was suggested that these symptoms should be unrelated to generalized seizures.

Evidence was delineated to support the belief that anxiety and depression in epileptics involves limbic circuits. Involvement of limbic tissue during seizure episodes increases vulnerability to respond to psychological and environmental stress with elevations in anxiety and depression (Adamec 1990). The constellation of complaints reported by mild head injured or whiplash patients including persistent pain and cognitive slippage may represent an example of such a precipitating psychological or environmental stressor. Social and genetic factors as well as characterological traits might then interact with dysregulation of limbic function to produce psychopathology (Adamec 1990).

1.6 Purpose of the Study.

Post concussion syndrome following both whiplash and mild traumatic brain injury, often seen in clinical psychological settings, needs to be recognised for its complexity and poly-symptomatic nature (Szmanski and Linn 1992). Identification of factors which contribute to the maintenance and perpetuation of lingering symptoms would help to dispel the negative psychological or neurotic connotations that have become associated with post-concussion syndrome (Dikmen 1989). The relationship between neuropsychological deficits and other components of PCS common following both head injury and whiplash has been largely ignored. In fact, Radonov *et al.* (1992) asserts that only a few studies assessing cognitive functions following whiplash have been performed. Little research has attempted to empirically investigate and integrate the relationship between cognitive deficits, pain, and affective features or to relate these disturbances to possible physiological abnormalities. The predictive significance of pre-morbid personality traits in identifying high risk patients has also been under-investigated from an empirical perspective. Robertson *et al.* (1994) emphasises that future research should focus on establishing whether pre-morbid characterological traits are related to the persistence of symptoms beyond the expected time of recovery.

Kay *et al.* (1992) suggest that future research should address the question of whether patient groups suffering trauma, depression or pain show similar deficits with similar or differing patterns from mild head injured patients. Whiplash patients represent an excellent comparison group to address this question since both whiplash and mild traumatic brain injury have lead to the diagnosis of post concussion syndrome.

Dividing whiplash patients into three groups will help to establish whether there are different patterns of symptoms depending on presence and level of cervical injury. Previous classification into two different syndromes including CES and LCSS patients was based predominantly on subjective complaints (Radonov *et al.* 1992). Since originally proposed, little research has investigated the validity of this division. Further, since the majority of patients suffering chronic symptoms following whiplash show no evidence of structural damage, a third group of patients, the NOEP group, was proposed. It was felt that the emergence of different neuropsychological profiles in these groups would help to refute the notion that residual cognitive consequences were solely attributable to secondary effects of anxiety, depression, pain or personality factors. Clearly more concerted effort is needed to characterize whether symptoms unique to these syndromes exist. This will help to identify high-risk patients in order to initiate appropriate therapeutic or preventative strategies depending on the etiology of factors involved.

1.7 Research Objectives

The study was designed to empirically investigate cognitive, affective and physical consequences of whiplash injury and to compare them with sequelae of mild traumatic brain injury. Whiplash patients were divided into three groups based on presence and level of cervical injury as delineated by medical investigation. Patients who suffered injury to the upper cervical spine were classified as the cervicoencephalic syndrome group (CES); patients with injury to the lower cervical spine were classified as the lower cervical spine syndrome (LCSS) group; patients who suffered whiplash injury but with no objective evidence of same on medical investigation were referred to as the 'no objective evidence of pathology' (NOEP) group. The study sought to examine and substantiate the validity of this division, through empirical investigation of symptom groups, to contribute to differential diagnosis of whiplash patients.

Neuropsychological profiles were administered to all patients. Characterological profiles, emotional inventories as well as pain profiles were also obtained since it has been established that pain (Kewman 1991), depression and anxiety (Radonov 1992; Taylor 1996) can have a potentially confounding influence on cognitive performance (Shapiro *et al.* 1993). Evidence for traumatic brain injury in whiplash patients requires clear trauma-related neuropsychological deficits in excess to that expected as a consequence of coexisting pain and/or emotional distress (Shapiro *et al.* 1993). Neuropsychological measures from all of these groups were compared with published normative data based on age. Personality profiles, as well as anxiety and depression, were also compared with published normative values. Normative data is not available for pain inventories. Therefore groups were compared to each other only.

One comparison group used in the study comprised patients who suffered a documented mild traumatic brain injury through a direct blow to the head in a motor vehicle accident (MVA). This group was chosen to allow a comparison between patients with a known direct head injury to those with suspected cerebral dysfunction via an indirect brain injury caused through a whiplash mechanism.

1.7.1 Hypothesis I

It was hypothesized that the absence of a direct blow to the head following whiplash would, in general, be expected to result in fewer and less severe neuropsychological deficits than those exhibited following a direct blow to the head resulting in post-concussive symptoms (Sweeney 1992).

1.7.2 Hypothesis II

It was hypothesized that patients with upper cervical spine injury (CES) would show more significant cognitive deficits than patients in either the lower cervical spine injured group (LCSS) or than whiplash patients with no objective evidence of cervical pathology (NOEP). This was postulated based on proximity of cervical injury in CES patients to brainstem structures which are believed to underlie attentional functions.

1.7.3 Hypothesis III

It was hypothesized that whiplash patients in the NOEP group would show less cognitive compromise based on the absence of identifiable damage on medical investigation. This is based on the belief that these patients may have suffered a less severe whiplash injury than patients in either the CES or LCSS groups.

1.7.4 Hypothesis IV

It was hypothesized that neuropsychological deficits in both head injured and whiplash groups are independent of: levels of pain; coping styles in response to pain: as well as the presence of anxiety or depression. It is also hypothesized that patients who suffer persistent symptoms following either whiplash or mild traumatic brain injury do not exhibit a unique pattern of personality traits as measured by the Millon Clinical Multiaxial Personality Inventory (MCMI). Although some research suggests patients with persistent deficits following such injuries exhibit a unique characterological profile. others refute this notion (Shapiro and Roth 1993).

METHODS

2.1 Subjects.

Ninety patients were asked to allow some of the test scores obtained through the normal course of their Neuropsychological evaluations to be possibly used for research purposes. They were assured that should their results be used, they would remain totally anonymous and that their names would never be identified. These evaluations took place over the course of approximately 7.5 years. When it was agreed that these data could be used specifically to fulfill the thesis requirements of the author, a proposal was sent to the Memorial University Ethics Committee for Science. On their recommendation, consent forms were sent by mail to ninety patients. Of the patients contacted, fifty-four sent back forms providing written permission to use test results. Eleven letters were returned due to patients having moved and forwarding address could not be located. Twenty-two forms were not returned. Three patients returned forms asking that their results not be used in the study despite the fact that they had no difficulty providing verbal consent. Difficulties associated with obtaining written consent relative to verbal consent have been documented elsewhere (Brod and Feinbloom 1990). It is also likely that some of the non-respondents were not comfortable providing written consent despite the fact that they had verbally indicated they had no difficulty being involved in a research study.

Of the 54 patients included in the investigation, 44 suffered a severe hyperextension/hyperflexion injury to the cervical spine. The remaining ten suffered a direct blow to the head capable of producing cerebral damage or dysfunction. These patients were classified as the mild traumatic brain injured group (MTBI). Criterion for diagnosis of MTBI, as obtained from medical records, included loss of consciousness of approximately thirty minutes or less; initial Glasgow Coma Scale (GCS) rating of 13 to 15; and post-traumatic amnesia (PTA) not greater than 24 hours (Anderson 1995).

In consultation with an orthopaedic surgeon (the late Dr. A.E.Shapter), patients who suffered whiplash injury were divided into three groups on the basis of presence and level of cervical pathology. This was obtained from medical/orthopaedic reports including, among other investigations, results of X-rays, neuro-imaging procedures and SPECT scans where available. Therefore, inclusion of whiplash patients into groups was independent of neuropsychological as well as psychological test results.

The cervical spine is made up of two anatomically distinct parts. The upper cervical spine is made up of the Occiput, the first vertebrae (Atlas) and the second vertebrae (Axis). The mid and lower cervical spine is made up of C3 through C7 vertebrae which are similar in their anatomical structure (Spitzer *et al.* 1995). Using this division, whiplash patients were divided into separate groups. Ten patients sustained injury to the upper cervical spine (C0-C2) and were called the cervicoencephalic group (CES). Twenty-one patients suffered injury to the lower cervical spine (C3-C7) and were referred to as the lower cervical spine syndrome group (LCSS). Patients who showed negative results on medical investigations, yet who suffered a severe whiplash injury, were treated in a separate group. This group, which included a total of 13 patients, were classified as having no objective evidence of cervical pathology (NOEP). Neuropsychological assessment results were not used to assign these patients to groups.

All patients in the study incurred their injuries in motor vehicle accidents. All patients in the LCSS, CES and MTBI groups were symptomatic in excess of six months and were therefore deemed chronic according to time axis guidelines as delineated by the Quebec task force study for patients suffering whiplash associated disorder (Spitzer *et al.* 1995). All patients in the study, but one in the NOEP group also met criterion for chronicity. Spitzer *et al.* also consider that the presence of continued complaints and disability after 45 days is an important warning of incipient chronicity and justifies vigorous clinical intervention as well as mandatory interdisciplinary consultation. All patients in all four groups met this criteria.

All but one patient was in the process of litigation at the time of Neuropsychological referral. Patients were referred by local doctors and/or lawyers who represented either the plaintiff or defense. Patient selection is consistent with earlier studies which drew exclusively from patients involved in litigation following whiplash (Taylor *et al.* 1996) and head injury (Sherman *et al.* 1997). Litigation was therefore a constant factor in all four groups. The purpose of the referral was to test for the presence and severity of cognitive deficits consequent to injuries suffered as well as to provide information on pain-related symptoms and affective consequences of injuries.

Patients referred for Neuropsychological assessment were excluded from the study if they suffered previous significant psychiatric illness such as major depression, bipolar illness or schizophrenia or had a neurological history including such diagnosis as previous head injury, learning disability, attentional deficit disorder, or alcohol abuse. They were also excluded if they had previously undergone neuropsychological evaluation. The average age of all patients was 33.7 years. They were all Caucasian, residents of Newfoundland, Canada, and spoke English as their maternal language.

2.2 Procedures.

Patients were contacted by telephone and scheduled for their assessment. They were asked not to take any over-the-counter medication or that prescribed on an as needed basis the day before their appointment if they felt it would affect their performance due to drowsiness.

All subjects underwent a standardized initial interview in order to establish their subjective account of the consequences and implications of their injuries. They then underwent an extensive, comprehensive neuropsychological evaluation which was administered over the course of either a full morning or two half day sessions depending on their stamina and speed in working through the battery. The total duration of the evaluation including self-evaluation inventories which were completed at home was approximately five to seven hours. All assessments were administered and scored by the author.

The reason for the neuropsychological referral as well as a brief description of the assessment was discussed with each patient by the referring agent. Referrals were only sent on patients who agreed to be assessed. A more thorough explanation of the nature of individual tests as well as the rationale for the assessment was discussed with every patient prior to starting the procedure as well as during the battery to introduce the various measures. Patients were encouraged to ask questions regarding the rationale for the different procedures as desired.

Following the assessment, patients were provided with an interpretive clinical account of their test scores once their results were reviewed. They were either provided with, or told they could obtain, a written copy of their test results as well as their clinical report from either the referring agent or the primary author. They were encouraged to telephone for further information or to seek clarification or simplification of their report if they so desired.

A copy of the written report on individual patients was sent to the referring physician when one existed as well as to the individual's lawyer who requisitioned the assessment. Confidentiality of test results was strictly enforced. This was explained to all patients. Patients were numerically coded, with no personal identifying information used, in order to ensure total confidentiality. Ethical guidelines as adopted by the Canadian Psychological Association (CPA) and the Newfoundland Board of Examiners in Psychology (NBEP) governing clinical psychological practise were strictly maintained. Deception was not a part of this study.

2.3 Neuropsychological Assessment.

The utility of a neuropsychological profile in which a set of scores is derived to show a unique pattern of cognitive functions associated with a specific clinical diagnosis was documented (Knights and Stoddart 1981). The importance of not relying solely on level of performance but also on patterns of abilities and deficits relative to estimated pre-morbid status is essential to accurate diagnosis based on neuropsychological findings. The oftentimes subtle, confusing and difficult to quantify nature of cognitive impairment following minimal brain dysfunction or whiplash injury makes assessment and interpretation of results more challenging. The profile approach to neuropsychological assessment was advocated especially in such cases due to its greater sensitivity over other assessment methods. This requires administration of various neuropsychological tests measuring diverse cognitive functions.

2.3.1 Wechsler Adult Intelligence Scale-Revised (WAIS-R).

The value of a neuropsychological evaluation, the sensitivity of which can yield positive findings when neuro-imaging tests and neurological exams are negative, has been established (Guilmette and Matazon 1992). A comprehensive neuropsychological battery includes an estimation of intellectual capacity using the Wechsler Adult Intelligence Scale Revised (WAIS-R). This test provides a general estimate of current cognitive capacity as well as information on differential functioning of verbal versus visual/spatial and constructional problem-solving skills. Variability among the eleven different subtests that make up the WAIS-R correlate with lateralized cerebral dysfunction asymmetric to either the right or left hemispheres.

Diagnoses including mild traumatic brain injury as well as whiplash injury are not typically associated with a significant diminution in intellectual capacity. For these diagnoses, FSIQ can be used to estimate pre-morbid level of functioning. In contrast, FSIQ would be a less appropriate estimate of pre-morbid status for diagnoses such as severe head trauma or the dementias given that intellectual potential is typically globally compromised in these patients.

General information and vocabulary subtests of the WAIS-R are considered highly resistant to the effects of cerebral insult and are often used, in isolation, to estimate pre-morbid functioning. Both the vocabulary and information subtests are more highly correlated with academic achievement than either of the other nine subtests comprising the FSIQ (Lezak 1995). However these two subtests are not the best estimates of pre-morbid status given potential cultural/educational variation in the Newfoundland population studied. That is, completing high school, particularly in more remote Newfoundland communities, has only gained greater importance over the past number of years. In addition, education standards may vary rural communities. Consequently these two subtests tend to underestimate intellectual potential, particularly in older adults from remote areas. In contrast, Newfoundlanders often perform as well or better on the comprehension subtest of the WAIS-R relative to vocabulary or information. This subtest examines the understanding of social rules and solutions to everyday problems. For these reasons the FSIQ, representing a composite of all subtests administered, was considered a better estimate of pre-morbid cognitive status for the population studied. The subtle influence of cultural variation also holds true for French Canadians wherein translations of the WAIS-R have adjusted the order of item administration, particularly on the vocabulary subtest, to adjust for this factor.

When coupled with years of education, FSIQ provides a more rigorous approximation of pre-morbid level of functioning. These measures were preferentially used in the present study to approximate pre-injury level of functioning and to ensure homogeneity between groups. These measures were chosen instead of using specific WAIS-R subtest scores, in order to eliminate potential cultural bias.

2.3.2 Wechsler Memory Scale-Revised (WMS-R).

The Wechsler Memory Scale - Revised (WMS-R), expanded in 1987, is the most widely accepted measure of learning and memory. This test yields composite indices including verbal and visual memory quotients, general memory quotient, attention and concentration quotient as well as a delayed recall quotient. As with the WAIS-R, each index on the WMS-R has a mean of 100 and a standard deviation of 15. Comparisons between the various indices on both the WAIS-R and the WMS-R are easily applied (Spreen and Strauss 1991).

2.3.3 Wisconsin Card Sorting Test (WCST).

Executive functions including planning, organization and goal-directed behaviours are assessed using a variety of tests. Common among them is the Wisconsin Card Sorting Test (WCST). This test measures the ability to establish a response strategy based on abstract concepts of color, form, and number. It also assesses the ability to monitor, maintain and switch mental set based on changing environmental or task demands (Lezak

1993). It provides information on the existence of "stuck-in-set" perseveration which is typically associated with dysfunction of the frontal lobe system, particularly in the mesolimbic region. A perseverative tendency is an inability to incorporate changing environmental demands, to adopt a new framework, or response strategy due to inadvertent elicitation of a previously correct strategy.

2.3.4 Verbal Fluency (FAS).

The ability to formulate, organize and initiate a verbal response is also associated with frontal functions asymetric to the left hemisphere. These are assessed using measures of verbal fluency. The timed nature of this task provides further information on speed of cognitive processing (Joseph 1991).

2.3.5 Complex Attentional Functions.

A battery of tests related to efficiency of information processing was administered. This battery is considered more sensitive to mild cerebral dysfunction relative to other neuropsychological measures . It is therefore well suited to detecting the subtle nature of deficits associated with post-concussional symptoms following either mild direct head injury or following hyperextension/hyperflexion injury to the neck. The battery includes several tests including the Paced Auditory Serial Addition Test (PASAT), Brown-Peterson Consonant Trigrams (CCC) and the Trail Making Test (TMT). Normative data for these three tests of attention and rapid information processing are published (Stuss, Stethem and Poirier 1987; Stuss, Stethem and Pelchat 1988; Spreen and Strauss 1991).

2.3.5.1 Paced Auditory Serial Addition Test (PASAT).

The PASAT, devised by Gronwall and colleagues (Gronwall 1977; 1991) provides an estimate of rate of information processing as well as sustained attention over time. The test is comprised of a pre-recorded tape which delivers a random series of sixty-one numbers from one through nine. The patient is required to add pairs of numbers such that each number is added to the one immediately preceding it. The second is added to the first and so on. Although the same string of numbers is presented on four separate trials, each differing in the rate of presentation, only the first three trials were used in the present study. The intervals of presentation vary from 2.4 seconds, to 2.0 seconds, and 1.6 seconds. This increases processing demands by increasing the speed of stimulus input. The sensitivity of the PASAT in detecting deficits in sustained attention and speed of information processing in patients suffering injury to the cervical spine (Radanov *et al.* 1992) as well as suffering mild traumatic brain injury (Schwartz *et al.* 1987) is established.

2.3.5.2 Brown-Peterson Consonant Trigrams (CCC).

In addition to the PASAT, the Brown-Peterson test of memory under interference (Consonant Trigram Test - CCC) correlated significantly with subtle neuropsychological deficits in head injured patients (Stuss *et al.* 1985). This test involves recall of three consonants after varying durations of counting backward aloud by three. The duration of the interpolated counting task varies from 0, 3, 9, and 18 second intervals. The test detects a tendency toward increased susceptibility to distraction resulting in difficulty maintaining consistent and directed attention (Stuss *et al.* 1985). It is commonly used to provide information on divided attention and efficiency in information processing. The CCC is among the most widely used and sensitive measures assessing the effects of brain injury in adults (Paniak *et al.* 1997). Age, level of education, and gender are not significantly related to CCC scores (Stuss *et al.* 1987; Paniak *et al.* 1997). Only the 9 and 18 second recall trial were used in this study.

2.3.5.3 Trail Making Test (TMT).

Finally, the Trail Making Test (TMT) is comprised of two separate parts and is a component of the Halstead - Reitan neuropsychological battery. It simply requires that a line be drawn to connect twenty-five encircled numbers randomly arranged on a standardized page on Part A of the test and of twenty-five encircled numbers and letters in alternating sequence on Part B. The number of seconds required to connect the stimuli is considered to provide an estimate of both cognitive and psychomotor response speed (Spreen and Strauss 1991). Part B requires dual information processing involving the ability to deal with more than one piece of information, aspect of a task or train of thought simultaneously.

Together, the tests that make up the battery to assess efficiency of information processing are most sensitive for revealing cognitive deficits associated with mild traumatic brain injury and acceleration injury to the neck (Gronwell 1991). They involve the greatest number of cortical and subcortical areas simultaneously (Gentilini *et al.* 1989). This feature is particularly evident on attentional tasks based on processing speed.

2.4 Personality Assessment.

2.4.1 Millon Clinical Multiaxial Inventory (MCMI).

The Millon Clinical Multiaxial Inventory (MCMI) is a valuable tool in personality assessment of patients suffering psychological problems. It is a self-report inventory to which patients respond either true or false on 175 items. It is comprised of twenty clinical scales. Eleven of these correspond to personality types associated with Axis 11 of the Diagnostic and Statistical Manual of Mental Disorders Revised (DSM-IV) and nine scales reflect more prevalent clinical syndromes corresponding to Axis 1 symptoms. It thus distinguishes between more enduring characterological traits (Axis 11) and acute clinical disorders (Axis 1) that are more transient and circumscribed by fluctuating situational events. It offers the advantage of ascertaining the presence of clinical syndromes in perspective of a persons personality pattern. Thus it offers information on the simultaneous differentiation and inter-relationship between clinical symptoms that wax and wane in severity over time and represent more acute forms of psychopathology versus more pervasive characteristics that underlie and provide a foundation or context for understanding these reactions (Millon 1981).

Eight basic personality scales of mild severity, measured by the MCMI, are designed to assess the following characterological traits (Millon 1982):

Scale 1. Schizoid-Asocial

Scale 2. Avoidant

Scale 3. Dependent (Submissive)

Scale 4. Histrionic (Gregarious)

Scale 5. Narcissistic

Scale 6. Antisocial (Aggressive)

Scale 7. Compulsive (Conforming)

Scale 8. Passive-Aggressive (Negativistic)

The MCMI can be used with a reasonable level of confidence in most clinical settings for patients with disorders that are primarily emotional. However it is not a general personality instrument to be used for "normal" populations or for purposes other than diagnostic screening or clinical assessment. Transformation scores of the MCMI are based entirely on clinical samples. MCMI raw scores are transformed into base-rate scores according to administration guidelines and based on known personality and syndrome prevalence data. Cutting lines were designed to maximize diagnostic accuracy in terms of optimal valid-positive to false-positive ratios. Base-rate scores on any of the MCMI scales have to reach a 74 point cutoff which corresponds to the "presence" of a personality symptom or feature. Base-rate scores of 84 were established for all scales as the cutting line above which scale percentages correspond to the most salient personality or symptom syndrome (Millon 1982).

2.4.2 Beck Depression Inventory (BDI).

The Beck Depression Inventory (BDI) is a self-administered questionnaire consisting of 21 items, for each of which the patient endorses a series of statements, rank-ordered by severity. Each is scored from zero for endorsement of a neutral statement to three for most severe. The items of the BDI, originally drawn from clinical interviews with depressed patients, provides a measure of severity of depression. It has been used to measure mood in chronic pain patients and patients with other physical illnesses (Williams and Richardson 1993).

2.4.3 Spielberger State-Trait Anxiety Inventory (STAI).

The Spielberger State-Trait Anxiety Inventory (STAI) is a self-evaluation questionnaire designed to measure symptoms associated with anxiety. Trait anxiety is considered to reflect an individuals general level of anxiety which is considered fairly stable in contrast to state anxiety which tends to be more circumscribed by present stressors including the conditions under which the test is administered (Spielberger 1983). The test requires that the respondent mark one of four numbers on the standard test form to the right of each item that best describes the intensity and frequency of their feelings. The responses range from (1) not at all; to (4) almost always or very much so. Scores for both state and trait anxiety were calculated as outlined in the Spielberger manual (1983). Results were then compared with published normative data based on age (Spielberger 1983).

2.5 Assessment of Pain.

2.5.1 West Haven Yale Multidimensional Pain Inventory (WHYMPI).

The West Haven-Yale Multidimensional Pain Inventory (WHYMPI) is a self-evaluation questionnaire which assesses various aspects of physical discomfort. These scales include, among others: pain intensity; the degree of interference pain has caused in various aspects of the person's life; the amount of control an individual perceives themselves to have over their pain; as well as their general activity level despite pain. It is a 52-item inventory divided into three parts each of which is further divided into several subscales. Clinical assets of the inventory include its brevity, its clarity as well as its multidimensional focus. It is theoretically associated with the cognitive-behavioural approach to pain (Kerns, Turk and Rudy 1985).

2.6 Statistical Analyses.

Analysis of variance was used to test the significance of difference between the four patient groups. Significant overall differences on a test were followed by multiple comparison procedures to establish which groups differed. Duncan's multiple range test was used in order to control for type I comparison-wise error rate.

Comparisons were also made between the means of each group and that of the normative population for neuropsychological and psychological measures. Normative means and variance were available so t-tests were used. Although directionality was predicted in most cases, two-tail t-tests were employed to maintain a consistent approach for all comparisons of group and normative means. In addition, the alpha level was adjusted to .0125 for all t-tests according to the Bonferroni procedure given that four t-tests were computed for each individual psychological measure employed. This more conservative approach was taken because of the small sample size of our study groups together with the number of comparisons being made.

Chi-square was used to test the significance between groups with respect to the number of patients per group who were able to complete the PASAT.

Finally, multiple regression analysis was used to determine the contribution of physical and psychological variables on delayed memory, attention/concentration and speed of information processing.

2.7 Use of Normative Data.

The practice of applied neuropsychology is based on the comparison of patient test scores to normative data of non-psychiatric, non-neurologic populations (Stuss *et al.* 1988). Published normative data available for each of the neuropsychological measures administered in the present study were compared to group scores in order to determine if cognitive performance differed in patient groups relative to a "normal" population. Provision of an adequate range of normative data across different age groups is critical for accurate interpretation of patient results. Normative data utilized for comparison in this study were chosen based on the age of the patient groups. Appendix A depicts a list of the number of patients in each of the normative samples used per representative age group: means; standard deviations; and references from which the normative data were cited. All of the normative data chosen for comparative purposes in this study are currently commonly used in clinical practice and are comprehensive in terms of the appropriate age groups assessed.

The number of subjects per relevant age group in the normative studies varied across the different tests used and was highest in the Wechsler Adult Intelligence Scale-

Revised (WAIS-R) (Appendix A). Although this served to inflate the degrees of freedom on some t-tests. it was felt that pooling variances and degrees of freedom from a larger number of normative subjects on any given neuropsychological measure provided a better estimate of the population variance.

RESULTS

3.1 Demographics.

Summary information is presented in Table 1 showing the distribution of age and gender, as well as level of education for each of the four patient groups. No differences were found between the groups with regard to the number of months from time of injury to time of neuropsychological evaluation [$F(3,48)=.85$, $p=.47$]. No differences were found between the four patient groups with respect to age at time of evaluation [$F(3,50)=1.85$, $p=.15$]. There was no significant difference between groups with respect to mean years of education [$F(3,44)=.99$, $p=.40$].

At the time of the neuropsychological evaluation, 59.2% of the population studied had returned to their previous occupation or were enrolled in a school program: 33.3% were not employed; and 1 % had retired. The employment status of the remaining 5% of the population could not be ascertained.

Five of the fifty-four patients (9.2%) reported routine use of medication including analgesics such as Atasol 30's, for pain relief or muscle relaxants; 46.2% reported occasional use; 44.4% reported they were no longer using any medication. See Appendix B for frequency of distribution use per group.

3.2 Neuropsychological Findings

Results on neuropsychological tests were compared between groups. These measures were also compared to published normative data to establish whether deficits

Table 1. Patient Demographics

		NOEP	LCSS	CES	MTBI
Age	Mean*	32.2	37.4	38.3	28.8
	Std. Dev.	12.4	10.1	10.3	13.8
Injury-Eval	Mean*	23	31.3	32.1	37.9
	Std. Dev.	17.1	19	21.8	34.8
Gender		6 F: 7 M	12 F: 9 M	10 F: 0 M	6 F: 4 M
Education (Years)	Mean*	14.58	12.94	13.78	13.11

Injury-Eval: Time (months) from Injury to Neurospychological Evaluation
* Differences between groups were not significant.

emerged on the various cognitive functions assessed. Summary of means and standard deviations for all neuropsychological tests are presented in Appendix C.

3.2.1 Wechsler Adult Intelligence Scale-Revised (WAIS-R)

Full Scale Intelligence Quotient (FSIQ).

The four patient groups did not differ with respect to Full Scale IQ (FSIQ) [$F(3,50)=1.25$, $p=0.29$]. Unpaired two-tail t-tests comparing the mean FSIQ in each of the four patient groups to the mean of the standardized normative sample in which 100 is the average FSIQ and 15 is the standard deviation were calculated (Wechsler 1981; Winer, Brown and Michels 1991).

As is shown in Figure 1 and Table 2, both the NOEP and LCSS groups had slightly higher average FSIQ scores than the norm mean of 100 (Table 2). In contrast, the CES and MTBI groups were not significantly different from the normative value. The average FSIQ in all groups was within the normal range (90-109) according to Wechsler interpretation guidelines (Wechsler 1981).

The mean of 100 and standard deviation of 15 on the various indices of the WAIS-R including the FSIQ as well as on the WMS-R including the GMQ, DMQ, and the Att/ConQ allows for comparisons between the two tests (Wechsler 1981; 1987). This provides valuable clinical information when making comparisons across test scores in a specific individual or group. It is the constellation of such scores, emphasizing relative strengths and weaknesses, which are clinically meaningful in interpreting neuropsychological test results.

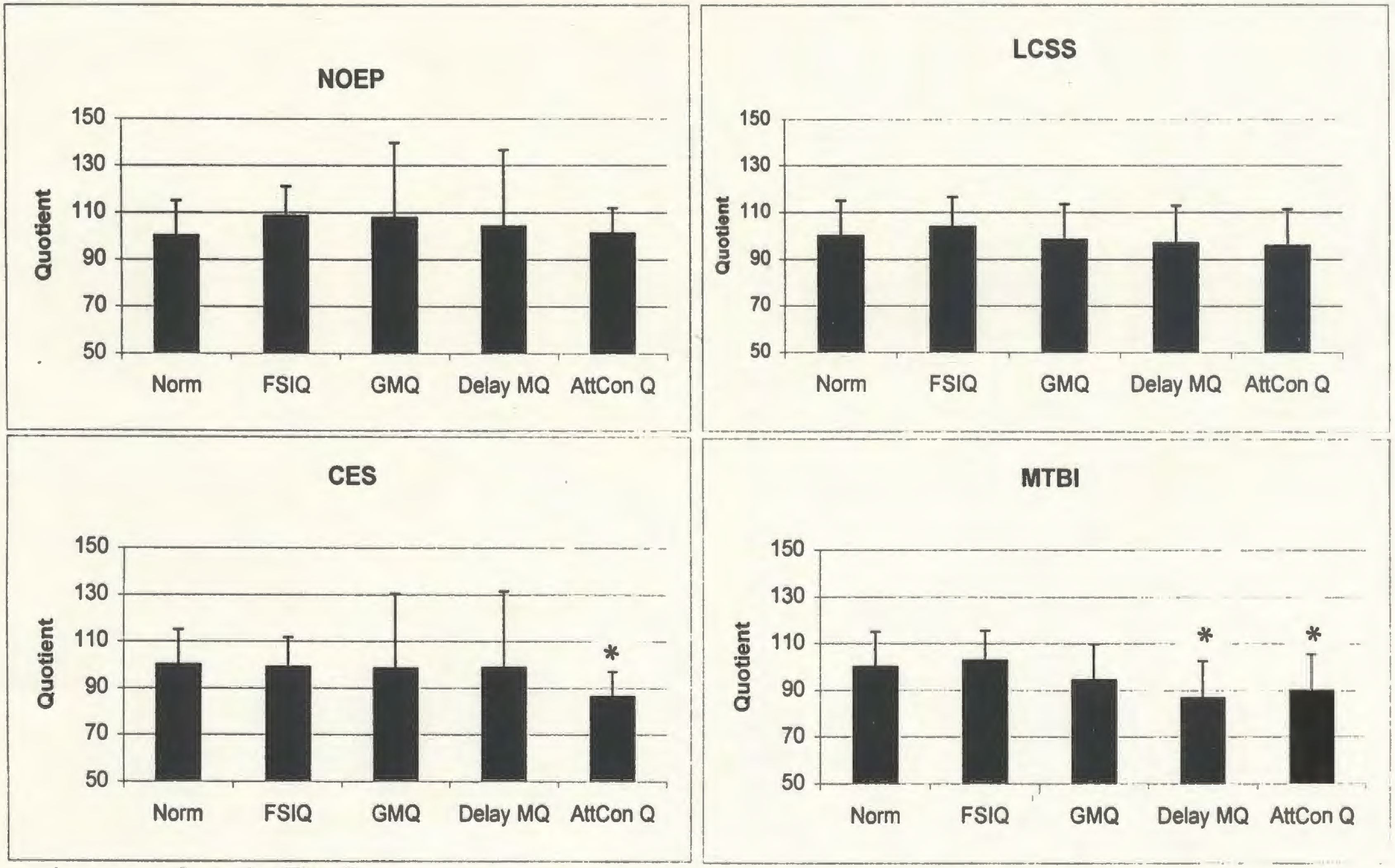

Figure 1. Comparisons between normative values and average FSIQ of the WAIS-R, GMQ, DMQ and ATT/CON Q of the WMS-R.

* Significant differences between groups on the WAIS-R (FSIQ) and WMS-R (GMQ, DMQ, and ATT/CON Q) compared to normative values (Normative mean = 100; s.d = 15).

Table 2. T-Tests Comparing Full Scale IQ (FSIQ) per Group to Normative Mean. (Normative Mean = 100; Standard Deviation = 15; Wechsler Adult Intelligence Scale-Revised Manual 1981).

Group	FSIQ	t value	df	p	Significance
NOEP	108.3	6.77	261	0	sig
CES	99	0.77	258	p>.05	ns
LCSS	103.8	3.4	269	0	sig
MTBI	102.8	2.15	258	0.03	ns

3.2.2 Wechsler Memory Scale-Revised (WMS-R)

Comparisons between General Memory Quotient (GMQ), Delayed Memory Quotient (DMQ) and Attention-Concentration Quotient (Attn Q) to Norm.

General Memory Quotient (GMQ).

Groups did not differ from each other with respect to the GMQ [$F(3,49)=1.82$, $p=.15$]. Group means for the GMQ were then compared to the standardized sample mean (Table 3; Figure 1). Since memory deficits are commonly reported following both mild traumatic brain injury (Bohnen and Jolles 1992) and whiplash injury (Gimse *et al.* 1997), for which patients are referred for neuropsychological evaluation, it was predicted that the GMQ would be significantly lower than the normative population in all patient groups. Despite this, two-tailed t-tests comparing sample means were used as a more conservative statistical approach to test this prediction given the relatively small number of patients per group coupled with the number of comparisons made.

The GMQ was not significantly reduced relative to the normative mean in either the MTBI, CES or LCSS groups (Wechsler 1987). In contrast, the average GMQ in the NOEP group was slightly higher than the normative mean of 100 although it remained within the normal range of 90 to 109 according to Wechsler interpretation guidelines. (Weschler 1987) (Table 3).

Table 3. T-Tests Comparing General Memory Quotient (GMQ) per Group to Normative Mean. (Normative Mean = 100; Standard Deviation = 15; Wechsler Memory Scale-Revised Manual 1987).

Group	GMQ	t value	df	p	Significance
NOEP	107.6	3.6	65	0	sig
CES	98.4	0.73	62	p>.05	ns
LCSS	98.3	0.82	73	p>.05	ns
MTBI	94.5	2.4	62	0.02	ns

Delay Memory Quotient (DMQ).

The four patient groups did not differ with respect to DMQ [F(3.49)=1.88, p=.14]. Two-tailed t-tests were used as a conservative approach to test the prediction that the DMQ would be significantly lower than the normative sample in all patient groups (Wechsler 1987). Only one group differed from the norm in the expected direction (Table 4 ; Figure 1). As predicted. MTBI patients did show a significant reduction in the DMQ compared to the norm [t(62)=5.61, p<.001].

Attention/Concentration Quotient (Att/ConQ).

Similar statistics, carried out on the Att/ConQ of the WMS-R revealed no difference between the four patient groups [F(3.50)=2.08, p=.11 ns].

Subsequent comparisons tested the prediction that Att/ConQ would be lower than the norm in both the head injury (Stuss *et al.* 1983;1989) and whiplash groups (Radanov *et al.* 1992;1993). Two-tailed t-tests revealed significantly reduced Att/ConQ in the CES and MTBI groups (Table 5; Figure 1). On average, the CES group had the lowest Attn/ConQ. The Attn/ConQ of the NOEP and LCSS groups did not differ from the normative population (Wechsler 1987) (Table 5) and was highest in the NOEP group.

3.2.3 Brown-Peterson Auditory Consonant Trigrams (CCC)

3.2.3.1 9-Second Delay Recall Trial.

The four patient groups did not differ on the 9-second delay recall trial of the CCC [F(3,50)=2.14, p=.106]. It was predicted that all patient groups would have

Table 4. T-Tests Comparing Delayed Memory Quotient (DMQ) per Group to Normative Means. (Normative Mean = 100; Standard Deviation = 15; Wechsler Memory Scale-Revised Manual 1987).

Group	DMQ	t value	df	p	Significance
NOEP	104.1	1.9	65	0.06	ns
CES	98.9	0.47	62	p>.05	ns
LCSS	96.9	1.45	73	0.148	ns
MTBI	86.7	5.61	62	0	sig

Table 5 . T-Tests Comparing Attention/Concentration Quotient (Att/Con) per Group to Normative Means. (Normative Mean = 100: Standard Deviation = 15: Wechsler Memory Scale-Revised Manual 1987).

Group	Att/Con	t value	df	p	Significance
NOEP	101.1	0.57	65	p>.05	ns
CES	86.4	6.03	62	0	sig
LCSS	95.8	1.95	73	0.05	ns
MTBI	89.9	4.4	62	0	sig

difficulty on the CCC relative to a normative population (Stuss *et al.* 1987). This prediction is based on the finding that both whiplash injury and mild traumatic brain injury can diminish information processing capacity (Gentilini *et al.* 1989; Paniak 1997). However, neither the NOEP nor the LCSS groups differed from the norm. Average scores in both the CES and MTBI groups were significantly lower than the normative value when compared using unpaired, two-tailed t-tests with alpha adjusted according to the Bonferroni procedure (Table 6a; Figure 2). Both of these groups therefore had significant difficulty recalling the consonant trigrams after performing an interpolated subtraction task for nine seconds. That is, the CES and the MTBI groups remembered less with 56% and 55% of the information recalled respectively. In contrast, patients in the NOEP and LCSS were able to remember 73% and 63% of the consonants respectively following a delay.

3.2.3.2 18-Second Delay Recall Trial.

A significant difference was found between the groups on the 18- second delay recall trial of the CCC [$F(3,50)=3.12$, $p=.034$]. Duncan's Multiple Range Test revealed the MTBI and CES groups remembered significantly less information following an 18 second interpolated task than the NOEP group (Duncan Test, $p<.05$). The NOEP group had the best performance (Duncan Test, $p<.05$).

Table 6a. Consonant Trigrams. T-Tests Comparing Sample Means to Mean of Normative Population for Number of Consonants Recalled Out of Fifteen After a 9 Second Interpolated Task. (Normative Mean = 12.8; Standard Deviation = 1.8; Stuss *et al.* 1987).

Group	CCC	t value	df	p	Significance
NOEP	10.9	1.65	21	0.12	ns
CES	8.4	3.97	18	0	sig
LCSS	9.52	3.17	29	0.02	ns
MTBI	8.2	3.82	18	0	sig

Table 6b. Consonant Trigrams. T-Tests Comparing Sample Means to Mean of Normative Population for Number of Consonants Recalled Out of Fifteen After an 18 Second Interpolated Task. (Normative Mean = 12.2; Standard Deviation = 3.0; Stuss *et al.* 1987).

Group	CCC	t value	df	p	Significance
NOEP	9.08	2.56	21	0.02	ns
CES	6.3	5.11	18	0	sig
LCSS	7.09	4.38	29	0	sig
MTBI	4.8	5.49	18	0	sig

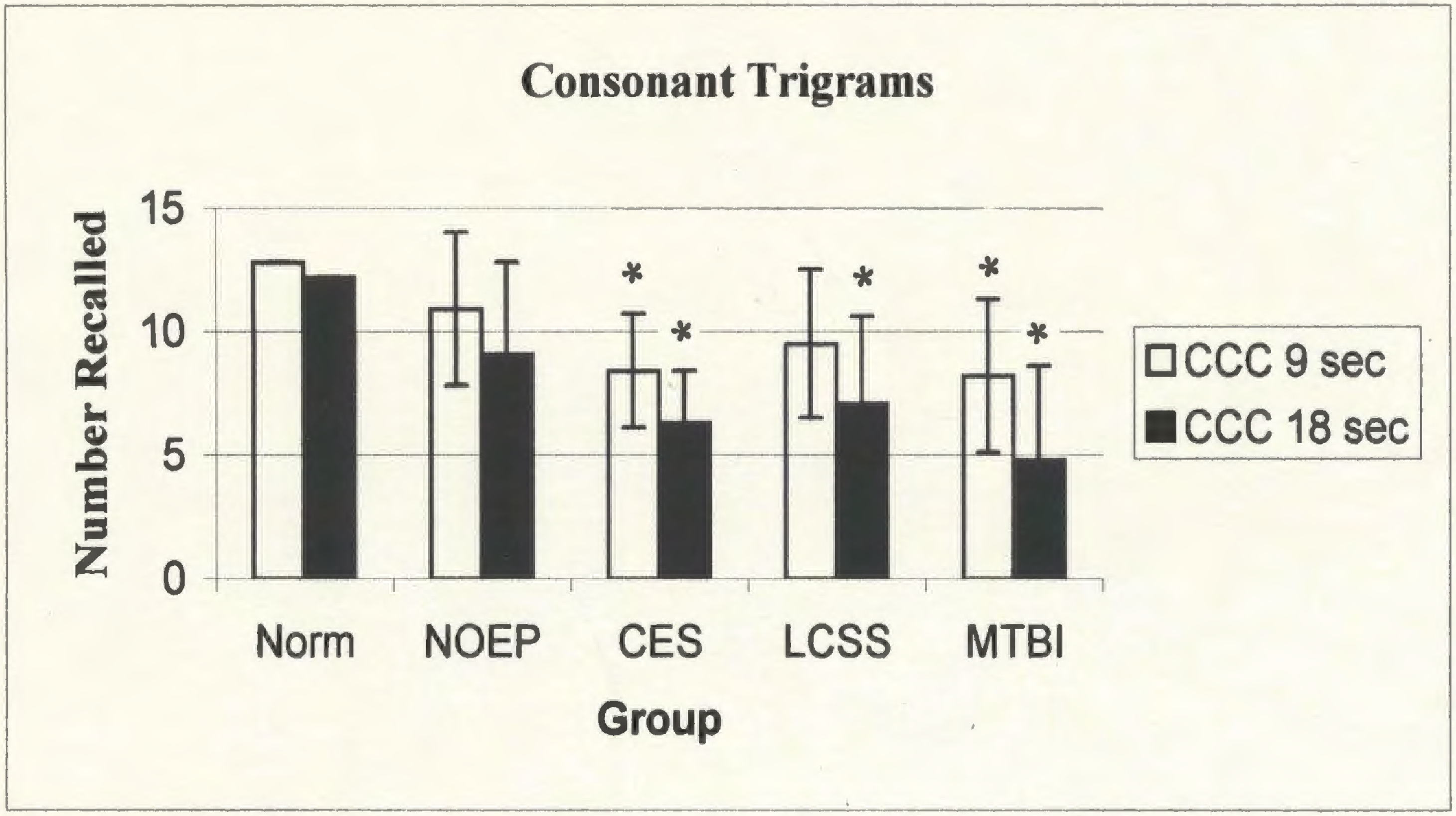

Figure 2. Comparison of group means to normative means (Stuss *et al.* 1987) on the Consonant Trigram Test (CCC).
* Means Differ significantly from normative values (Stuss *et al.* 1987).

LCSS patients fell in between and did not differ from the NOEP group, nor did they differ from the MTBI and CES patients.

Group means for all but the NOEP group were significantly lower than published normative values when compared using unpaired two-tailed t-tests (Stuss *et al.* 1987) (Table 6b; Figure 2). As with the 9-second delay recall trial of this task, the mild traumatic brain injured patients were more severely compromised than either of the three whiplash groups in terms of their ability to remember information while simultaneously performing an interpolated task. They were able to remember only 32% of the information compared to the normative value of 81% (Stuss *et al.* 1987). The CES patients recalled 42% of the material. The NOEP and LCSS groups remembered 60% and 47% respectively

3.2.4 Trail Making Test (TMT)

3.2.4.1 Part A.

Analysis of Variance (ANOVA) comparing results of Part A of the TMT in each of the four patient groups was statistically significant [$F(3,50)=3.01$, $p=.038$] (Figure 3). Duncan's Multiple Range Test revealed the MTBI group took significantly longer to complete the task than either of the NOEP or LCSS groups (Duncan test, $p<.05$). CES patients fell in between the MTBI versus NOEP and LCSS groups. That is, CES patients were slightly faster completing the task than the MTBI group, but were less time efficient than the NOEP and LCSS patients who performed equivalently.

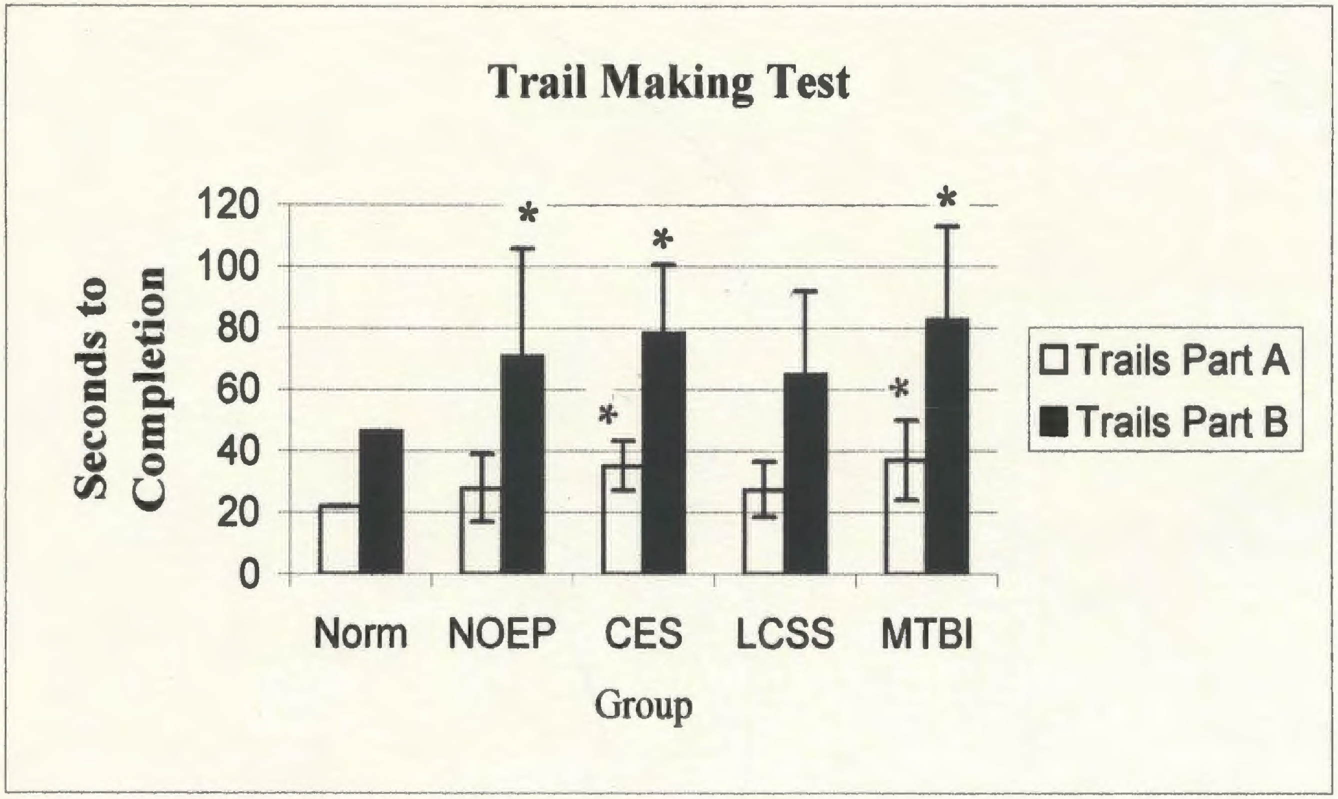

Figure 3. Comparisons of group means to normative means on Parts A and B of the Trail Making Test (TMT) (Stuss *et al.* 1987).
* Means Differ significantly from normative values (Stuss *et al.* 1987).

It has been shown that the TMT is sensitive in detecting subtle impairments in attentional functions, including speed of information processing, in patients who have otherwise been considered to have made a good recovery following closed head injury (Stuss *et al.* 1985; Cicerone 1997). Unpaired two-tailed t-tests were computed to determine if each group mean differed from the mean of a normative sample with alpha adjusted given the low number of subjects per group coupled with the number of comparisons made (Stuss *et al.* 1987). T-test results revealed the number of seconds to complete the task was significantly longer in both the CES and MTBI groups relative to the normative population (Stuss 1987)(Figure 3; Table 7a). Time to completion on Part A of the TMT was not significantly increased relative to the normative value in either the NOEP or LCSS groups.

3.2.4.2 Part B.

The four patient groups did not differ on the length of time it took to complete Part B of the TMT [$F(3,50)=1.06$, $p=.37$]. Patients in the MTBI and CES groups took significantly longer, on average, to complete this task compared to the normative value when compared using two-tailed t-tests (Stuss *et al.* 1987) (Table 7b; Figure 3). The NOEP group just reached statistical significance with respect to time to completion relative to normative data. In contrast, LCSS patients averaged the shortest time to complete the task than the other three groups and were not significantly longer than the norm.

Table 7a . Trail Making Test Part A. T-Tests Comparing Group Means to Normative Mean for Time to Task Completion. (Normative Mean =21.9; Standard Deviation 6.3; Stuss *et al.* 1987)

Group	Trails A	t value	df	p	Significance
NOEP	27.8	1.89	21	0.07	ns
CES	35.1	5.39	18	0	sig
LCSS	27.38	2.1	29	0.04	ns
MTBI	36.95	4.56	18	0	sig

Table 7b. Trail Making Test Part B. T-Tests Comparing Group Means to Normative Mean for Time to Task Completion. (Normative Mean =46.3; Standard Deviation 13.7; Stuss *et al.* 1987)

Group	Trails B	t value	df	p	Significance
NOEP	70.77	2.76	21	0.01	sig
CES	78.5	5.44	18	0	sig
LCSS	64.93	2.5	29	0.02	ns
MTBI	82.8	4.89	18	0	sig

3.2.5 Paced Auditory Serial Addition Test (PASAT).

The PASAT is considered to be sensitive to speed of information processing and is a very challenging measure to complete for patients who have suffered even mild cerebral dysfunction (Spreen and Strauss 1991). The validity of the PASAT in measuring parameters of attention/concentration, including sustained attention and speed of information processing has been established (Sherman *et al.* 1997). It is a test in which patients can become readily frustrated and overwhelmed when they are unable to meet task demands with ease, given that they have only to add series of single digit numbers. It is the externally timed nature of the task which renders it most challenging.

When patients showed overt signs of frustration on the PASAT in the present study, it was discontinued. As a result of this, the data were only analyzed from the first three trials of the test. Presumably patients who discontinued the task did so because of their difficulty with speed of information processing and in this way would be considered impaired relative to a normative population or to patients who were able to complete it. In fact, Sherman *et al.* (1997) recommend that the 1.6 second presentation of the PASAT be omitted in patients who have performed poorly on the first trial of the task, particularly since it has been described as stressful (Lezak 1995).

Table 8 shows the percentage of patients in each group who were able to complete the PASAT. Proportions of patients completing the PASAT in the NOEP and LCSS groups were equivalent ($x^2(1)=.29$, $p>.05$). Similarly, CES and MTBI groups showed equivalent proportions of patients completing the PASAT ($x^2(1)=.67$, $p>.05$). Comparing

NOEP and LCSS versus CES and MTBI reveals fewer of the latter two groups were able to complete the task ($x^2(1)=5.13$, $p<.024$).

As evidenced in these percentages, patients in both the CES and the MTBI groups had sufficient difficulty with the PASAT to require discontinuation of the task. Results obtained on the separate trials of the PASAT are therefore considered an overestimation of average performance.

3.2.5.1 All Pacing Intervals.

Three separate ANOVA's were calculated to compare test performance in each of the patient groups across the three separate interval pacings of the PASAT used in the study. Patient groups did not differ on any of the three trials {2.4 second interval [$F(3,40)=1.97$, $p=.133$]; 2.0 second interval [$F(3,39)=1.29$, $p=.290$]; 1.6 second interval [$F(3,32)=.754$, $p=.527$].

3.2.6 T-Tests Comparing Means on Each Trial of the PASAT to Normative Values in Each Patient Group.

Comparisons of means in the four patient groups, on each of the three trials of the PASAT, to the normative value for each pacing of the test (Stuss *et al.* 1988) were computed (Figure 4). Two-tailed tests were used with alpha level again adjusted according to Bonferonni procedure.

Table 8. Percentages in each group who were able to complete the PASAT.

Group	Percentage	Discontinued
NOEP	83.0%	17%
CES	40.0%	60%
LCSS	83.3%	17%
MTBI	53.0%	47%

3.2.6.1 2.4 Second Interval.

Both the CES and MTBI groups were significantly slower than the norm in completing the 2.4 second pacing interval of the PASAT (Stuss *et al.* 1988) (Table 9a). In contrast, LCSS and NOEP groups were able to complete the task within normal limits.

3.2.6.2 2.0 Second Interval.

All groups were consistently significantly slowed relative to the normative mean on the 2.0 second pacing interval of the PASAT (Stuss *et al.* 1988) (Table 9b).

3.2.6.3 1.6 Second Interval.

As with the 2.4 second pacing interval of the PASAT, there was not a significant difference between the normative mean and either the NOEP or LCSS group means when compared using two-tailed t-tests. Both CES and MTBI groups, in contrast, were significantly slower than the normative population. (Stuss *et al.* 1988) (Table 9c).

3.2.7 Verbal Fluency Test (FAS)

The number of words generated in one minute for each of the letters "F", "A", and "S" was insignificant across the four patient groups [$F(3,49)=1.43$, $p=.244$]. Unpaired two-tailed t-tests were used to compare the means in each group to the mean of published normative data (Yeudall, Fromm, Reddon and Stefanyk, 1986). Use of the "FAS" to document residual neuropsychological deficits following whiplash has been demonstrated (Gimse *et al.* 1997). There was a significant reduction in verbal fluency in all four groups relative to normative data {NOEP[$t(11)=5.35$, $p<.001$]; CES[$t(9)=8.99$, $p<.001$]; LCSS[$t(20)=2.6$, $p=.006$]; MTBI [$t(9)=8.97$, $p<.001$]}

Table 9a. Paced Auditory Serial Addition Test. T-Tests Comparing Group Mean to Normative Mean on the 2.4 Second Pacing of the PASAT. (Mean Normative Value = 43.4; Standard Deviation 10.2; Stuss *et al.* 1988).

Group	PASAT	t value	df	p	Significance
NOEP	39.8	1.73	40	0.1	ns
CES	31.2	5.51	33	0	sig
LCSS	38.6	2.3	48	0	ns
MTBI	29.7	6.71	35	0	sig

Table 9b. Paced Auditory Serial Addition Test. T-Tests Comparing Sample Variance to Normative Mean on the 2.0 Second Pacing of the PASAT. (Mean Normative Value = 41.9; Standard Deviation 10.2; Stuss *et al.* 1988).

Group	PASAT	t value	df	p	Significance
NOEP	34.7	3.51	40	0	sig
CES	25.2	7.65	33	0	sig
LCSS	32.8	4.32	48	0	sig
MTBI	27.3	6.8	34	0	sig

Table 9c. Paced Auditory Serial Addition Test. T-Tests Comparing Group Mean to Normative Mean on the 1.6 Second Pacing of the PASAT. (Mean Normative Value = 33.1; Standard Deviation 12.2; Stuss *et al.* 1988).

Group	PASAT	t value	df	p	Significance
NOEP	30.7	0.94	39	p>.05	ns
CES	20.8	4.78	32	0	sig
LCSS	27.9	2.27	45	0.03	ns
MTBI	24.8	3.25	32	0	sig

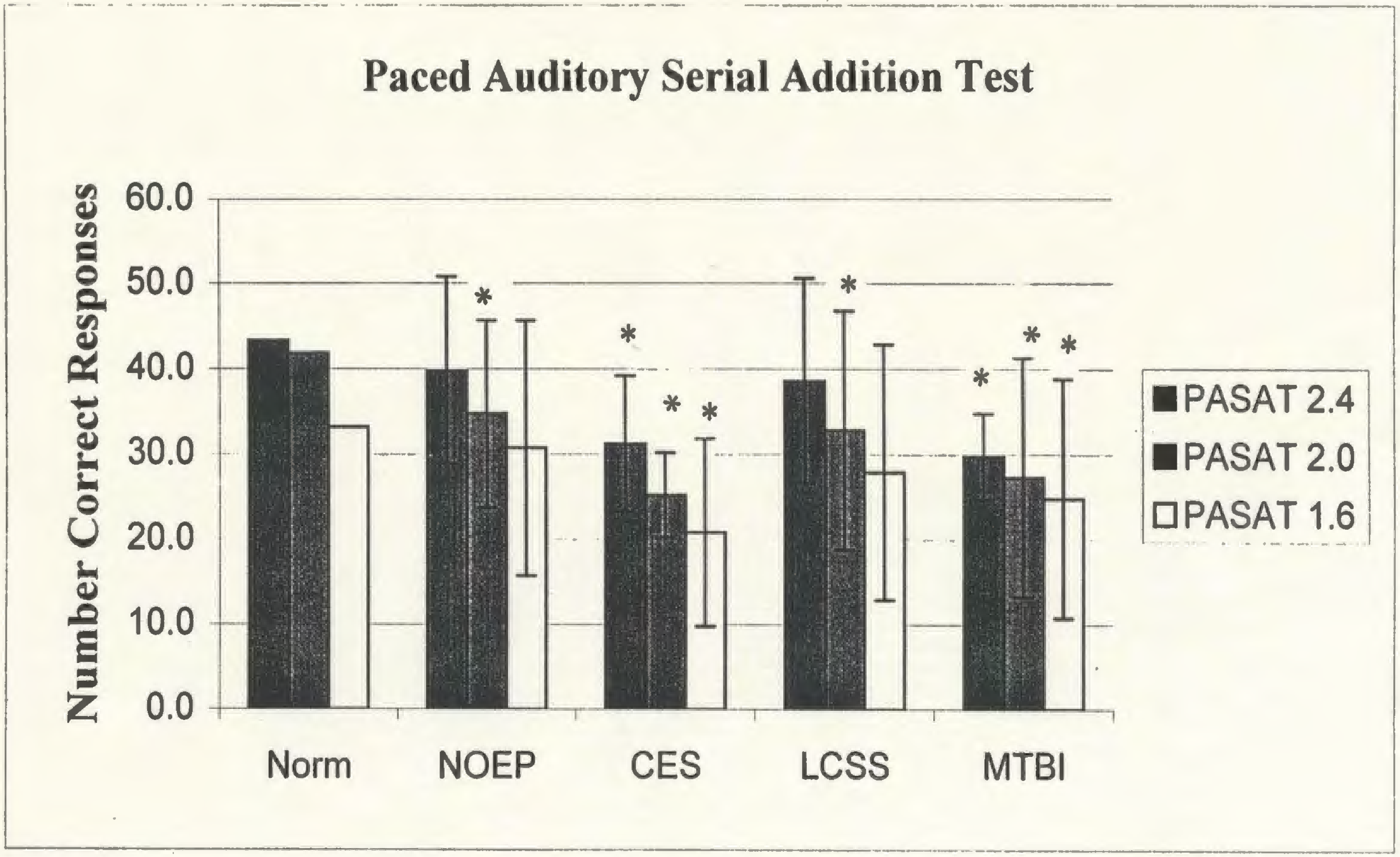

Figure 4. Comparisons of means of groups to normative means (Stuss *et al.* 1988) for three trials of the Paced Auditory Serail Addition Test (PASAT).
* Means Differ significantly from normative values (Stuss *et al.* 1988).

3.2.8 Wisconsin Card Sorting Test (WCST)

3.2.8.1 Categories Generated.

The number of concepts generated on the WCST by the four patient groups did not differ [$F(3,5)=2.79$, $p=.53$]. The NOEP group obtained an average of 5.6 categories; the CES group obtained 5.5; the LCSS group obtained 5.8; and the MTBI group obtained on average 6 of the categories. Two-tailed t-tests comparing the normative mean to the mean in each patient group were not significant (Spreen and Strauss 1991).

3.2.8.2 Perseverative Errors.

The number of perseverative errors elicited on administration of the WCST was not significantly different across patient groups [$F(3.48)=.503$, $p=.682$]. None of the group means differed significantly from normative values on subsequent t-test comparisons (Spreen and Strauss 1991).

3.3 PERSONALITY / EMOTIONAL ASSESSMENT

3.3.1 Millon Clinical Multiaxial Inventory (MCMI)

In the present study, none of the eight personality scales reached the 84 point cutoff used to detect the highest or most salient personality symptom which corresponds to a personality disorder in any of the four patient groups. In fact none of the groups obtained base-rate scores of 74 set as the cutting line which corresponds to the presence of personality or symptom features and which does not approach the level of personality disorder. Figure 5 depicts personality profiles in each of the patient groups. Since none of the groups reached a base-rate score of 74, statistical analysis was not indicated. It was

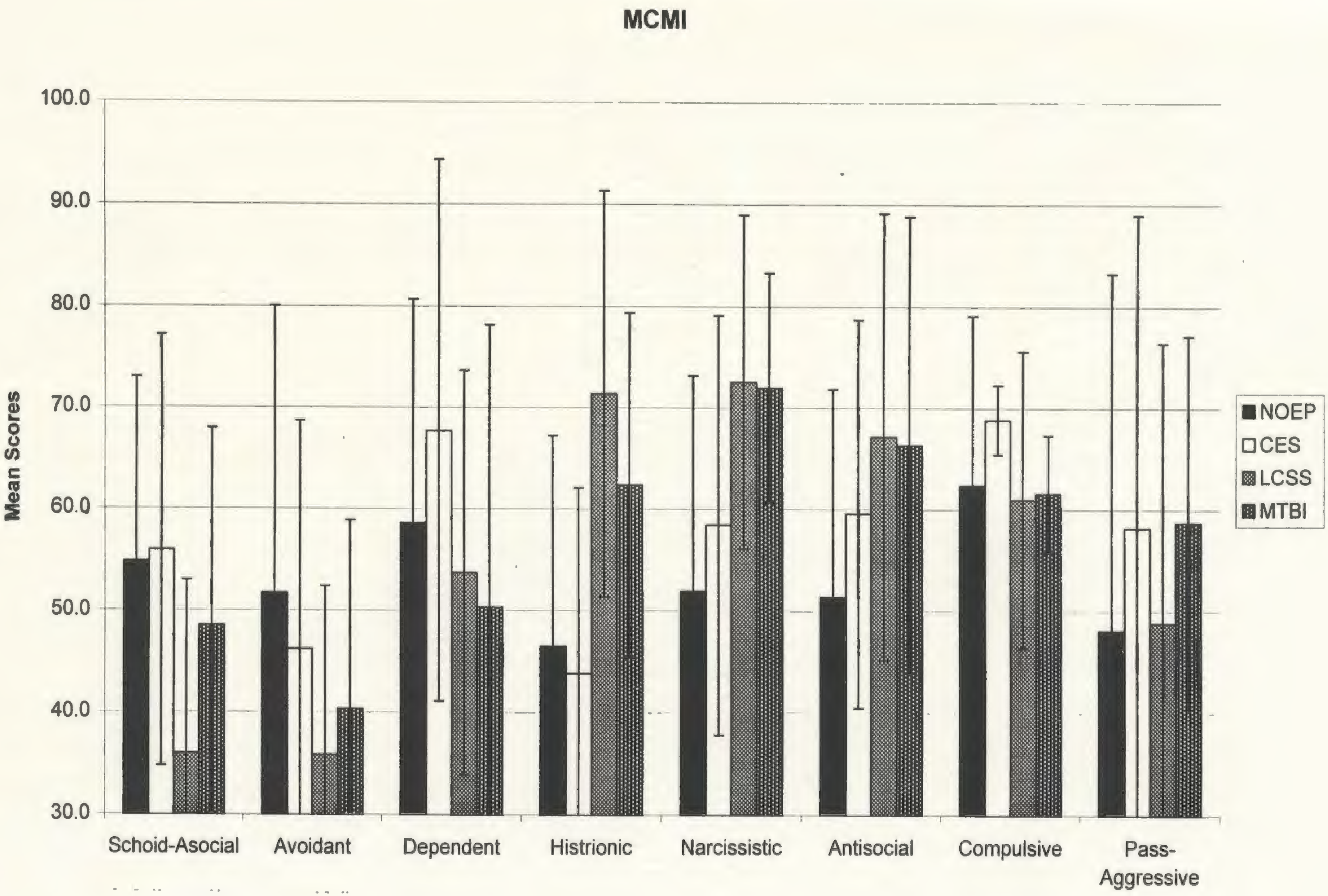

Figure 5. Personality Traits.

felt that further analysis would erroneously lead to overemphasis of obtained scores and possibly incorrect diagnostic classification (Millon 1982).

3.3.2 Beck Depression Inventory (BDI)

The four patient groups differed on the BDI [$F(3,41)=2.95$, $p=.044$]. Duncan's Multiple Range Test revealed significantly higher depression scores in the CES group relative to LCSS or MTBI groups who had lower BDI scores (Duncan Test, $p<.05$). The NOEP group fell in between and did not differ significantly from CES patients, nor did they differ from LCSS and MTBI groups (Figure 6).

Two-tailed t-tests comparing means in each group to the mean estimate of a depressed population (Beck and Steer 1987) were calculated. These comparisons were made as it has been established that elevations in depressive symptomatology are commonly associated with post-concussion syndrome following both mild traumatic brain injury as well as whiplash (Kay *et al.* 1992; Anderson 1995). It was therefore predicted that all groups would show elevations on the BDI and would not differ significantly from a depressed population.

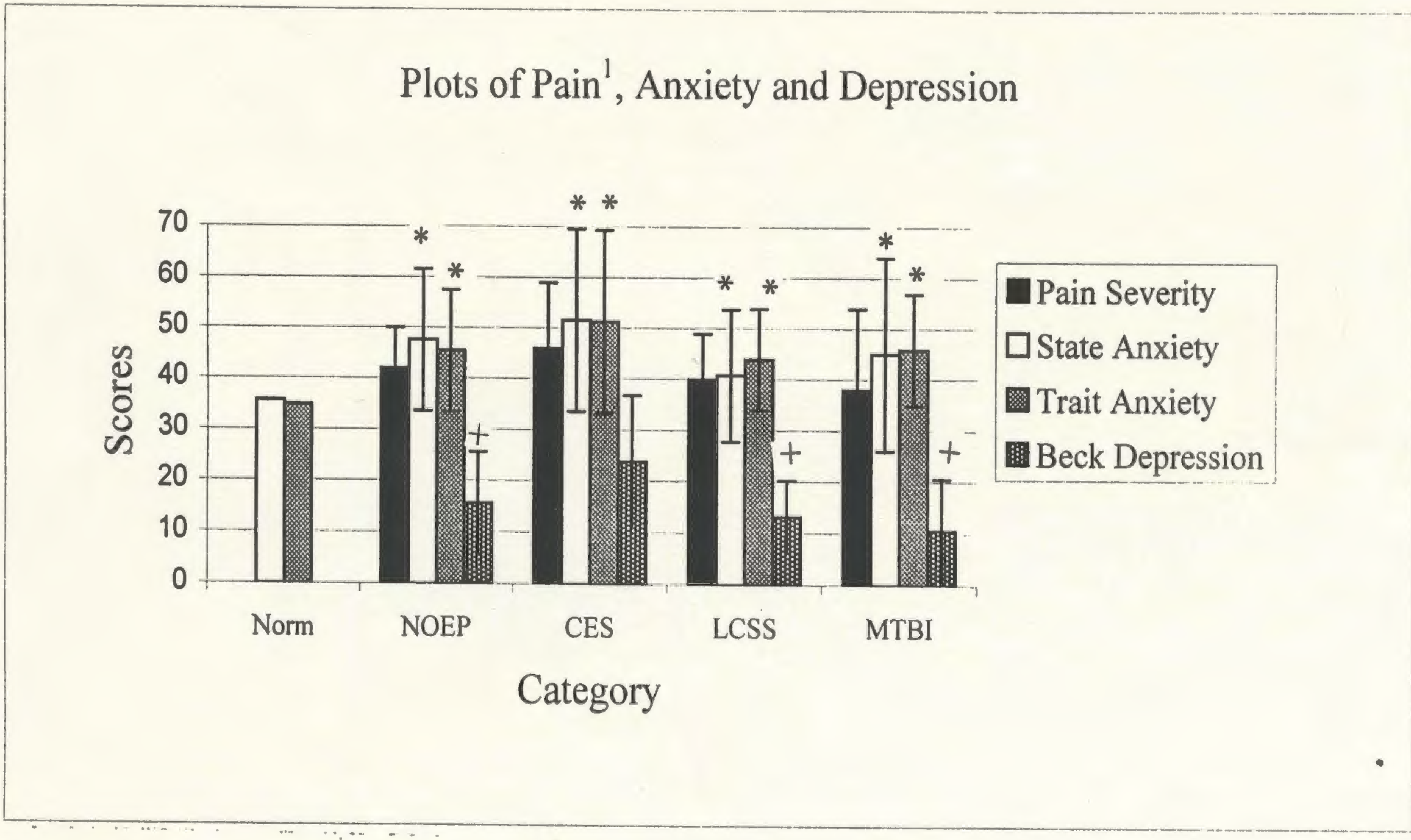

Figure 6. Plots of pain, anxiety and depression.
+ BDI score was significantly lower than a depressed population (Beck and Steer 1987).
* Significant elevation compared to normative data based on age (Speilberger 1983).
[1] Pain is plotted for information purposes as normative data were not available for the WHYMPI.

BDI score in the CES group did not differ from a depressed population. CES patients obtained an average score of 23.75 on the BDI consistent with a moderate to severe degree of depression (range 20-29) (Beck and Steer 1987). All other groups had significantly lower BDI scores compared to published data of a depressed group (Beck and Steer 1987). Average scores in the NOEP, LCSS and MTBI groups were 15.6, 13.1 and 10.6 respectively. These averages fall in the minimal depression range (10-15) (Spreen and Strauss 1991).

3.3.3 Spielberger State-Trait Anxiety Inventory (STAI)

3.3.3.1 State Anxiety.

Groups did not differ on state anxiety scores [$F(3,41)=.987$, $p=.408$]. Since affective change characterized by depression and anxiety following both whiplash and mild traumatic brain injury is common (Merskey 1993), unpaired 2-tailed t-tests were used to compare means in state anxiety scores to that of a normative group (Spielberger 1983). State anxiety was consistently elevated relative to the normative population in all groups at the .001 level of significance (Figure 6). Patients in the CES, NOEP, and MTBI groups averaged 51.6, 47.6, and 44.9 on this scale respectively. LCSS patients had a mean state anxiety score of 40.8. The normal score on this scale is 35.72 with a standard deviation of 10.4 (Spielberger,1983).

3.3.3.2 Trait Anxiety.

Patient groups did not differ in trait anxiety scores on the STAI [$F(3,37)=.672$, $p=.57$]. As with state anxiety, trait anxiety was elevated in all patient groups at the .001

level of significance when means were compared to the normative population (Spielberger 1983) (Figure 6). Average scores for patients in the NOEP, the LCSS, and the MTBI groups were 45.5, 44, and 45.9 respectively. Trait anxiety was highest in the CES group with an average score of 51.25 compared to the normative value of 34.89 with a standard deviation of 9.19.

3.4 Pain Assessment

3.4.1 West Haven Yale Multidimensional Pain Inventory (WHYMPI)

Select scales of the WHYMPI were chosen to assess various aspects of pain including: pain severity; interference in various aspects of an individual's life due to pain; perceived control over pain; as well as general activity level. All of these measures are considered clinically relevant in determining not only the patients perception of pain, but their coping response to it. The scales also provide valuable information on functional changes to the individuals life as a result of physical discomfort. Perceived control of pain is considered a prognostic indicator associated with the development of affective symptoms in response to pain. That is, it has been suggested that individuals who feel they have little control over their pain are more vulnerable to developing affective symptoms characterized by anxiety and depression. In contrast, patients who feel they have some control of physical discomfort are less susceptible to developing emotional distress in response to it.

Group comparisons were performed on these scales of the WHYMPI using analysis of variance. T-test comparisons were not done as normative data are not available for the inventory.

3.4.2 Pain Severity.

Analysis of variance comparing subjective endorsement of pain severity revealed no differences among the four patient groups [$F(3,41)=.812$, $p=.49$]. Patients in the CES and NOEP groups endorsed the highest levels of pain with average scores of 4.6 and 4.23 respectively out of a possible score of 6. Patients in the LCSS and MTBI groups averaged their pain levels at 3.9 and 3.8 respectively out of 6 (Figure 7).

3.4.3 Interference.

As with pain severity, there were no group differences in interference scores [$F(3,41)=1.45$, $p=.24$]. Patients in all of the whiplash groups averaged higher interference scores than patients who suffered mild traumatic brain injury. The average ratings in the whiplash groups were 4.83 in the CES group; 4.71 in the NOEP group; and 4.46 in the LCSS group. In contrast, the head injury group rated their level of interference due to pain at 3.78 out of 6 (Figure 7).

3.4.4 Pain Control.

The amount of control patients perceived they had over their pain did not differ across the four groups [$F(3,41)=2.43$, $p=.078$]. On average, CES patients felt they had less pain control than the other three groups and rated themselves as 1.92 out of 6 on this measure. NOEP and LCSS patients fell in between and averaged scores of 2.59 and 3.04

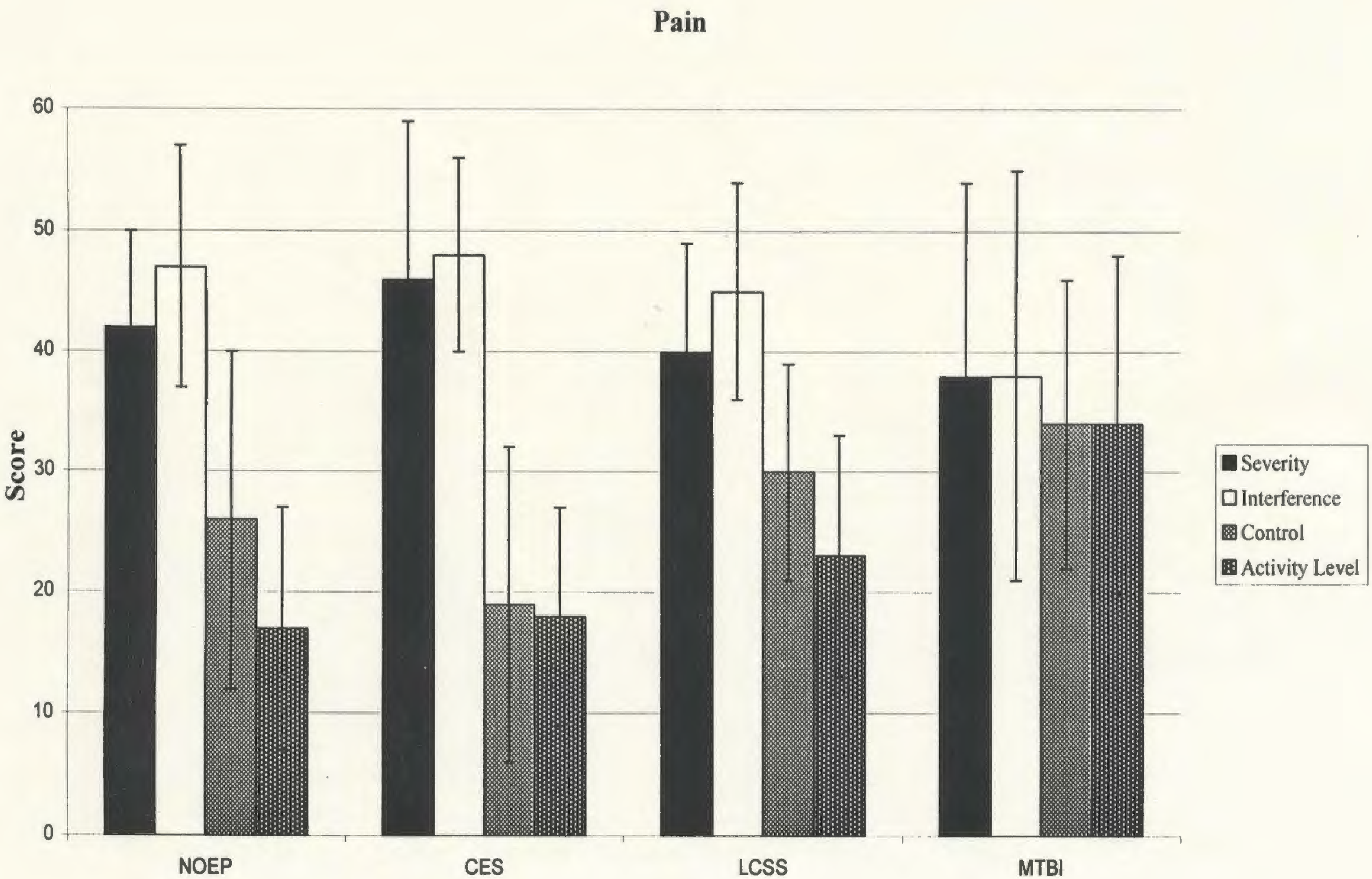

Figure 7. Pain Measure by Injury Group.

with respect to pain control. Patients in the mild traumatic brain injury group felt they had more pain control than patients in the whiplash groups and averaged 3.39 out of 6 (Figure 7).

3.4.5 General Activity Level.

A statistically significant difference was found in general activity level between the four patient groups [$F(3,41)=4.04$, $p=.013$]. Duncan's Multiple Range Test showed that the MTBI group had a significantly higher activity level than either of the three whiplash patient groups (Duncan Test, $p<.05$). The whiplash groups did not differ from each other with respect to activity levels.

Lowest average ratings were endorsed in the NOEP and CES groups with scores of 1.73 and 1.83 respectively out of six. The LCSS group averaged 2.29 with respect to general activity level. In contrast, the MTBI patients averaged 3.39 on this self-endorsed measure (Figure 6).

A summary of psychological test results is presented in Appendix D.

3.5 Relationship of Neuropsychological Variables to Pain, Depression and Anxiety.

Multiple regression analysis was used to determine the contribution of pain severity, depression and both state and trait anxiety on representative cognitive functions. The delayed memory quotient of the Wechsler Memory Scale-Revised (WMS-R) was used as representative of memory processing. This measure was chosen as it reflects the amount of information consolidated over time in contrast to immediate recall which reflects short-term memory as measured by the GMQ of the WMS-R. The attention/concentration of the WMS-R was used as representative of attentional functions. Although this was not the only attentional measure used in the study, it is considered a more pure estimate of attention not confounded by speed of information processing or memory under conditions of interference as are the TMT and the CCC respectively. Finally the 2.4 second pacing of the PASAT was used as representative of speed of information processing. This trial of the test was selected as it was the trial most patients were able to complete relative to the latter two trials of the task used in this study. In addition, the PASAT reflects mental processing speed relative to the TMT in which visual scanning as well as visual-motor speed contribute to the obtained score. Data from all groups were pooled for each of the three regression analyses to increase the subject to variable ratio. None of the F-tests of the multiple correlations were significant (.85 > p > .12) (Table 10-12).

Table 10. Results of Multiple Regression Analysis of Pain Severity (WHYMPI), State and Trait Anxiety (STAI) and Depression (BDI) on Delayed Recall (WMS-R) (N =44).

Variable	R	R^2	F(df)	P value	Significant
DMQ	0.212	0.045	0.459(4,43)	0.765	n.s.

Independent Variable	Regression Coefficient	Standard Error	t Statistic	P value	Significant
WHYMPI	-3.43	2.95	-1.16	0.252	n.s
State Anx.	-0.001	0.259	-0.005	0.996	n.s
Trait Anx.	-0.075	0.393	-0.191	0.849	n.s
BDI	0.069	0.464	0.149	0.882	n.s

Table 11. Results of Multiple Regression Analysis of Pain Severity (WHYMPI), State and Trait Anxiety (STAI) and Depression (BDI) on Attention/Concentration (WMS-R) (N =46).

Variable	R	R^2	F(df)	P value	Significant
Att Con	0.395	0.156	1.899(4,45)	0.129	n.s.

Independent Variable	Regression Coefficient	Standard Error	t Statistic	P value	Significant
WHYMPI	-3.17	2.42	-1.3	0.199	n.s
State Anx.	0.48	0.21	2.29	0.028	n.s
Trait Anx.	-0.733	0.322	-2.27	0.028	n.s
BDI	0.43	0.364	1.18	0.243	n.s

Table 12. Results of Multiple Regression Analysis of Pain Severity (WHYMPI), State and Trait Anxiety (STAI) and Depression (BDI) on the PASAT 2.4 (N =46).

Variable	R	R^2	F(df)	P value	Significant
PASAT 2.4	0.178	0.031	0.338(4,45)	0.85	n.s.

Independent Variable	Regression Coefficient	Standard Error	t Statistic	P value	Significant
WHYMPI	1.46	1.86	0.787	0.435	n.s
State Anx.	-0.061	0.16	-0.382	0.704	n.s
Trait Anx.	0.101	0.246	0.413	0.681	n.s
BDI	0.022	0.279	0.081	0.935	n.s

DISCUSSION

4.1 Demographics

4.1.1 Gender.

The greater number of males to females in the mild traumatic brain injured group in this study, with a ratio of 60.9 percent males to 39.1 percent females, is consistent with previous studies and is considered to reflect a greater propensity of males to suffer head injury than females. Research has shown that young men are at a greater risk of suffering a head injury than women. A survey of mild traumatic brain injury conducted in San Diego in 1984 reported the rate of mild traumatic brain injury for men was almost 175 per 100,000 whereas the rate for women was slightly more than 85 per 100,000 (Gronwall 1991). The higher incidence of males suffering head injury in motor vehicle accidents (MVAs) has been associated with premorbid characterological traits including increased risk-taking and use of alcohol by young men who "live in the fast lane".

According to Teasell (1993), ongoing symptoms following whiplash are more prevalent in women than men. The higher incidence of whiplash injury in women than men is presumed to be at least partially attributed to biomechanical factors. That is, women typically have a slimmer, less muscular neck rendering them susceptible to more severe damage following a whiplash injury (Teasell 1993; Teasell and Shapiro 1998). The gender distribution of 64 % female to 36 % male found in whiplash patients in this study supports this biomechanical hypothesis. These results are not consistent with a recent investigation designed to establish incidence rates of males to females following rear-end motor vehicle accidents which did not support gender differences in whiplash associated symptoms (Brault *et al.* 1998).

4.1.2 Age.

Robertson *et al.* (1994), in studying pre-morbid characteristics of 30 mild head injured patients, found the average age was 27.3 years. This is comparable to the mean age of 28.8 years found in the present study. Sixty-seven percent of their subjects were under age 30 and male.

In contrast to mild traumatic brain injury, it has been suggested that the older the adult, the greater the risk of ongoing neuropsychological impairment following acceleration forces generating a nonimpact brain injury or whiplash (Sweeney 1992). They further affect a broader age band ranging from 21-40 years old.

4.2 Interpretation of Neuropsychological Test Results

Results on intelligence testing are commonly used as a bench-mark in a comprehensive neuropsychological evaluation against which performance in other cognitive areas can be compared. Quantitative approaches to neuropsychological assessment assume that performance in one cognitive domain reflects cognitive abilities in general in the normal population (Lezak 1995). To be neuropsychologically meaningful, pre-morbid level of functioning must be estimated in order to provide a comparison standard. This comparison standard is ideally based on normative data derived from an appropriate population. It is more clinically relevant if it incorporates information on past academic and occupational history. In the present study, years of education did not differ significantly which suggests homogeneity across the four patient groups and contributes to an estimation of pre-injury level of functioning. The combination of both individual and normative comparison standards for estimating pre-morbid level of functioning and relative deficits in a given cognitive area is a fundamental cornerstone in interpreting neuropsychological test results.

Differences in cognitive performance across diagnostic groups as well as between the various tests used become clinically meaningful when the neuropsychological evaluation assesses many different functional areas. Test score analysis requires that a discrepancy exist between two or more scores. Marked quantitative discrepancies in test results are more clinically relevant. Whether these differences are considered directly injury-related or affected by other, secondary factors, such as emotional disturbance or pain, becomes a critical point in differential diagnosis of contributing etiological factors.

4.2.1 Intelligence

In the present study, the four groups did not differ with respect to Full-Scale Intelligence Quotient (FSIQ) as measured using the Wechsler Adult Intelligence Scale-Revised (WAIS-R). FSIQ was consistently within the average range in all groups. This, coupled with the fact that they did not differ educationally, demonstrates homogeneity across the four different groups upon which other test score differences were considered valid indicators of deficit in the respective cognitive areas assessed. It also reflects the fact that the population of patients assessed in the present study is representative of the normative population upon which the WAIS-R was originally standardized (Wechsler 1981) and later "Canadianized" (see Spreen and Strauss 1991).

Although there is controversy surrounding cultural variation and bias in using the WAIS-R for different ethnic populations (Neisser, Boodoo, Bouchaard, Boykin, Brody, Ceci, Halpern, Loehlin, Perloff, Sternberg and Urbina 1996), international application of the test was demonstrated on a Swedish population of subjects who were administered a translation of the intelligence test (Wirsen and Ingvar 1991). The average FSIQ of the control group in that study, estimated at 105.6, is comparable to that exhibited by patients in the present study. It is also similar to published normative data based on age (Wechsler 1981; Neisser *et al.* 1996). Results of the present study show that intellectual potential of Newfoundlanders tested was within the average range compared with the general population upon which the test was standardized.

Despite the fact that the mean FSIQ in the NOEP and LCSS groups were within the normal range, scores tended to be slightly higher than the mean of the normative population. That FSIQ was slightly higher than the normative mean in these groups supports the finding that intellectual potential increases in the population over time, a tendency which is referred to as the "Flynn effect" (Neisser *et al.* 1996). It has been estimated that the average gain is approximately three IQ points per decade. Restandardization of intelligence tests, undertaken periodically to compensate for this increase, reestablishes the average IQ to 100. In light of the Flynn effect, however, average scores on the WAIS-R would be expected to be at approximately 105 since the version used was last standardised in 1981. This estimation is commensurate with results in the present study. The most recent revision of the Wechsler Adult Intelligence Scale (WAIS-III), published in 1997, has removed outdated items; provided current normative data; and has updated test materials. This newest version of the test, only recently available for purchase, has not undergone rigorous use in either clinical or research settings to date.

That FSIQ was not significantly different from the normative value in either the MTBI or CES groups, but was higher than the norm in the other two groups, may reflect a mild differential degree of intellectual blunting in patients who have sustained a direct blow to the head or injury to the upper cervical spine. FSIQ is a composite score and includes several measures sensitive to attention and concentration as well as speed of information processing. These cognitive processes have been associated with intact brainstem functions the integrity of which may be slightly disrupted by high cervical cord injury. Sweeney (1992) asserts that intelligence testing on neuropsychological assessment may not reflect impairment in individuals who were functioning at a higher intellectual level prior to their injuries. That is, even though CES and MTBI patients were within the average range intellectually, they may have been functioning at a slightly higher level pre-morbidly as were the other two groups. CES and MTBI groups may have therefore experienced a mild degree of global cognitive slippage associated with their injuries as reflected in lower FSIQ relative to the other groups . The degree of blunting was not large enough to reach statistical significance since FSIQ in the MTBI and CES groups still fell within the average range.

In general WAIS-R findings suggest that neither whiplash injury nor mild traumatic brain injury results in a significant diminution of intellectual capacity *per se.* This is consistent with past research (Schwartz *et al.* 1987). Further, that all groups performed in the average range confirms use of the WAIS-R in providing a reference against which scores on other tests administered could be compared.

4.2.2 Memory

Bornstein, Prifitera and Chelune (1989) examined the clinical utility of using a discrepancy score between the Full Scale IQ (FSIQ) of the WAIS-R and the Delayed Memory Quotient (DMQ) of the WMS-R. They found that only 10 % of a normal control population exhibited a difference of 15 points between these scores. In contrast one third of the clinical sample they studied exhibited such a discrepancy. This sample was comprised of patients with diagnoses such as epilepsy, head injury, dementia and aneurysm. The authors point out that their clinical sample included patients with a diagnosis associated with memory problems even though the patients may not have progressed to the point that they subjectively identified such memory problems themselves. They caution that single scores should not be used in isolation to form clinical judgements about amnestic syndromes.

4.2.3 Mild Traumatic Brain Injury.

Results in Figure 1 depict comparisons made between the FSIQ of the WAIS-R, the GMQ and DMQ of the Wechsler Memory Scale - Revised (WMS-R) relative to normative data for these tests. The results show that although the GMQ is not significantly reduced, the DMQ is significantly lower than the normative population in the mild traumatic brain injured group. This reflects a loss of detail following a thirty minute consolidation period. The constellation of findings comparing memory indices to normative data (Tables 3 and 4; Figure 1) in the mild traumatic brain injured group. suggests that delayed recall is vulnerable to impairment following mild traumatic brain injury. These results are consistent with numerous studies documenting that memory deficits are commonplace following traumatic brain injury (Lezak 1995). In fact, memory impairment is one of the most common neuropsychological effects of mild traumatic brain injury. The differential between memory indices to the normative population suggests that the degree of memory loss is mild. This is in contrast to more significant memory problems documented following moderate and severe head trauma (Bohnen and Jolles 1992; Guilmette and Matazow 1992; Dikmen, Temkin, McLean, Wyler and Machamer 1987).

4.2.4 LCSS.

Neither the GMQ nor the DMQ were significantly lower than the normative sample variance in the LCSS group. These results suggest that whiplash injury affecting the lower cervical spine does not cause a diminution in either immediate or delayed recall relative to the individual's normative sample group based on age. That the GMQ and DMQ were not significantly lower than the norm suggests the memory impairment subjectively reported by LCSS patients is not large enough to be quantified on formal neuropsychological assessment and is likely not clinically relevant.

4.2.5 NOEP.

Whereas the GMQ in the NOEP group tended to be slightly higher than the norm, the DMQ did not differ significantly from the normative population. The average GMQ and DMQ were also highest in the NOEP group compared with the other three patient groups. This, together with the fact that these patients show no objective evidence of cervical pathology on standard medical investigations, suggests that they suffered a less severe injury, at least in terms of residual memory loss, than that suffered by patients with mild traumatic brain injury. Esentially, whiplash patients who show no structural damage, yet who continue to report subjective memory complaints, are not memory impaired on formal neuropsychological testing.

4.2.6 CES.

As with the LCSS group, there was also an insignificant difference between both GMQ and DMQ relative to the norm in the CES group. In contrast to the LCSS group however, the average FSIQ in the CES group was the lowest of the four patient groups and was not significantly higher than the norm as was evident in both the NOEP and LCSS groups.

4.3 Summary of Memory Results.

Several structures in the brain have been correlated with memory functions. Primary regions associated with memory disturbance include lesions in the deep temporal region involving the hippocampus and the amygdala as well as diencephalic structures including the mammillary bodies and medial thalamus (Wirsen and Ingvar 1991). Damage to these structures such as that sustained in a traumatic brain injury can impair memory functions. Typically the severity of the head injury positively correlates with the extent of memory impairment. This pattern was consistent with memory results in the mild traumatic brain injured group in this study. In contrast, neither of the whiplash groups showed a significant impairment in memory compared with normative data. While this is consistent with reports that impairment of memory is not common after whiplash (Radanov *et al.* 1993), it is certainly contrary to subjective complaints of forgetfulness in these patients.

Lack of correspondence between subjective complaints and neuropsychological test performance assessing memory in a group of patients diagnosed with post concussion syndrome has been documented elsewhere (Ruff, Levin and Mattis 1989). It was speculated that patients' inaccurate appraisal of their symptoms were due to a variety of factors, most notably, pre-morbid personality characteristics and psychological reactions to the trauma. It has also been speculated that an individual who functions at a higher percentile level prior to an injury and recovers to a level which remains average or above on testing, yet is lower than their pre-injury level, can continue to experience cognitive compromise (Ruff *et al.* 1989). This is typically not detected when patients data are compared to an average population based on normative data. It is possible, therefore, that these patients were suffering relative losses in memory and that the deficits were not severe enough to be detected on formal memory testing.

It is also likely that subjective complaints of memory deficits are associated with disturbed attentional functions in some whiplash patients. That is, although the relationship is unclear, disturbed functioning of the frontal lobes has been associated with memory impairment secondarily through a deleterious effect in other cognitive functions (Stuss and Benson 1983). Frontal cognitive impairments which influence successful functioning of memory include reduced attentional functions, problems with organization of information as well as reduced initiation or motivation. The interaction between memory and attention is important in that information not adequately attended to will not be remembered.

4.4 Attention/Concentration

The attention/concentration quotient of the WMS-R correlates highly with general intelligence in a normal population (Spreen and Strauss 1991). The attention/concentration quotient of the WMS-R was significantly lower than the norm in both the CES and MTBI groups. The upper cervical cord injured group (CES) demonstrated the lowest performance on this measure. NOEP and LCSS groups had among the highest attention quotients and neither differed significantly from the normative population. That attentional deficits were only evidenced on this measure in the CES group relative to the other two whiplash groups supports the hypothesis that upper cervical spine injury causes a differential reduction in attention than that experienced by patients with lower cervical cord injury or in whiplash patients with no evidence of structural damage.

Given that the CES patients incurred damage to C0, C1 and/or C2, these findings support the hypothesis pertaining to etiological relevance relating level of cervical injury to cognitive deficits. That is, high cervical cord injury may cause greater disruption to brainstem structures believed to underlie attentional functions. This reflects a more circumscribed pattern of cognitive change following upper cervical spine injury relative to that exhibited by the other whiplash groups.

The attention quotient of the WMS-R was also impaired relative to the normative population in the mild traumatic brain injured group. Discrepancies exhibited on neuropsychological assessment between standardized norms and this measure are clinically relevant (Shum, McFarland, Bain and Humphreys 1990). Post-concussion symptoms following whiplash or mild traumatic brain injury are typically characterised by a higher intelligence quotient than attention/concentration quotient. The degree of difference between the attention score in the MTBI and CES groups relative to the norm reflects the severity of impairment in attentional functions. In the absence of a significant past medical history to account for the difference, it can be attributed either directly or indirectly to injury-related causes.

The overall pattern of findings based on the attention/concentration quotient of the WMS-R supports the belief that high cervical cord injury can cause attentional deficits akin to those experienced following a direct blow to the head when compared to normative data. Comparisons between attention quotients in the four groups with normative data supports further differentiation of whiplash patients into separate groups based on the degree of attentional deficits. This differentiation corresponds with presence and level of cervical injury sustained through a whiplash mechanism as proposed by Radonov (1993). That is, it appears that patients with upper cervical cord damage to C0, C1 and/or C2 exhibit more significant attentional deficits compared to other whiplash groups. Although subjectively reported, they were not significantly reduced when compared to the normative population in the NOEP or LCSS groups.

Spreen and Strauss (1991) caution however that single index discrepancies with normative data, not be used in isolation to identify areas of cognitive deficit. Therefore, other tests measuring complex attentional functions involving various parameters of efficiency of information processing were administered to mild traumatic brain injured and whiplash patients. Variability among measures designed to assess various components of attention are often incorporated into clinical neuropsychological protocols. The rational for using multiple variables, some of which are closely inter-correlated, allows for the exploration of the pattern of relations between variables (Wirsen and Ingvar 1991). Emerging patterns can be compared across different diagnostic groups in an attempt to facilitate differential diagnosis.

In his study on attentional deficits following mild traumatic brain injury, Cicerone (1997) postulated that variability among attentional measures may be attributed in part to different sensitivities of the measures used. Both sensitivity and specificity of various measures, applied to different groups of patients, can assist in characterising differential neuropsychological profiles unique to each. Attentional tests used in the present study including the Consonant Trigrams, Trail Making Test and the PASAT provide adjunct information which, together with IQ-WMS-R index discrepancies in the Att/ConQ, offers finer differentiation of cognitive deficits following mild traumatic brain injury and whiplash.

4.5 Brown Peterson Consonant Trigram Test (CCC).

The consonant trigrams test is among the most widely used and sensitive measures documenting the effects of brain injury in adults (Paniak, Miller, Murphy andrews and Flynn 1997). It provides information on the ability to attend to or process two pieces of information simultaneously (Stuss *et al.* 1987; Paniak *et al.* 1997). In comparing three measures of divided attention and information processing capacity, Stuss, Stethem, Picton, Leech and Pelchat (1989) found that the CCC significantly differentiated a group of mild traumatic brain injured patients from a group of matched controls. Although Stuss found that scores on the Trail Making Test (TMT) and the Paced Auditory Serial Addition Test (PASAT) in the mild traumatic brain injury group were also lower than controls, the differential was not as great as that found on the CCC. The authors therefore concluded that all three tests were not equally sensitive across all levels of head injury severity.

In the present study, the NOEP group did not differ significantly on either the nine or eighteen second delay recall trial of the CCC. Whereas the LCSS group were not impaired on the nine second delay recall trial, their scores were significantly diminished on the more difficult eighteen second recall trial relative to published normative data (Stuss *et al.* 1987). Both the mild traumatic brain injured and upper cervical spine injured groups were impaired on both CCC trials. These latter two groups remembered less information, on average, on both trials of the task than either of the other two whiplash groups. The difference between their scores relative to normative data reflects a mild to moderate degree of impairment. A milder degree of blunting was present in the LCSS group.

Patients with mild traumatic brain injury and upper cervical damage have more difficulty processing verbal information while simultaneously performing an arithmetical interpolated task than patients with low cervical cord injury or whiplash injury with no discernable evidence of physical damage. High cervical cord injured patients (CES) exhibit more severe impairment than the other two whiplash groups in this study. The most marked impairment with respect to average scores was noted following mild traumatic brain injury. These results are consistent with those of Stuss *et al.* (1985) in their attempt to assess subtle, residual neuropsychological deficits in a group of patients considered to have made a good recovery following closed head injury. Of the several measures sensitive to the pathophysiology of diffuse impact, inertia effects they used, maximal statistical significance was found on the CCC. In comparing head injured patients to matched controls, Stuss *et al.* (1985) found little correlation between CCC results and the duration of time since injury. This suggests that residual cognitive compromise is relatively independent of recovery time in patients who were otherwise considered to have made a good recovery.

Impaired performance on the CCC has been interpreted as increased susceptibility to the effects of interference resulting in difficulty maintaining consistent and directed attention in the face of interference (Stuss *et al.* 1985). It reflects impaired divided attention which results in difficulty simultaneously keeping track of more than a single piece of information, aspect of a task, or train of thought at a time. The precise pathophysiology for impaired divided attention has not been determined. However it has been postulated that diffuse white matter lesions and brainstem dysfunction, or alternatively, a disruption in frontal-limbic-reticular activating system (RAS)-brainstem control may underlie these deficits (Cicerone 1997).

Results of the CCC closely parallel those of the attention/concentration quotient of the WMS-R. That is, patients with upper cervical cord injury and mild traumatic brain injury had significantly lower attention quotients than patients in the other two whiplash groups. Whiplash patients with no discernable evidence of pathology performed better, on average, than patients in the other three groups. This supports the hypothesis that NOEP patients suffered a less severe injury with respect to lingering neuropsychological sequelae than patients with documented structural damage. As with results from the WMS-R attention index, CCC results further support the hypothesis that upper cervical injury and mild traumatic brain injury results in more marked lowering in complex attentional functions, characterised by impaired dual information processing, than that observed in the other whiplash groups.

4.6 Information Processing Speed

4.6.1 Trail Making Test (TMT).

Cicerone (1997) examined the clinical sensitivity of several measures commonly used to assess attention following mild traumatic brain injury including, among others, the TMT and the PASAT. Both tests were sensitive to subtle cognitive deficits following mild traumatic brain injury. Despite this, Cicerone did find differential sensitivities among the tests used which he attributed to the possibility that they measure different aspects of attention.

In this study, patients in the MTBI group took longer to complete both Parts A and B of the TMT than the other groups. In addition, CES patients took longer to complete the task than the other two whiplash groups. Both of these groups were significantly slower than the norm in completing both components of the TMT. This suggests that as with mild traumatic brain injury, patients who suffer upper cervical spine damage also experience more marked cognitive slowing than a normal population. Although patients in the NOEP group were also significantly slowed compared to normative data on Part B of the TMT, they were not as compromised as patients in the CES and MTBI groups. Nor was their performance slowed on Part A of the test relative to normative data. The LCSS patients were the only group who were not impaired on either trial of the test.

The pattern of results on the TMT is generally consistent with that obtained on the Attention/Concentration Quotient of the WMS-R as well as on the CCC. That is, both CES and MTBI groups were more consistently significantly impaired on all of these measures. Impairment on the Trail Making Test has been closely related to disruption of the anterior attentional network involving the anterior cingulate gyrus (Cicerone 1997).

4.6.2 Paced Auditory Serial Addition Test (PASAT).

The Paced Auditory Serial Addition Test (PASAT) provides information on the ability to attend to and sustain attention over a protracted period of time (Stuss *et al.* 1988; Gronwall 1991). Because the task is externally paced, it also provides valuable information on speed of information processing. It therefore tests various parameters of complex attentional functions.

Results of the PASAT in this study revealed a statistically significant difference in both CES and MTBI groups on each of the three trials of the test utilised compared to the norm. The NOEP and LCSS groups did not differ significantly from the normative population on the first 2.4 second pacing or on the third 1.6 second pacing. These groups were significantly compromised on the second trial of the PASAT although this trial of the task is easier to complete than the third trial on which they were not impaired compared to the norm. Despite this, however, all groups demonstrated a typical pattern wherein the average number of correct responses was reduced in successive, more difficult, trials as the numbers were presented at a faster pace. This was consistent across all trials in all groups.

PASAT results reflect significant impairment in rate of information processing in PCS following both mild traumatic brain injury as well as high cervical spine injury. Taken across trials in all groups, these results support the hypothesis that patients who suffer whiplash injury regardless of presence or level of structural damage experience at least some degree of blunting in the ability to respond to externally paced stimuli. This is consistent with previous investigations which found dysfunction of attention and concentration more frequently than expected following whiplash injury (Ettlin, Kischka, Reichmann, Radii, Heim, à Wengen and Benson 1992). That patients in the NOEP and LCSS groups performed better overall on the task corroborates the hypothesis that the neuropsychological consequences of their injuries are less severe than those of whiplash patients who showed evidence of tissue damage to the upper cervical cord or than mild traumatic brain injured patients.

The CES group was significantly compromised relative to normative data on all trials whereas LCSS patients were only impaired on the second trial with respect to PASAT performance. This is consistent with Radonov *et al.* (1992) who found that LCSS patients performed within the normal range on the PASAT while CES patients were impaired. In fact the differential in performance, most obvious on the PASAT than on any of the other cognitive measures Radanov used, assisted in differentiating whiplash patients into two distinct groups correlated with upper and lower cervical cord damage.

In the present study average scores tended to be better in the LCSS group than in the CES group across all trials of the task. Further, average scores of CES and mild traumatic brain injured patients were lower than those of NOEP and LCSS patients on all measures assessing information processing speed as well as attentional functions. This pattern of findings is consistent with those described by Radonov *et al.* (1992). Although differential patterns of performance emerged on the PASAT as well as on other memory and attentional tests utilised in the present study, the results should be considered preliminary given the small number of patients per group, particularly in the CES group. Although more data were available, it could not be used in this study because patients could not be contacted to provide written consent as ruled by the ethics committee.

According to Cicerone (1997) the PASAT has two primary components which accounts for its sensitivity in detecting processing deficits following mild cerebral dysfunction. The first is the requirement for information processing speed. This has been demonstrated through reducing the rate of stimulus presentation which has resulted in a concomitant reduction in the sensitivity of the test. The second primary feature of the PASAT involves demands on processing capacity required to perform the test. That is, the PASAT requires the ability to simultaneously attend to multiple sources of information. It has been proposed that it is the interaction of these components which contribute to the sensitivity of the test in detecting subtle cognitive compromise.

A high rate of impairment emerged on all trials of the PASAT in both the CES and MTBI patient groups in this study as well as on trial two in the NOEP and LCSS groups. Cicerone (1997) raised concerns regarding the high percentage of mild brain injured patients classified as impaired in their study based on PASAT findings. This, they felt, could contribute to a high false positive diagnosis of brain damage. This situation could have very significant financial repercussions such as in medical legal situations. That is, an individual could conceivably be unjustifiably compensated for cognitive dysfunction associated with a possible brain injury falsely diagnosed if impaired performance on the PASAT was overemphasised. Cicerone (1997) suggests that this be mitigated in clinical practise by using multiple measures and setting more stringent criteria for impairment on the PASAT.

Evaluation of construct and criterion-related validity of the PASAT revealed "respectable correlations" between it and other neuropsychological constructs including general intelligence as well as arithmetical ability (Sherman, Strauss and Spellacy 1997). They therefore recommend caution in interpreting impaired performance in patients with poor arithmetic skills. That a high correlation exists between the PASAT and intelligence supports interpretation of the differential between these measures in providing useful clinical information. It is assumed that patient groups with average intelligence as was found in all groups in this study would be expected to perform within approximately average limits on the PASAT. That all groups showed differential lowering on one or more trials of the PASAT, while functioning within the average range intellectually, corroborates that they had problems with speed and capacity of information processing.

4.6.3 Verbal Fluency (FAS Test).

Verbal fluency reflects the ability to formulate and organize thought processes as well as to initiate a verbal response within a fixed time period. The FAS test of verbal fluency involves elicitation of words in one minute per three different letters presented. In this study, all patient groups were less time efficient in completing this task than the normative sample. Therefore both whiplash and mild traumatic brain injury results in slowed verbal fluency. This supports previously documented findings showing impaired verbal fluency in a mild traumatic brain-injured population (Verduyn *et al.* 1992) as well as in a whiplash population (Gimse *et al.* 1997).

Impaired performance on a controlled word association task in the Verduyn *et al.* (1992) study was interpreted as an indication of localized involvement of frontal functions. Similar results were found by Gimse *et al.* (1997) in a group of whiplash patients. These authors suggest that the ascending reticular activating system (ARAS), important in activating higher cortical functions, can be disturbed following whiplash. This disruption can translate into reduced efficiency in frontal lobe functions even in the absence of structural frontal damage (Gimse *et al.* 1997). Verduyn *et al.* (1992) emphasised that despite "meagre results" on more traditional neurodiagnostic techniques, the majority of patients in their study showed evidence of cerebral dysfunction involving frontal processes on neuropsychological testing. That verbal fluency was reduced in the present study supports the hypothesis that cognitive disruption can occur in patients with post-concussion syndrome whether they experienced a direct blow to the head or an indirect one through a whiplash mechanism.

4.7 Executive Functions

4.7.1 Wisconsin Card Sorting Test (WCST).

The number of problem solving strategies generated out of a possible six on the WCST reflects abstract reasoning skills based on the concepts of colour, form and number. The test measures executive functions which have also been associated with frontal lobe regions (Stuss and Benson 1986). In the present study, all patient groups performed equally well on this measure and all were comparable to normative data. This suggests that whiplash injury does not disrupt frontal lobe functions involving abstract reasoning skills, problem solving and mental flexibility.

Patients in the MTBI group also performed well in terms of the number of categories generated on the WCST and they did not differ from normative values. Although some studies have shown that mild traumatic brain injury can interfere with executive functions, as measured by the WCST and associated with the frontal lobe region (Verduyn *et al.* 1992), results of the present study do not support this finding. In addition, despite the fact that attentional functions and speed of information processing were relatively more impaired in the CES and MTBI groups than in the LCSS and NOEP groups, these deficits did not have a secondary deleterious effect on executive functions.

The number of perseverative responses elicited on administration of the WCST was comparable to the normative value in all four patient groups. This further supports the finding that whiplash injury does not appear to cause frontal, perseverative responding. Even in the head injury group, there was no clinical evidence of perseveration.

4.8 Personality and Affective Symptoms

Neurobehavioural sequelae associated with post concussion syndrome after mild traumatic brain injury provokes continued controversy (Putnam *et al.* 1996). Differentiating between the effects of primary neurological injury and secondary psycho-social problems remains at the centre of this debate (Bohnen and Jolles 1992; Rosenthal, Christiansen and Ross 1998). Similar controversy exists for whiplash patients. That is, although 70% of whiplash patients experience a diminution of symptoms in the first six months post-injury (Lee, Giles and Drummond 1993), the remaining 30% remain symptomatic indefinitely. It has been implied that patients who remain symptomatic are those who have a predisposing characterological make-up which renders them more vulnerable to psychological disturbance as well as lingering cognitive and physical complaints (Putnam *et al.* 1996). Personality features such as passive-aggressive and negativistic traits (Putnam *et al.* 1996); neuroticism, associated with a high level of subjective symptom endorsement (Radonov *et al.* 1992); as well as hypochondriacal and hysterical tendencies as measured using the MMPI (Youngjohn, Burrows and Erdal 1995) are among some of the personality traits associated with persisting post concussion symptoms following both mild traumatic brain and whiplash injury. Others have refuted the notion that personality plays a major role in PCS in either whiplash (Gimse *et al.* 1997) or mild traumatic brain injured patients (Robertson *et al.* 1994).

In past research, use of the MMPI to assess personality in these patient groups has been criticized as inappropriate and can lead to misleading characterisations (Merskey 1993). That is, use of the MMPI is only considered valid after the exclusion of physical illness has been confirmed. Elevations in hypochondriacal and hysterical scales on the MMPI therefore likely reflect endorsement of valid physical symptoms which these patients continue to suffer based on their physical injuries. Lack of consistent information in past research regarding the role of assessment of pre-morbid personality traits and coping styles, as well as how these factors contribute to ongoing symptoms even after the expected time of recovery, makes it difficult to define relevant variables which may affect cognitive compromise on neuropsychological testing following mild traumatic brain injury and whiplash.

In the present study, personality assessment was undertaken to examine the contribution of underlying characterological traits to persisting complaints following both mild traumatic brain injury and whiplash injury. The MCMI was used as it is uniquely suited to distinguishing more enduring personality characteristics (Axis II) from acute clinical disorders (Axis I) which are transient and circumscribed by situational stress (Millon 1981). The test measures a total of eight basic personality patterns all of which were below the cutoff level in this study. This was consistent across all four patient groups. That no clear pattern of elevation emerged on the personality scales of the MCMI suggests that pre-morbid characterlogical make-up is not a primary operative factor in the development, maintenance and perpetuation of long-term sequelae following either mild traumatic brain injury or whiplash injury. That is, in these samples, the persistence of symptoms including cognitive disruption, pain and anxiety or depression does not appear to be related to a unique characterological predisposition based on pre-morbid personality features. This is consistent with recent use of the MCMI in neck sprain patients which documented normal personality and clinical profiles compared with standardized norms, both in the initial phase following injury as well as on six month follow-up (Borchgrevink, Stiles, Borchgrevink and Lereim 1997). These results do not support the contention that prolonged disability following neck sprain injury is due to premorbid personality style or psychiatric syndromes. Borchgrevink *et al.* (1997) therefore suggest that symptoms such as nervousness, irritability and depression which may evolve over time are a consequence, rather than a cause, of long-lasting symptoms following neck sprain injury.

These results are consistent with earlier work which attempted to evaluate the predictive relationship between psychological factors and persisting complaints following whiplash injury. In their study, Radonov *et al.* (1993) found psycho-social factors, negative affect and personality traits measured shortly after whiplash injury were not predictive of persisting symptoms. Rather initial neck pain intensity, age and cognitive impairment associated with the injury were considered poor prognostic indicators and were correlated with persisting complaints. Results of the present study supports

Radonov's interpretation of the lack of influence of personality variables. This suggests that it may be the actual severity of the injury, coupled with residual consequences thereof, as opposed to predisposing personality traits, which correlated with eventual recovery (Lee *et al.* 1993).

4.8.1 Depression and Anxiety

In contrast to characterological traits, emotional status refers to affective features which are more transient in nature and typically circumscribed by situational events. Emotional status therefore fluctuates over time and is related to how a person responds to a current situation. Understanding both basic personality features as well as emotional status is important when interpreting neuropsychological profiles, although it is often overlooked. These factors should, however, be considered when formulating conclusions on relevant etiological factors in determining final diagnosis as well as when rendering recommendations for therapeutic intervention. That is, symptoms which are more psychological in nature are less likely to dissipate through a normal healing process. In contrast, symptoms of neurogenic origin would be expected to resolve more readily through the expected course of recovery which has typically occurred by six months. Furthermore, psychological symptoms tend to plateau or may worsen over time whereas neurological symptoms plateau or recover. The impact of continued symptoms in terms of both the physical toll accumulated and psychological distress in response to it, together with financial concerns when individuals are unable to return to work, results in multifactorial contributions to emotional change following injury (Kay *et al.* 1992).

In the present study, only the CES group showed elevated depression akin to that of a depressed population (Beck and Steer 1987). All other group BDI ratings were significantly lower than those of a depressed population. Mild traumatic brain injured patients, whiplash patients with no discernable evidence of structural damage and low cervical cord injured patients did not meet established criteria to warrant the diagnosis of major depression yet all groups in the study exhibited variable degrees of impairment across at least some measures of attention/concentration and speed of information processing. This pattern of findings is inconsistent with the notion that these cognitive deficits are primarily attributable to depression since three of the four groups studied were not considered to be clinically depressed.

In addition, only the head injured patients in this study had impaired memory relative to a normative population while none of the whiplash groups were memory impaired on formal testing. These results do not support the attribution of forgetfulness following mild traumatic brain injury to depressive symptomatology since this group did not reach criteria for depression based on BDI ratings. In fact the average BDI score in the head injury group was lower than in any of the whiplash groups yet this group was more compromised in terms of memory functions.

In contrast to depression, all groups in this study showed elevations on both state and trait anxiety as measured by the Spielberger index. However when a single score is derived from an affective measure, it is expected that the evaluation will overestimate the prevalence of psychological disturbance in medical patients whose somatic symptoms may have a physical origin. Based on this assumption, Williams and Richardson (1993) argue that depression can be overestimated in pain patients. Few studies to date have attempted to factor analyse responses of pain patients on the BDI although item analyses have been scrutinized for other medical populations. This situation is also true in endorsement of anxiety symptoms in pain patients. Williams and Richardson (1993) found three primary factors in their attempt to more clearly delineate which symptoms contribute to elevated BDI scores in pain patients. Their results support the view that somatic concerns need to be considered separately from affective concerns as well as items concerned with self-reproach. They recommend when assessing pain patients for depression, somatic items be scored separately and their contribution to the total score appreciated so as not to exaggerate the impression of depression in patients who also experience some degree of pain. This suggests that ratings on the BDI should be reviewed on a per item basis to circumvent false positive diagnosis of depression in mild traumatic brain injured and whiplash patients who also experience pain (Kendall, Hollon, Beck, Hammen and Ingram 1987).

This situation also holds true for pain patients who show elevated anxiety ratings. Anxiety is typically characterized by such somatic symptoms as motor or muscle tension and aches, feelings of restlessness and easy fatiguability. Feelings of being keyed up or on edge, difficulty concentrating and increased irritability are also common. As well, trouble falling or staying asleep, which can be related to physical discomfort and positioning, are also typical of anxious patients. Anxiety is also commonly associated with mild depression. Trait anxiety, characterized by concern or worry for a prolonged period of time, reflects apprehensive expectations regarding one's life circumstances (Spielberger 1983). In the case of mild traumatic brain injured and whiplash patients, to experience cognitive and physical symptoms for a prolonged period of time yet not to see the possibility of relief can present a distressing situation and thereby concern for future outcome. Therefore many anxiety-like symptoms following whiplash and mild traumatic brain injury can be readily attributed to ongoing physical discomfort as well as cognitive deficits. Given symptom overlap between anxiety and chronic pain, it is clear that patients who suffer whiplash or mild traumatic brain injury have as much risk to be falsely diagnosed with anxiety as they do depression.

Future research should therefore examine item endorsement on anxiety measures of patients who experience ongoing physical discomfort and compare these results to patients who suffer lingering cognitive disruption without pain as well as to anxious patients without pain to differentiate which symptoms are primarily associated with anxiety and which are not.

4.9 Pain

In general, increases in pain severity predict increases in life interference and decreases in perceived control of pain, which together predict an increase in depression (Keefe, Dunsmore and Burnett 1992). That is, patients who experience pain, yet feel strongly that they are able to control their discomfort, will exhibit greater pain tolerance and will experience less distress while coping. Depressed chronic pain patients report greater pain intensity, greater interference in their lives due to pain and exhibit more overt pain behaviours relative to pain patients who are not depressed (Haythornwaite *et al.* 1992).

Although statistical differences between groups with respect to pain severity were not found, this relationship was otherwise surprisingly consistent with that found in the present study based on average pain ratings and is therefore considered clinically relevant. To avoid Type II errors, the following interpretation is based on patterns of relations rather than on single significant results. By so doing, a qualitative approach was adopted to supplement quantitative findings. CES patients averaged the highest pain rating and was the only group who did not differ in BDI ratings from a clinically depressed population. This group also reported greater life interference due to pain and had the lowest average general activity level than any of the other three groups. The NOEP group exhibited the same general pattern of scores on pain and depression ratings as the CES patients, although the degree of endorsement was not as high. That is, they endorsed the second highest level of pain and life interference, and had the second lowest level of pain control as well as general activity level relative to the other groups. Although these patients had significantly lower BDI scores than a depressed population, their average BDI ratings were the second highest of the four groups studied.

In comparing these two groups, it appears that the higher the level of pain severity and life interference, the lower the level of perceived pain control and general activity level, the greater the degree of depression. This pattern was most marked in the CES group and appeared, but to a less significant degree, in the NOEP group.

In contrast, although no statistical difference was found in pain intensity across groups, mild traumatic brain injured patients averaged the lowest pain level as well as interference due to pain, the highest sense of control over pain and the highest general activity level, and averaged the lowest depression score relative to the other groups. The LCSS group demonstrated the same general pattern of results but to a less marked degree than the head injured group.

In comparing the two patterns of results, an inverse relationship emerged between pain intensity and interference on the one hand, and control and activity on the other, both of which are related to depression. It is clear that as pain intensity and interference increase, perceived control of pain and general activity decreases, and depression mounts. This pattern was most obvious in the CES group and present to a less significant degree in the NOEP group. In contrast, as perceived control of pain and general activity level increases, pain intensity and interference due to physical discomfort decreases, and depression can be held at bay. This pattern was most obvious in the MTBI group and present to a lesser extent in the LCSS group.

4.10 Relationship of Neuropsychological Variables to Depression, Anxiety and Pain.

Patterns of results on pain, depression and anxiety do not correspond in a predictable way with neuropsychological profiles. Multiple regression analysis between pain severity, state and trait anxiety and depression for the delayed memory quotient of the WMS-R to represent memory functions; the attention/concentration quotient of the WMS-R to reflect attentional functions; and the first trial of the PASAT to reflect speed of information processing were all statistically insignificant.

The mild traumatic brain injured group demonstrated more global and significant cognitive deficits relative to the other three groups. That is, these patients were impaired with respect to memory, as well as on all measures assessing attentional functions and speed of information processing. On a continuum of severity, these patients were more significantly compromised compared to the three whiplash groups. Despite this, the MTBI group demonstrated the most 'psychologically well' pattern of results on pain-related variables and depression. This suggests that affective reactions may be governed more by pain-related factors than by the presence or extent of cognitive deficits.

In comparison, the CES group was generally comparable to head injured patients in term of severity of deficits on measures of attention and speed of information processing, although they were not memory impaired as were the MTBI patients. Notwithstanding physical and emotional concomitants of their injuries, the CES group was second in terms of injury severity across cognitive deficits. Unlike MTBI patients who fared well in terms of depression and pain-related variables, the CES group was the most 'psychologically unwell' compared with the other three groups with respect to depression and pain ratings.

The LCSS group fared second best with respect to neuropsychological test results. This suggests that damage to the lower cervical spine is associated with a very mild degree of cognitive "slippage" which was evident only on the 18 second delay recall trial of the CCC, the 20 second pacing of the PASAT, and the FAS. These results, together with the fact that these patients showed evidence of structural damage on medical investigation, places them second best, next to the NOEP group, if conceptualized on a continuum of severity with respect to physical injury and consequences thereof. The LCSS group had the second best 'psychologically well' profile with respect to depression and pain-related variables. Their relative wellness, psychologically, may be associated with the fact that they received a confirmatory medical diagnosis. Such a diagnosis is typically associated with prognostic information on potential recovery or lack thereof over time. However given their diagnosis, they have the assurance that once symptoms plateau, even to the point of chronicity, they are benign in nature. That is, symptoms do not typically worsen progressively even though they might fluctuate under certain conditions such as excessive physical exertion. Involvement in physical activity, however, is discretionary and therefore controllable. These factors may contribute to better psychological well-being in the LCSS group relative to the NOEP group.

The NOEP group exhibited the best overall performance on neuropsychological assessment compared to the other three groups despite subjective complaints of cognitive compromise. The fact that this group performed well cognitively, together with the fact that they showed no objective evidence of structural damage, suggests that they suffered a less significant injury on a continuum of severity relative to the other three groups with respect to the physical injury and cognitive consequences of it. Yet this group demonstrated the second highest 'psychologically unwell' pattern of results in terms of pain-related variables. While significantly different compared to a depressed population, their average depression score was the second highest among the groups. As with the other groups, these patients underwent fairly extensive medical investigations without confirmatory diagnosis on the presence or level of injury to substantiate their subjective complaints. This may contribute to escalating concern regarding the etiology of their symptoms which may generate a feedback loop, further heightening anxiety about their condition. Essentially they know they have been injured and remain symptomatic, yet have no reasonable medical explanation for their condition. Increased anxiety and depression regarding the etiology of continued complaints may, in turn, perpetuate such physical symptoms as muscle tension and headaches, thereby potentially exacerbating physical and affective symptoms.

Pain severity and coping responses to physical discomfort including activity levels, perceived control of pain, and interference in life due to pain vary in a predictable way and, together, predict the presence of depressive symptoms (Keefe *et al.* 1992). In contrast, when neuropsychological profiles are superimposed onto pain and depression, no clear, predictable pattern emerged which could account for all of the results. That is, the severity of cognitive deficits does not predict increased depression, nor do high pain levels correspond to increased neuropsychological deficits. Therefore cognitive impairments in PCS patients following whiplash or head injury do not appear to be primarily attributable to the effects of pain, coping strategies in response to pain, or personality traits. This does not preclude the possibility that whiplash patients experience pain and emotional distress to it, but rather that cognitive impairment is not necessarily secondary to these factors. This supports the belief that cognitive disruption following acceleration injury is likely of neurogenic origin. The results also suggest that cognitive deficits do not necessarily lead to depression in a predictable way.

4.11 Medication Effects.

It has been suggested that medication used by pain patients including predominantly analgesics and muscle relaxants can adversely affect neuropsychological test results particularly those related to attention and concentration. In addition, such medication has been associated with electrophysiological change characterized by " focal slowing" (Ettlin *et al.* 1992). Despite this, Ettlin *et al.* felt medication effects in their study of twenty-one whiplash patients played only a minor role on cognitive testing. Sixty-seven percent of their patient group were not using medication at the time of testing. In addition, patients using medication were no more impaired in any of the tests than those who were medication-free. Similarly, Gimse *et al.* (1997) found the idea that medication effects influence cognitive results was not supported in their study of whiplash patients. In contrast, Radanov *et al.* (1993) felt medications had a considerable effect on tasks requiring complex attentional functions such as the TMT and the PASAT in their study of common whiplash patients.

In the present study, only five of the 54 patients studied reported routine use of medication. Forty-four percent of the population reported they were no longer using any medication. Forty-six percent reported occasional use when their pain was particularly bad or when they were unable to sleep due to physical discomfort. All patients were asked to refrain from taking medication the day before their evaluation if they felt it would interfere with their performance. Since they typically used medication on a p.r.n. basis and not routinely, it is therefore unlikely that medication side-effects would account for the patterns of results obtained.

4.12 Litigation Considerations.

The impact of litigation in post-concussion cases following both mild head injury and whiplash has continued to be controversial. Differential diagnosis in an effort to distinguish PCS from malingering, in which the desire for financial compensation may contribute to production or prolongation of symptoms, is the focus of this debate (Anderson 1995). Lee *et al.* (1993) contend that exaggeration of symptoms in chronic pain patients need not be intentional. That is, psychological distress associated with pending court proceedings may influence the perception of and response to pain particularly if work status and income potential have been adversely affected by injuries incurred.

Given potential secondary gain in litigating patients following whiplash and mild traumatic brain injury, together with persistence of complaints in a subgroup of patients beyond expected time of recovery, knowledge and consideration of malingering is important on an individual patient basis for both diagnostic and therapeutic reasons. It is important to acknowledge the potential impact of secondary financial gain and to systematically examine and adopt protocols to examine potential malingering as more neuropsychologists are required to evaluate patients for litigation purposes.

Increasingly, research has focussed on detecting malingering on neuropsychological testing in patients who may contrive or exaggerate their deficits following personal injury for secondary financial gain. Although adoption of forced-choice procedures has been advocated to assess patients effort and motivation, these measures have significant limitations. It has been shown that the majority of malingerers tend not to perform below chance levels on forced choice testing (Putnam *et al.* 1996). In addition, the intent of the test is often quite transparent because of its simplicity and is therefore of limited clinical use (Putnam *et al.* 1996). In response to these limitations, and because detection of feigned or exaggerated impairment is not accomplished with a single test (Putnam *et al.* 1996), qualitative analysis of consistency/inconsistency in neuropsychological profiles has been advocated.

Examination of consistency/inconsistency in test profiles for the patient groups used in the present study was adopted to determine potential effects of malingering (Larrabee 1997). This method involves examination of consistency both within and between tests (Mittenberg, Azrin and Millsaps 1993); compatibility of results with established patterns for known disorders (eg. acceleration injuries are not typically associated with aphasia or apraxia); consistency between test performance and severity of injury; as well as consistency between test performance and behavioural presentation in interview and testing sessions (Larrabee 1997). All patient groups in the present study demonstrated intellectual potential which was within the average range. This is consistent with the finding that intellectual potential is not typically significantly diminished following mild head injury (Schwartz *et al.* 1987). Average scores on intelligence testing is also consistent with that anticipated based on education level which was not significantly different across the four patient groups. This pattern of results on intelligence testing is inconsistent with that of a malingered profile.

General memory indices were within the average range in the four patient groups and the delayed memory quotient was within average limits in all whiplash groups. Since patients were generally referred for neuropsychological assessment based on complaints of forgetfulness, it is likely that they would have selectively faked-bad on memory tests to substantiate their subjective complaints. That this was not the case argues against exaggeration of at least memory deficits.

All patient groups exhibited the same general pattern of results on measures of attention/concentration and speed of information processing albeit to varying degrees of severity. This demonstrates compatibility of results with established patterns following both whiplash injury (Radanov, Hirlinger, Di Stefano and Valach 1992a; Gimse *et al.* 1997) as well as mild head injury (Stuss *et al.* 1985). It is unlikely that all groups could malinger in such a well organized manner so as to simulate the same general pattern on the same tests. Gimse *et al.* (1997) argue that it is highly improbable that the whiplash patients they studied could accurately judge on which tests to demonstrate normal performance and on which to perform poorly if they had the intention of malingering.

This would require fairly in-depth knowledge of neuropsychological procedures which most lay people do not possess. Consistency demonstrated in neuropsychological profiles across groups in this study is also an indication that exaggeration of deficits likely did not contribute significantly to results obtained. This conclusion is supported by the work of Dikmen *et al.* (1995) who found the impact of litigation did not have systematic effects on neuropsychological outcomes when they compared results of 88 head injured patients involved in litigation with 341 who were not litigating. Further, litigation was considered a constant factor in the present study since all except one patient was involved in litigation at the time of their neuropsychological assessment. Differential patterns of results found across groups is therefore not likely attributable to either malingering or litigation. Results of the present study can, therefore, likely be generalized to mild traumatic brain injured and whiplash patients whether or not they are involved in litigation.

Summary.

It is important to recognize the complexity of the interrelationship between cognitive, affective, and physical aspects of PCS, isolating the contribution of specific symptom complexes which contribute to the development, maintenance, and perpetuation of lingering sequelae beyond expected time of recovery. Assessment of composite groups of symptoms involving neuropsychological deficits, pain related variables, and affective symptoms are clinically useful in that they unmask the unique etiological contribution of the specific groups of symptoms. More systematic analysis of symptoms associated with mild traumatic brain injury, upper cervical cord injury, lower cervical cord injury, and whiplash with no evidence of structural damage demonstrates overlapping yet unique combinations of features specific to each group of patients. This permits greater insight into the mediating processes responsible for the co-morbidity of neuropsychological deficits, pain related variables, and emotional disturbance in PCS patients vulnerable to ongoing sequelae.

Thus a matrix of factors emerge which contribute to the complexity of symptom development and maintenance in patients suffering PCS following a direct or indirect blow to the head following acceleration forces. The first component of the matrix involves the relationship between presence and level of cervical injury and the similarity in neuropsychological profiles between CES and MTBI groups versus NOEP and LCSS groups. These results support both Hypothesis I and II of the study. That is, patients who did not suffer a direct blow to the head as represented by the whiplash groups, experienced fewer and less severe cognitive compromise than patients who suffered direct head trauma. In general, the whiplash groups were not memory impaired as was the MTBI group. Other than the CES group which was as impaired on measures of attentional functions and speed of information processing as the MTBI group, the LCSS and NOEP groups were not as cognitively compromised by comparison. It therefore appears that the higher the level of neck injury, the greater the propensity for cognitive compromise, with most significant deficits observed following direct head trauma.

Hypothesis II predicted that patients with upper cervical cord injury would be more cognitively impaired in attentional functions and speed of information processing than patients in the other two whiplash groups. This hypothesis was also supported in the results of the CES group who experienced more significant impairment on the attention/concentration quotient of the WMS-R, on all trials of the CCC, TMT, PASAT, as well as in verbal fluency relative to the other two whiplash groups. This provides more comprehensive support for the differentiation of whiplash patients into separate groups based on presence and level of cervical injury as proposed by Radanov *et al.* (1992). However, Radanov's study did not rely on empirical investigation in their attempt determine comparability of CES and LCSS groups with respect to estimation of premorbid level of functioning, emotional factors, personality traits, or pain related factors. Nor did they use a comparison group which was represented in the present study by the MTBI group as well as with use of standardized, normative data.

Hypothesis III relating to NOEP patients was also supported by results of the study. The NOEP group scored higher overall than any of the other groups on the attention/concentration quotient of the WMS-R, all trials of the CCC and PASAT, and on Part B of the TMT. This supports the belief that whiplash patients who show no objective evidence of structural cervical injury are less impaired than whiplash patients who do show physical damage. Their injuries and consequences thereof are therefore less severe. Despite the relative strength of their neuropsychological profile compared to the other three groups, they were impaired on several measures of attentional functions and speed of information processing when compared to normative data.

Finally, it was hypothesised that cognitive deficits associated with PCS following whiplash and mild traumatic brain injury would be independent of levels of pain and coping responses to physical discomfort; emotional disturbance; and personality traits. This hypothesis was also supported by test results. None of the groups exhibited personality disorders as measured using the MCMI. A predictable pattern emerged with respect to pain. coping strategies in response to pain as well as depression. That is. as perceived pain intensity and interference due to physical discomfort increased. ability to control pain and activity levels decreased, and patients were more susceptible to depression. This pattern was most apparent in the CES group and tended in the same direction in the NOEP group. In contrast. as perceived control of pain and activity levels increased. pain intensity and interference decreased, which rendered patients with this profile less susceptible to depression. This pattern was most obvious in the head injured group and tended in the same direction in th LCSS group. That these patterns of results were not predictive of neuropsychological profiles suggests that they are based on different etiological origins.

5.1 Directions for Future Research

Whiplash injuries represent a significant public health problem throughout the world, with significant socio-economic consequences. Etiology of chronic symptoms remains controversial (Teasell and Shapiro 1998; Larrabee 1997). The present study provides promising preliminary results in identifying potential etiological factors associated with ongoing cognitive, physical and affective symptoms following both whiplash injury as well as mild traumatic brain injury. It appears that the presence and level of cervical injury is an important factor in determining the degree of cognitive compromise following whiplash. The validity of characterizing unique symptom complexes which evolve following whiplash may contribute to identification of syndromes specific to CES, LCSS and NOEP groups. However this study should be replicated with a much larger sample size before definitive conclusions can be drawn and extrapolated to clinical cases.

Future research should also address the question of whether other patient groups suffering trauma, depression and anxiety, or pain show similar neuropsychological deficits with a similar or differing profile of results from the groups used in this study. This is particularly important in pain patients since there is a decidedly small body of empirical data assessing cognitive functions in this population. Despite lack of research, it is often assumed that pain has a deleterious effect on cognitive acuity. Item analysis of the Beck Depression Inventory (BDI) for use in pain patients has begun and it has been recommended that the contribution of physical symptoms be analysed separately in order to avoid false-positive diagnosis of depression in pain patients. Despite these recommendations, this practise has not been generally applied in either clinical or research protocols. However such a practise would provide more accurate information on the etiology and treatment of the various symptoms suffered by whiplash patients. The same principle also holds true for anxiety-like symptoms suffered by these patients. Whiplash and mild traumatic brain injured patients are too often considered to be neurotics when their symptoms persist following the expected time of recovery. This conception is reinforced when they exhibit high scores on anxiety inventories despite the fact that there is considerable overlap between anxiety symptoms and those associated the physical injury suffered. Patients may, therefore, also be at risk of false-positive diagnosis of anxiety. Item analysis of anxiety inventory scores in pain and cognitively compromised patients would be beneficial given the paucity of research in this area.

Research suggests that symptoms which occur within the first several months following mild traumatic brain injury, including whiplash injury, are physiogenic in origin. Despite the proposal that protracted symptoms are likely attributable to other factors such as psychological variables or litigation (Binder and Willis 1991; Binder, Rohling and Larrabee 1997), few studies exist which empirically address the etiology of prolonged neuropsychological deficits due exclusively to nonimpact acceleration forces (Sweeney 1992).

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Appendix A. Normative Data for Neuropsychological Variables

Test	N	Mean	s.d	Reference
WAIS-R FSIQ	250	100	15	WAIS-R Manual 1981
GMQ	54	100	15	WMS-R Manual 1987
DMQ	54	100	15	WMS-R Manual 1987
Attn Con	54	100	15	WMS-R Manual 1987
CCC 9"	10	12.8	1.8	Stuss *et al.* 1987
CCC 18"	10	12.2	3.0	Stuss *et al.* 1987
TMT A	10	21.9	6.3	Stuss *et al.* 1987
TMT B	10	46.3	13.7	Stuss *et al.* 1987
PASAT 2.4	30	43.4	10.2	Stuss *et al.* 1988
PASAT 2.0	30	41.9	10.2	Stuss *et al.* 1988
PASAT 1.6	30	33.1	12.2	Stuss *et al.* 1988
FAS	45	44.75	5.81	Yeudell 1986
WCST C	100	5.6	1.0	Spreen & Straus 1991
WCST Pe	100	10.4	8.0	Spreen & Straus 1991

Appendix B. Medication use by patient group.

	Drug Use		
Group (N)	Routine	Occasional	None
NOEP (13)	0%	54%	46%
CES (10)	20%	50%	30%
LCSS (21)	14%	43%	43%
MTBI (10)	0%	40%	60%

Appendix C. Means and Standard Deviations for Neuropsychological Tests in Each of the Four Patient Groups.

	NOEP	CES	LCSS	MTBI
	N=13	N=10	N=21	N=10
Age	32.2 (12.4)	38.3 (10.3)	37.4 (10.1)	28.1 (13.8)
FSIQ	108.3 (12.7)	99 (9.8)	103.8 (11.3)	102.8 (12.0)
GMQ	107.6 (11.5)	98.4 (12.9)	98.3 (13.5)	94.5 (18.2)
DMQ	104.1 (15.1)	98.9 (19.6)	96.9 (14.9)	86.7 (21.6)
Att/ConQ	101.1 (10.8)	86.4 (16.4)	95.8 (15.6)	89.9 (18.5)
CCC 9"	10.9 (3.1)	8.4 (2.3)	9.52 (2.9)	8.2 (3.1)
CCC 18"	9.08 (3.7)	6.3 (2.1)	7.09 (3.5)	4.8 (3.8)
TMT A	27.8 (11.4)	35.1 (8.0)	27.38 (8.6)	36.95 (12.7)
TMT B	70.7 (11.1)	78.5 (22.3)	64.9 (26.6)	82.8 (30.2)
PASAT 2.4	39.8 (11.1)	31.2 (7.9)	38.6 (12.2)	29.7 (5.4)
PASAT 2.0	34.7 (10.8)	25.2 (5.3)	32.8 (12.3)	27.3 (7.8)
PASAT 1.6	30.7 (14.8)	20.8 (7.8)	27.9 (11.6)	24.8 (5.8)
FAS	38.1 (7.8)	31.9 (12.8)	40.5 (16)	32.4 (11.1)
WCST Cat.	5.6 (1.1)	5.5 (1.2)	5.8 (0.45)	6 (0)
WCST P.err.	9.2 (7.4)	7.5 (4.5)	10.1 (8.2)	7 (7.5)

Appendix D. Means and Standard Deviations for Psychological Tests in Each of the Four Patient Groups.

	NOEP	CES	LCSS	MTBI
Age	32.2 (12.4)	38.3 (10.3)	37.4 (10.1)	28.1 (13.8)
BDI	15.6 (9.5)	23.7 (9.9)	13.1 (7.0)	10.6 (10.1)
State Anx.	47.6 (14.4)	51.6 (18.1)	40.8 (13)	44.9 (18.9)
Trait Anx.	45.5 (12.4)	51.25 (17.8)	44 (10.2)	45.9 (11.4)
Pain Sever.	4.23 (0.8)	4.6 (1.3)	3.97 (0.8)	3.8 (1.6)
Interference	4.7 (1)	4.8 (.08)	4.5 (0.9)	3.8 (1.6)
Pain Control	2.6 (1.4)	1.9 (1.3)	3.0 (0.9)	3.4 (1.2)
Act. Level	1.7 (0.9)	1.8 (0.9)	2.3 (1.0)	3.4 (1.4)