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Neuropsychological Changes Following Computer-driven Cognitive Remediation of Severe Traumatic Closed Head Injured Patients

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A Thesis

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ABSTRACT

Neuropsychological Changes Following Computer-driven Cognitive Remediation of Severe Traumatic Closed Head Injured Patients

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Concordia University, 1991

The controversy regarding the efficacy of computer-driven cognitive remediation has been an ongoing concern in the remediation of closed head injured victims for many years. There also exists a pervasive notion that closed head injury patients are limited in their ability to learn beyond the immediate learning exercises. This thesis will evaluate the effectiveness of computer-driven cognitive remediation and possible generalization of learning on neuropsychological tests.

Two groups (experimental, control, n = 17 each) were group-matched on sex, age, education, percentage vocabulary score, coma duration, presence/absence skull fracture, and percentage of neuropsychological test deficits at pre-test. The experimental group, following the structured interview and neuropsychological assessment, received two weekly sessions of two hours each for a period of six months of computer-driven cognitive remediation exercises. The computer exercises were presented to experimental patients in a hierarchical order of difficulty. The exercises trained attention, visuospatial skills, memory, auditory discrimination, and problem solving skills. The control patients received comparable hours of "standard" rehabilitation unrelated to cognitive remediation. Following six months of therapy all patients were reassessed using the same test battery.

Univariate ANOVAs (experiment-wise adjusted) demonstrated no significant interactions. The ANOVA on averaged Z scores of the entire battery, however, demonstrated a significant interaction. The control patients showed a significant decline in neuropsychological performance six months following initial assessment, whereas the experimental patients improved non-significantly.

Results failed to support the notion that computer-driven cognitive remediation produces benefits five years after injury. Due to the lack of significant improvements it is not possible to endorse widespread use of computer-assisted remediation in clinical practice. The results also support the view that closed head injured patients are limited in their ability to generalize from the training exercises to tasks that are similar in cognitive structure. However, the results also demonstrated that there is "spontaneous" decline in performance in untreated patients. This significant decline in control patients points to the importance of maintaining cognitive activity to prevent mental deterioration.

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Finally, I would like to dedicate this thesis to my only son Alex, who I know missed out on mothering throughout these long years.

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INTRODUCTION

A: HEAD INJURY

1: Head injury, epidemiology, implications, and sequelae

Road accidents account for half of all traumatic closed head injury (CHI) and 70% of the brain injuries resulting in coma (Kalsbeek, McLaurin, Harris, & Miller, 1980). Other accidents (e.g., various tumours, intracranial vascular accidents-strokes, aneurysms, thromboses, and missile wounds) account for the balance of the brain injuries. The two current classifications of head injury, however, are missile injury (e.g., gunshot wounds) and traumatic CHI where nothing penetrates the brain (which excludes any primary cerebral vascular accidents or strokes or tumours).

Victims of road accidents are primarily young males between 16 and 24 years of age (Annegers, Grabow, Kurland & Laws, 1980; Lee, 1989), who mainly come from low socioeconomic backgrounds (Kerr, Kay & Lassman, 1971). They have often consumed illicit drugs and/or alcohol just prior to the accident (Field, 1976).

In the investigation of head injuries, it is essential to differentiate those caused by blunt impact from those caused by other injuries (e.g., missile wounds). The importance of distinguishing CHI resulting from road accidents from other head injuries, relates to differences in the neuropathology and the consequences for the individual. For example, in CHI resulting from road accidents there is diffuse brain damage. In contrast, other injuries present with a more circumscribed lesion. Additionally, the former more often results in unemployment and long term care of the patient compared to the latter injuries which are functionally more manageable and less devastating. This project will focus on CHI that results from road accidents rather than any other head injury. Hence, the term CHI will refer to injury following such events.

Blunt trauma to the head, following road accidents, result from diffuse stress imparted to the brain. Primary neuropathological sequelae include brain lesions due to either linear and/or rotational, decelerational, or accelerational forces that most often cause diffuse damage. Post mortem studies of traumatic CHI patients have demonstrated that there are widespread microscopic and macroscopic lesions especially in the fronto-temporal areas (Alexander, 1982). These lesions result primarily when the brain strikes the inwardly projecting rugged ridges and rough surfaces of the inner skull. The severity of diffuse brain injury is an important determinant of recovery.

Secondary to this type of injury

neuropathological sequelae such as oedema, brain-shifting and intracranial hematoma can result, often causing additional damage. Microscopic and microvascular lesions are also found throughout the brain (Miller, 1984). Lesions also occur within the brain stem and sub-cortical white matter (Strich, 1979). Subcortical lesions are usually found in conjunction with cortical lesions resulting from the pressure exerted by brain swelling or other brain deformations (Teasdale & Mendelow, 1984).

Loss of consciousness following head injury is widely viewed as a characteristic feature of acute CHI. Disruption of the reticular formation in the brainstem has been implicated in the onset of coma especially with rotational acceleration. Coma is usually defined as the absence of eye opening, inability to obey commands, and failure to utter recognizable words (Teasdale & Jennett, 1974). The depth and duration of coma are considered as the most useful indicators of brain damage. These are most often determined using the Glascow Coma Scale score (the lower this score the more severe the coma).

2. Incidence of CHI

Although there seems to be no way to avoid the sequelae of CHI, improved ambulatory care, improved diagnostic tools, decreased speed limits, and the mandatory use of seat belts may have a preventive effect. Quebec statistics have shown an increase in the number of car accidents from two percent in 1983 to 12 percent in 1984 (Quebec Office on Statistics, 1985-1986). The incidence of survival following these accidents has increased by 58 percent in Canada from 1973 to 1983 (Dumas, 1987). This remarkable increase in the rate of survival from severe CHI during the last 20 years, indicates that there are an impressive number of posttraumatic victims with important behavioral deficits who must be helped to reach some level of satisfactory life adjustment. Hence, the provision of appropriate remediation services for these head-injured survivors is of major importance.

3. Cognitive deficits and other effects of CHI

In survivors of CHI, brain damage ultimately results in impaired intellectual and cognitive functioning most often corresponding to well-defined neuroanatomical structures. Cognitive deficits refer to difficulties in information processing which alter the ways in which the person experiences and responds to environmental stimuli (Ben-Yishay & Diller, 1981). Hence, cognitive deficits following CHI are measurable and are often a consequence of some form of structural lesion that can be measured. Neuropsychological assessment enables us to identify the particular cognitive dysfunctions resulting from structural deficits.

Numerous studies have indicated that severe traumatic CHI can have profound and prolonged physical and cognitive effects on the victim. Individuals who survive their injuries frequently experience various sensory and motor deficits, but the cognitive deficits are more debilitating since they are usually unnoticeable hence, not treated. Cognitive deficits following severe CHI have been intensively studied and widely reported in the literature. For example, poor performance has been documented in the literature for concentration and mental tracking (Gronwall & Wrightson, 1981), language (Sarno, Buonaguro & Levitta, 1986), information processing (Wilson, Brooks & Phillips, 1982; Van Zomeren & Deelman, 1978), processing of pragmatic and facial affective information (Braun, Baribeau, Ethier, Daigneault & Proulx, 1989; Prigatano & Pribram, 1982), sustained, controlled, and divided attention (Brouwer, Pijl, Van Zomeren & Rothengatter, 1984; Little, Goldstein, Klisz & Rosenbaum, 1985; Stuss, Ely, Hugenholtz, Richard, LaRochelle, Poirier & Bell, 1985; Van Zomeren, 1981), resistance to distraction (Lezak, 1983), memory (Brooks & Aughton, 1979; Brouwer, Brettschneider, & Deelman, 1984;

Levin, Grossman, Rose & Teasdale, 1979; Squire, 1986), humour appreciation (Braun, Lussier, Baribeau & Ethier, 1989), and socio-affective adaptation (Jackson & Moffat, 1987; Levin, Benton & Grossman, 1982; Oddy, Hamphrey & Uttley 1978b; Wood, 1984).

Although recovery of cognitive function may occur with the passage of time, more severely injured individuals are left with significant social and cognitive deficits that are catastrophic and prevent them from being gainfully employed or from being autonomous (Drudge, Williams, Kessler & Gomes, 1984; Levin, et al., 1979; Uzzell, Langfitt & Dolinskas, 1987). Brain injured individuals must live with the prospect of 30 to 40 more years of a disabled life. Although a large burden rests with their families (Oddy, Humphrey & Uttley, 1978a), in most cases of severe CHI the heavy financial burden ultimately rests on social support systems (e.g., short-term hospital rehabilitation, long-term rehabilitation centers, etc.) that are implicated in short and long-term care of these patients (Brooks, et al., 1984).

4. Spontaneous recovery following CHI

Spontaneous recovery refers to the brain's healing process that is unaided by treatment or any other intervention. As the brain heals itself, brain function also begins to recover. For simplicity, this process will be refered to as "spontaneous recovery" from hereon. Spontaneous recovery following head injury is maximal during the first year but continue to occur to a lesser degree beyond this period (Miller, 1984) especially for memory functions (Squire, 1986).

The nature and speed of cognitive recovery have been well documented in the literature suggesting that the recovery of function in CHI patients may be negatively accelerated (Artiola i Fortuny & Hiorns, 1979; Bond & Brooks, 1976: Brooks & Aughton, 1979; Hiorns & Newcombe, 1979; Lezak, 1979; Van Zomeren & Deelman, 1978). However, repeated testing used in these studies to estimate the natural history of recovery presents methodological problems in trying to separate practice effects from genuine recovery. Practice effects may simply indicate that the patient is capable of profiting from familiarity (i.e., repeated exposure to the given task) despite his/her deficits. Distinguishing between the process of practice and genuine recovery has obvious theoretical (further discussed below) and clinical implications. Some strategies in dealing with this problem include using control groups or alternate forms of tests.

B: REMEDIATION IN CHI PATIENTS

1. Remediation issues

Beyond immediate life sustaining care, modern conventional medical therapies can do little to restore lost cognitive functions following head injury. With respect to cognitive recovery, Luria (1973) discussed how there is considerable overlap in neural innervation in the central nervous system. However, specificity of function within the central nervous system is maintained primarily through inhibition. Brain damage does not obliterate an entire functional unit and its subunits unless the damage is very extensive. Recovery of function, therefore, following brain damage may occur through disinhibition. That is, given that the "primary" functional unit is damaged but not its subunits, then these subunits that were initially inhibited by the dominant area are now activated through disinhibition. These subordinate units somehow compensate or "mimmick" the lost function to a certain degree allowing for some residual function. This process may take the form of reorganization in the brain. Perhaps with structured and sustained mental activity (i.e., cognitive remediation) this process is fascilitated following CHI. Hence, teaching an individual to engage in specific mental acitivity may encourage behavioral/functional plasticity. In this regard it is also hoped that this basic trained function may underly a number of skills required in other similar situations. Hence, the hope is that the trained function will generalize to other situations having this funtion as a sub-requirement for optimal performance (e.g., attending may facilitate memory). This study on the other hand, will not address itself to selective arborization within the central nervous system using a cognitive remediation approach.

The onus is on those involved in cognitive remediation who must focus on training the victims in basic functioning (e.g., initiating responses, making differential responses, improving various memory functions or problem solving skills, etc.) that are required to carry out simple everyday activities (e.g., self-care).

Cognitive remediation therapy may be viewed as a systematic attempt to reduce these resultant intellectual and cognitive deficits that undoubtedly interfere with the processing of information. Cognitive remediation is a quickly growing specialty which attempts to help CHI patients to regain some level of functional competency in order to resume a more complete social role (Stambrook, Peters, Moore, Deviaene & Hawryluk, 1988). Indeed, the proliferation of remediation programs to treat CHI victims reflects recent accentuation of litigation (e.g., social services, insurance) and development of various organizations that most often provide funding for survivors (e.g., The National Head Injury Foundation).

2. Generalization abilities in CHI patients

In cognitive remediation and research a given deficit is often studied or remediated in isolation. Deficits in CHI victims, however, do not occur in isolation. Rather, CHI victims present with diffuse impairment as well as focal damage. Since the majority of CHI patients do not have single specific deficits, the hope for cognitive remediation therapies which attempt to retrain multiple functions, is that patients will apply trained skills in a number of different contexts. Therefore, it is hoped that this approach would be more efficient than training a given skill in isolation. Such an approach relates to the individual's ability to go beyond or generalize from one situation to another similar situation.

According to Gordon (1987) generalization can occur on three levels. Level one generalization is the most basic. At this most basic level it is expected that the result of cognitive training should persist from one training session to the next, or on alternate forms of the training materials. Level two generalization is a more complex type of generalization. This occurs when improvement is noted on psychometric tests that can be similar to or different from the trained task demands. Level three generalization is the highest order of generalization. This involves the transfer of what has been learned in training to everyday functioning (see Ponsford & Kinsella, 1988; Scherzer, 1986). For example, training attention with the hope that this will lead to improved performance on a number of measures requiring attention.

3. Clinical predictors and/or confounds in CHI remediation

Isolated clinical reports indicate that a significant proportion of CHI patients can be helped to live autonomously and often return to gainful employment (Ben-Yishay & Diller, 1981; Scherzer, 1986; Stambrook, et al., 1988). However, most often, these patients are mildly head injured and only a small proportion of them can return to gainful employment (this issue is further discussed below). Additionally, previous remediation attempts have involved multidisciplinary teams working in unison over an extended period of time, hence tending to be very expensive in manpower, time and money.

To date, there exists a paucity of well controlled experimental research related to cognitive perceptual remediation in this population. Therapists have reported that considerable time and effort were required to attain minimal gains, with frequent references to the problem of staff burn-out.

There are a number of variables that may influence cognitive remediation efforts. Prospective studies have found that psychosocial and emotional symptoms are perceived as being less problematic by patients than by relatives (McKinlay, Brooks, Bond, Martinage, & Marshall, 1981; Oddy, et al., 1978a). The discrepancy might be related to what has often been reported as a lack of insight (e.g., inability to predict when and where errors are made) on the patient's part following CHI (Dolon & Norton, 1977; Johnston & Diller, 1983; Wolfe, Dennis & Short, 1984).

Comparisons between symptom reports (i.e., emotional, social, cognitive, vegetative changes following traumatic CHI) of CHI patients and their relatives before and after cognitive remediation indicated that the perceived symptom discrepancy remains unchanged following cognitive therapy (Braun, Baribeau & Ethier, 1988). This factor (i.e., perceived symptoms), which can be equated with a form of awareness (Diller & Gordon, 1981), can potentially impede efforts to remediate such patients (Johnston & Diller, 1983). Compounding other deficits, lack of anticipatory behavior (e.g., insight) by CHI patients may be problematic in the remediation process (Freedman, Bleiberg & Freedland, 1987).

Other variables influencing cognitive remediation outcome include age, education, chronicity (i.e., elapsed time since injury and commencement of therapy or assessment), and extent and depth of trauma (i.e., severity) (Bricolo, Turazzi & Feriotti, 1980; Lewin, Marshall & Roberts, 1979; Timming, Orrison & Mikula, 1982). Coma duration is one of the most reliable indicators of severity (Levin, et al., 1982) and has been found to correlate with CHI outcome (Williams, Gomes, Drudge & Kessler, 1984) and performance during remediation therapy (Ethier, Baribeau, & Braun, 1989; Ethier, Braun, & Baribeau, 1989).

The above literature supports the conclusion that there are various issues and variables which should be considered before conclusions can be made regarding the usefulness of remediation of CHI patients. Some research studies have failed to control for these variables. Such studies often confuse rather than elucidate the issue of efficacy of remediation of CHI patients.

C: EFFICACY OF MICRO-COMPUTER-ASSISTED REMEDIATION IN CHI

1. Micro-computers and their advantages

With the advent of the micro-computer, remediation of CHI may become more manageable. Computer-assisted cognitive therapy is thought to have many advantages. For example, computers are reliable and tireless compared to human therapists. They provide immediate and accurate feedback to the user. The reduced cost of computers now makes them more readily attainable. Additionally, most available computer programs provide the flexibility of choosing rate and time of stimulus exposure as well as the level of difficulty to meet the patient's need. Clinicians ascribe them as useful adjuncts and prosthetic tools (see Lynch, 1984b for applications of computer technology).

2. Anecdotal observations

In the last 15 years various anecdotal reports have been published regarding the benefits of cognitive remediation with the aid of micro-computers. Bracy (1983), Gianutsos (1982) and Lynch (1983, 1984a,b) are all firm believers in the benefits of using computers for cognitive remediation of head injured individuals. Each in turn has publicly discussed (Bracy, Lynch, Sbordone & Berrol, 1985) and written extensively about the benefits of using such a tool based on anecdotal observations of individuals with varying symptomatologies and etiologies.

Gianutsos (1982) presented a case of a 23 year old air force veteran who suffered severe CHI, was in a coma for 3 months and was treated a year and a half following a motorcycle accident. This patient received cognitive remediation for free recall and also received home-based computer remediation with minimal supervision. The author reported improvements in the trained skills. Hence, she ascribed benefits in using such an approach. Although such a report cannot be discounted, it is difficult to evaluate its scientific value since, among other methodological difficulties, no baseline measures were presented.

Similarly, Lynch (1984c) reported on four individuals with varying etiologies (one right frontal cerebrovascular accident, one cerebellar tumour, and two with diffuse trauma). All patients showed some progress on the practiced exercises (e.g., Space Invaders, Caverns of Mars, Simple visual reaction time, and Visual reaction differential response). However, there were no matched controls. As well, the patients had heterogeneous etiologies which complicates comparison between them. Finally, patients did not receive similar exercises and performance scores were not standardized, hence it is impossible to compare across exercises and between patients.

This type of anecdotal reporting which promotes the use of the micro-computer as a therapeutic tool may have caused a ripple of unrealistic expectations. One should not assume that replication of the putative treatment effects are likely. More systematic studies would be required to investigate the efficacy of computer-assisted cognitive remediation.

Research designed to investigate the efficacy of cognitive remediation typically employs one of two methodologies, namely single case designs and group designs.

3. Evaluating the efficacy of remediation using single case designs

A few case studies have reported on cognitive remediation with (Alan & Finlayson, 1983; Finlayson, Alfano & Sullivan, 1987; Robertson, Gray & McKenzie, 1986) and without (Crosson & Buenning, 1984; Major, Favreau, Spivack & Gerber, 1982; Sohlberg & Mateer, 1987) computer aids. Although the focus of this thesis relates to computer assisted cognitive remediation, some studies which did not involve this technology will be presented to support or to elucidate a point.

Glisky and her colleagues at the University of Toronto have attempted to address the issue of learning and memory function with the aid of computers (Glisky & Schacter, 1989; Glisky, Schacter & Tulving 1986a,b). They reported improvements in memory performance. However, it is difficult to dissociate more general skill improvement per se from practice effects since they looked only at performance changes across trials. Although they demontrated computer learning under highly constrained conditions, comparisons across cases were not possible since etiologies varied. It is interesting to note that patients could acquire and retain the computer-related vocabulary after a delay of six weeks (i.e., level one generalization). In addition, new learning attained by the method of "vanishing cues" was shown to be superior (e.g., more rapid and flexible) than rote repetition procedures.

One important issue to consider is whether increasing scores on a given task reflects enduring skill improvement (level one generalization) as opposed to task-specific practice effects. Dissociating practice effects would require outcome measures which are different from those used to train the patients.

The finding that patients were unable to respond when questions were not worded in the identical manner as in the training program suggests that patients may have been unable to generalize to similar trained skills even with minimal changes (i.e., alternate forms of the task) (Glisky et al, 1986b). Since the flexibility of applying a learned skill to a different but somewhat similar situation is a prerequisite for everyday functioning, the issue of generalization beyond the training tasks (i.e., beyond level one generalization) warrants further investigation. Hence, this question is critical when evaluating the benefits of an intervention program. One question that arises from this is the degree of task remoteness from the training exercises to the criterion task. This issue remains unaddressed in CHI patients, as far as the present literature review allows to ascertain.

Although Major et al. (1982) did not use computer-driven cognitive remediation exercises, they attempted to remediate verbal deficits in a 32 year old male 10 months after CHI. The patient received bi-weekly one hour training sessions over 8 weeks. These authors measured therapy benefits by investigating pre-treatment and post-training performance (i.e., level two generalization) on verbal skills that differed from training tasks (e.g., they looked at Wechsler Adult Intelligence Scale (WAIS) subtest scores, the Token test, and the Controlled Word Association Test). They reported a significant improvement only on the arithmetic subtest of the WAIS, and attributed this increase to improved attentional ability that resulted from engaging in a variety of verbal tasks which they believed improved concentration abilities. However, since multiple generalization measures were used (i.e., 10) the probability of attaining significance purely by chance was greatly enhanced since the alpha level was not adjusted. Moreover, the arithmetic subtest on the WAIS is more susceptible to practice effects than any of their other measures (e.g., digit span) especially when short post-test intervals are used (8 weeks in this study).

Similarly to Major et al. (1982), Sohlberg & Mateer (1987) attempted to evaluate the effectiveness of an attention-training program. In this study four cases were studied varying in etiology (two CHI, one aneurysm, one gunshot wound) and chronicity. They were somewhat similar in age, sex and education. They received intensive remediation (seven to nine weekly) sessions for five to ten weeks during an eight month period of attention training exercises. During this period, patient performance was evaluated at regular intervals over the training course using the Paced Auditory Serial Addition task (auditory processing) and the Spatial Relations test (visual processing). At least eight measures were obtained on each of these two tests before, during, and after training. The authors concluded that all patients improved from baseline and maintained these improvements up to eight months later, when they were last tested. However, these results must be interpreted with caution due to repeated use of independent measures which may have introduced a confound of practice effects.

Other case reports also support the view that patients benefit from computer-driven cognitive exercises (Alan & Finlayson, 1983; Finlayson, et al., 1987; Robertson, et al., 1986). Alan and Finlayson (1983) showed how a young female patient manifested interval gains on repeated neuropsychological testing (e.g., on the WAIS-R, the Wechsler Memory Scale, etc.) following remediation. Based on these results they concluded that the micro-computer can be an effective and efficient tool in a cognitive remediation program. However, since remediation was given during the interval of 10 to 50 weeks after injury, it is difficult to tease apart how much of a gain resulted from spontaneous recovery or from the therapy per se.

Robertson, et al., (1986) addressed the issue of whether generalization occurs on related trained function following computer-driven procedures. Using a single case design, they attempted to remediate four patients with varying etiologies (one with right middle cerebral artery infarction, two from traumatic head injuries following car accidents, and one with sub-arachnoid and intra-cerebral hematoma following a fall). Based on their results, the authors concluded that cognitive remediation procedures given by micro-computer can result in generalization to tests related to the trained function yet not used as the training tools (i.e., level two generalization). However, since remediation of these patients was given during the period where spontaneous recovery occurs, it is difficult to attribute, at least in whole, any benefits to the treatment itself (i.e., an improvement may occur independent of intervention). Moreover, there were no control patients employed. These authors rightfully conclude that their results do not justify the recommendation that micro-computer cognitive remediation be implemented on a widespread clinical basis.

Finlayson, et al. (1987), in contrast to Robertson et al. (1986), hold that micro-computers are well suited to remediate cognitive deficits. These authors reported improvements on neuropsychological measures (e.g., the WAIS, various Halstead Reitan tests -- the Categories test, the Speech Perception, the Seashore Rhythm test, Finger tapping, the Tactual Performance Test, the Trail Making Test, the Grooved Pegboard test, and Grip Strength) following computer-driven exercises in a female patient. However, whether these results support the potential efficacy of micro-computer based cognitive remediation is difficult to determine since the patient was tested during the period of spontaneous recovery and the follow-up period was not specified.

Reports of computer-assisted remediation using single case design, similar to anecdotal observations, present with somewhat similar methodological difficulties. It is difficult to generalize from such a design given that the experiments were not repeated several times on the same patient.

Group studies in cognitive remediation are better able to tease apart benefits of cognitive remediation therapy by looking at the interaction effect between group effects and treatment effect (i.e., pre-post criterion test score changes by group-experimental versus control) (Brooks, Deelman, Van Zomeren, Van Dongen, Van Harskamp & Aughton, 1984). Hence, group studies can consider statistical significance as well as clinical significance.

4. <u>Evaluating the efficacy of remediation using group design</u>

The issue of spontaneous recovery and the format of treatment presentation were most often not considered in the above case studies. It has been well documented that during the acute phase (i.e., the first three months) and for up to one year following head trauma, CNS recovery is at a maximum and occurs independently of remediation (Brooks, et al. 1984; Kertesz & McCabe, 1977; Vignolo, 1964).

Vignolo (1964) found no significant statistical differences between 42 treated aphasics and 27 untreated aphasics during the spontaneous recovery period suggesting that recovery occurs independently of treatment during this period. These results were later corroborated by Kertesz and McCabe (1977).

A further indication that therapy effects should not be tested during the recovery period come from Batchelor, Shores, Marosszeky, Sandanam and Lovarini (1988). These researchers demonstrated that during this period, two groups of CHI patients did not respond differentially to computerized versus noncomputerized cognitive remediation.

Ponsford and Kinsella (1988) found that once both spontaneous recovery and practice effects were controlled, there was little response to computer remediation in 10 severely head-injured patients. This study suggests that previous reports, from both case and group studies that found cognitive improvement following remediation, may have been confounded by spontaneous recovery.

The format of treatment presentation is another issue of practical concern. This parameter refers to whether frequent spaced sessions are more effective than massed trials. Traditional experimental psychology predicts that short frequent practice sessions in "normal" non CHI individuals might be more effective than massed sessions. Whether this applies for head-injured patients is an important research question.

Two studies by Ethier and colleagues (1989a,b) controlled for spontaneous recovery and addressed the issue of presentation format. These researchers evaluated the efficacy of computer-driven cognitive-perceptual training in 22 severe cases of traumatic CHI. These two studies were the first to address these issues and to use such a large sample. The patients' chronicity ranged between 12 and 204 months in these studies. Patients were required to practice various computer exercises (e.g., speeded and non-speeded exercises) over a period of six months in either a spaced (i.e., one completion of a given exercise in each of the 10 sessions) or massed (i.e., 10 repetitions of a given exercise within one session) practice condition. The results of both these studies indicated that, similar to traditional experimental psychology findings, it appears preferable to space practice sessions on both speeded and non-speeded exercises over several days rather than to mass the practice within a single session.

The only exception to this form of general conclusion (i.e., spaced practice) was related to memory exercises for which benefits are greatest within a massed condition. Memory related exercises are probably more beneficial (with respect to performance over trials) in a massed condition because memory traces may strengthen with immediate repetition and memory decay does not occur as readily as in spaced practice. In addition, these patients manifested greater performance improvements on untimed self-paced exercises than timed tasks. These findings have important theoretical and clinical implications in the design of training programs for CHI populations. Although both of these studies controlled for spontaneous recovery and also addressed the issue of format of treatment presentation, they looked at very basic generalization (level one) and they did not use a control group nor did they address the question of whether cognitive remediation may or may not be generalized.

A major problem inherent in many studies of cognitive remediation is related to the confounding of results by using the training exercises as assessment tools. The tool used to assess an underlying function is also often used as the primary training exercise. In order to support a claim of an improved underlying cognitive process, the change in the dependent measure must not be a mere reflection of practice effects or simply task familiarity. Ideally, more complex generalization abilities in CHI must be addressed.

Systematic and controlled scientific group research are non existent in the literature with the exception of a few studies with methodological limitations or which did not employ micro-computers for remediation (Malec, Jones, Rao, & Stubbs 1984; Miller 1980; Ponsford & Kinsella 1988; Prigatano, Fordyce, Zeiker, Roueche, Pepping & Case Wood 1984; Ragain 1983).

Miller (1980) addressed the issue of generalization and also used a control group. This researcher investigated learning and transfer of training in head injured patients using a non computerized psychomotor task. The patients were required to fit the appropriately shaped block into its corresponding hole on a rectangular board as quickly as possible. There were 5 trials for each of the five, 58 hole, boards used. Level one generalization was measured by looking at performance time improvement across boards. Transfer of training occurred from board to board in that the time to complete each board decreased within board and between boards. The experimental patients' performance level approached that of age-matched neurologically intact controls.

These results suggest that learning may occur with practice and can be generalized to similar situations. However, this study did not address the spontaneous recovery issue. It also used neurologically intact controls. The groups were not closely matched on most variables known to affect outcome. It evaluated only tasks used in training as opposed to different outcome measures with similar underlying cognitive functions. One good generalization measure (and perhaps a more valid test) that could have been used in this study, which is very similar to the training tasks, is the Tactual Performance Test.

Malec et al., (1984) and Ragain (1983) investigated the efficacy of video games in cognitive remediation. Both studies looked at changes in neuropsychological test scores following video game practice. Despite some methodological difficulties, both studies did not support the use of video games as being beneficial in cognitive remediation. Similarly to the patients studied by Glisky and colleagues cited above, these patients were also unable to generalize from the training games to neuropsychological test measures.

It is possible that because video games cannot be modified to control for individual needs, their utility in the rehabilitation setting is limited. Perhaps a more important consideration is whether the treatment tasks (i.e., video games) have similar underlying cognitive structures as the neuropsychological test measures used. Moreover, video games may not provide sufficient feedback to the patient so as to enable him/her to make adjustments in his/her approach. The importance of appropriate reinforcement in the form of adequate and consistent feedback has been well documented in CHI patients (Dolan & Norton, 1977; Wolfe, et al., 1984). Simply seeing test scores (as in video game practice) or providing "yes-no" feedback to the patient may be insufficient to alter and/or sustain performance. Verbal reinforcement, perhaps in the form of verbal praise, acknowledgement by various facial or bodily gestures, and various visual approaches (e.g., reliable immediate consistent performance feedback and graphing of performance across trials and time) may help to keep the patient constantly aware of his/her behavioral patterns. This approach may help the patient alter and/or correct his/her behavioral response.

A study by Prigatano et al. (1984) is one of the better methodologically controlled group studies to date. These researchers investigated noncomputerized cognitive retraining after CHI. They closely matched two groups, that were beyond the spontaneous recovery period, on nontreatment variables which affect outcome (i.e., age, sex, education, injury severity, and chronicity). Both groups were evaluated before and after cognitive remediation using 16 well established neuropsychological tests. Although they did not describe in detail the training exercises used, these exercises apparently focused on residual functions. The experimental patients received an unusually lengthy cognitive retraining program (i.e., 24 hours weekly for six months or 576 total hours each). Based on their results the authors concluded that training may improve neuropsychological status. They also reported that trained patients became more organized and less confused. Perhaps this may have resulted in better test performance. The authors further concluded that patients who were aware of and accepted their deficits gained most from remediation since they were more motivated to use various intervention techniques (e.g., compensatory strategies to compensate for a deficit).

These researchers, however, reported significant neuropsychological test score gains on only three of the 16 measures used in the experimental group. If we adjust for the alpha error, which they did not, we are left with only one measure (i.e., Block design) showing significant improvement. Furthermore, in this study, only 50% of the experimental patients (9 out of 18) returned to gainful employment while 36% of the controls returned to work without any specific treatment. These are sobering results which raise the question of whether extensive time investment (as provided in this study) to remediate CHI is justifiable or even necessary.

Ponsford and Kinsella (1988) attempted to remediate deficits in speed and selectivity of information processing following CHI. Experimental patients, following pre-test neuropsychological evaluation, were trained on 5 computer-mediated tasks in feedback versus no feedback conditions. This manipulation was implemented to evaluate previous beliefs that patients require feedback, they may lack insight and motivation, and they have the capacity to carry-over performances from one session to the next. Hence, they felt that feedback would serve to maximize performance. The results indicated that performance was similar in the feedback and no feedback conditions. However, in this study the nature and extent of feedback in each condition was not controlled well enough to conclude that there were no benefits from such intervention. In the "no feedback" condition patient's performance was nonetheless provided on the computer. Hence, the control group did receive some feedback. This might explain the absence of group differences in this investigation.

Additionally, it was found that when spontaneous recovery was controlled, there was no conclusive evidence that patients showed a significant response to remedial intervention which involved repeated practice on computer-mediated attentional tasks designed to improve speed of information processing. Ponsford and Kinsella's (1988) results are in keeping with Malec et al. (1984) who used computer-mediated training tasks in an attempt to remediate attentional deficits in head injured patients and who failed to document significant treatment effects.

In contrast to Ponsford and Kinsella (1988) and Malec et al. (1984), Sohlberg and Mateer (1987) did show more positive results. However, the methodological difficulties in this study put limitations on interpretations of their results.

It may be possible that head injured individuals require extensive cognitive remediation before any benefits are manifested. The number of hours of remediation in most studies is unspecified or extremely short (i.e., less than 50 hours).

5. Summary of the literature and Goals of this study

Despite various methodological difficulties, new possibilities for intervention arise out of these studies using the micro-computer as a therapeutic tool, and these studies offer new approaches to conventional cognitive therapeutic intervention. Although results tend to be mixed, most of these studies report gains in cognitive functioning. However, despite these attempts, the evidence for the effectiveness of micro-computer based cognitive training has not been adequately demonstrated with valid and well controlled methodology.

In summary, some of the methodological shortcomings included: 1) using patients with varying etiologies; 2) treating patients during the spontaneous recovery period; 3) insufficient and/or inappropriate measures; 4) neglecting the issue of practice effects; 5) and of treatment presentation; 6) inappropriate or non existent generalization measures; and 7) most importantly, absence of control groups. All these, taken together, make it difficult if not impossible to compare efficacy across studies.

More tightly controlled research studies, employing less costly cognitive intervention methods, and addressing the issue related to the benefits of computer-driven cognitive remediation in CHI patients are required. Many clinicians and rehabilitation centers use various programs readily available on the market. Yet, these programs' efficacy remain unknown.

The goals of this study were to:

1) evaluate the efficacy of computer-driven cognitive remediation therapy in severe traumatic CHI patients long after spontaneous recovery. 2) improve on

previous studies by using more appropriately controlled research methodology. This included using controlled treatment groups, a large sample, varied cognitive exercises, more detailed neuropsychological measures, and matching the groups on variables known to influence remediation outcome. 3) examine whether generalization occurs following CHI remediation. The question of carry-over of treatment effects appears to be most critical in any intervention program. Hence, the extent to which CHI patients can generalize from the training exercises to other tasks with similar underlying structures (e.g., psychometric criterion measures) were evaluated.

Since it was not possible to make clear predictions as to outcome from the existing literature, the null hypothesis of the treatment effect was tested. To fulfill the goals of this study a two group (experimental, control) by two treatment condition (pre-test, post-test) ANOVA design was employed.

Method

Subjects

Forty-five individuals who had sustained severe traumatic CHI were assessed as possible candidates for this study. Initial patient selection criteria included: 1) having had a minimum of three day coma duration; 2) chronicity status beyond the generally expected spontaneous recovery period of the central nervous system (i.e., one year); 3) absence of premorbid or present psychotic symptoms or severe behavioral problems; 4) absence of recent history of seizure; 5) ability to understand verbal instructions and ability to verbalize; 6) being between 18 and 50 years of age; 7) having autonomous mobility, assistive devices notwithstanding; 8) being autonomous with respect to bowel and bladder elimination; 9) being available for a period of six months. These criteria were verified during an initial one hour interview with the patient as well as from neuropsychological questionnaires completed by the experimenter and patient and a second similar questionnaire by a family member or custodian (see Appendix 1). Further patient information was available through the rehabilitation center's reports (Lucie Bruneu and Lethbridge) and/or hospital medical reports when necessary.

Six patients were dropped from the study due to a group - mismatch (i.e., gender, age, education, coma duration, etc.), three due to unavailability, one due to severe behavioral problems, and one owing to the fact that she did not suffer closed head injury. Two groups (experimental, control) were formed from the initial selection (n=17 each, hence N=34). The demographic, medical and neuropsychological data for individual patients are presented in Table 1. Since it has been previously reported that variables such as sex, age, education, coma, vocabulary, percentage neuro-psychological deficits, and skull fracture (Ethier, 1987) are related to remediation outcome the two groups were group-matched on these variables since it was impossible to pair the patients one to one on all these variables (see Table 2). None of the matching variables compared were significantly different when compared using a Students t-test (adjusted for alpha inflation) ($p < .01$).

Materials

A battery of standardized neuropsychological tests was administered, pre and post remediation, to assess central nervous system dysfunction (see Table 3). To facilitate recognition and understanding of tests for the non-clinical reader, Table 3 also provides a list of equivalent key words for each test. These key words will be used in the text instead of the usual clinical

Table 1

Demographic, Medical and Neuropsychological Data for each patient.

ID	Sex	Age (yrs)	Education (yrs)	Chronicity (months)	Coma (days)	Skull fracture	Vocab. (%)
Experimental							
BA	M	29	12	128	90	N	73
BF	M	32	12	170	60	N	33
BM	M	31	19	68	105	N	80
DJ	M	24	12	101	21	N	70
DC	M	20	8	68	60	N	45
GL	M	19	12	12	8	N	58
GM	F	19	11	28	38	Y	68
HM	M	33	15	166	35	N	65
LD	M	23	12	47	90	N	58
MR	M	21	13	12	15	Y	68
MJ	M	28	9	42	60	N	40
MJ	M	23	10	14	7	Y	54
MB	M	25	10	36	270	N	24
PR	M	37	12	115	235	N	50
SJ	M	35	13	73	10	N	60
SK	M	30	11	75	22	N	24
TB	M	29	9	92	28	Y	43
Control							
AS	M	29	11	32	90	Y	75
DJ	M	27	12	72	75	N	50
DM	M	21	11	39	17	Y	73
DR	M	36	11	36	30	N	48
FS	M	21	8	72	182	Y	40
GJ	M	31	6	222	30	N	38
HJ	M	21	14	39	21	Y	67
LG	F	23	12	62	60	N	43
LM	M	22	11	48	31	N	35
LR	M	27	8	83	60	N	45
LG	M	20	7	53	22	N	48
LJ	M	21	13	50	11	N	68
NK	M	26	11	49	42	N	37
OT	M	32	12	47	7	N	69
PR	M	27	12	24	75	N	43
RM	M	29	12	84	75	N	58
LT	M	20	10	14	21	Y	60

Table 2

Matching variables of the two groups (means, standard deviations-SD, t-test).

	Experimental	Control	t-test
Sex			
Male	16	16	
Female	1	1	
Age			
Mean	26.94	25.47	.81
SD	5.68	4.84	
Education			
Mean	11.76	10.65	- 1.37
SD	2.54	2.18	
Vocabulary (%)			
Mean	53.59	52.76	.16
SD	16.72	13.54	
Coma			
Mean	64.94	53.47	.59
SD	64.12	47.20	
Skull fracture			
Yes	4	5	
No	13	12	
Percentage Neuropsychological Test deficits (< 2 SD)			
Mean	28.65	23.47	.99
SD	15.37	15.32	

Note: The calculated t must exceed t (.01,32) = ± 2.750 in order to be significant.

Table 3
Neuropsychological Tests Included in the Battery with key words.

<u>Tests primarily related to integrity of the frontal lobes</u>

Benton C.O.W.A.T. (verbal fluency)
Design Fluency (design fluency)
Dynamometer motor strength (grip strength)
Finger Tapping (finger tapping)
Kolb Sequential Praxia (praxia)
Wisconsin Card Sorting (sorting)

<u>Tests primarily related to integrity of the temporal lobes</u>

Audiometry (audiometry)
Dichotic listening (dichotic digits/melodies)
Ekman Facial Affect (facial affect)
Russell Delayed Recall (delayed recall)
Verbal contextual affect (verbal affect)
Wechsler Memory Scale (memory scale)

<u>Tests primarily related to integrity of the parietal lobes</u>

Aesthesiometer two point sensation (two point sensation)
Benton Right-Left Orientation (right-left orientation)
Semmes Body Placement (Semmes)
Single Double Simultaneous Stimulation (stimulation)
Tactual Performance test (tactual)

<u>Tests primarily related to integrity of the occipital lobes</u>

Visual Acuity (visual acuity)
Visual field perimetry (perimetry)

<u>Auxiliary Tests</u>

Corpus Callosum (corpus callosum)
D2 letter cancellation (letter cancellation)
Harris Lateral Dominance (dominance)
Humour appreciation test(humour appreciation)
Token test (language)
Manual Reaction Time (reaction time)
Manual Tremometer (tremometer)
WAIS Vocabulary subtest (vocabulary)

Note: The following tests will not be included in this thesis since, they were covered elsewhere or were purely control measures: Audiometry, visual acuity, Corpus Callosum, various measures from the Humour test, and Harris Lateral Dominace.

acronyms. The rationale in choosing these tests was the following: the tests' localization and functional validity had to have been already established in the neuropsychological literature. This was however, not always possible for each and every measure collected in this thesis (see Appedix 2). It is common clinical practice to ascribe certain neuropsychologically-defined functions in terms of the performance on a given test, which is in turn associated with a specific lobe of the brain. However, this does not necessarily imply that a given test does not utilize other functional systems. Indeed, this interaction was intended to be analyzed by looking at the relationship between tests. For example, "auxiliary" tests were grouped together because their execution could not be attributed to the functional integrity of a specific lobe. Rather, each test may require parallel and/or sequential (i.e., orchestrated) processing and functioning between lobes. Nevertheless, the first goal was to select neuropsychological tests for which previous research has pointed to their localization and functional validity. Second, performance on a large range of problematic behavioral dimensions in CHI had to include perception, memory, cognition, language, attention, sensation, and motor control. It is obvious, therefore, that standardized tests were required.

The target areas of the brain in the present project were the left and right frontal, temporal and parietal lobes. The occipital lobes were to be superficially evaluated since their role is primarily sensory, therefore, less pertinent in the type of cognitive intervention in this project. A detailed description of the neuropsychological test battery, normative references, and a brief discussion of the validity studies available for each measure used are provided in Appendix 2.

For the cognitive-perceptual remediation, 6 Apple II micro-processors, each equipped with cathodic color monitors, joysticks and game paddles were used to present a diversified selection of software programs. Briefly, the software comprised exercises focusing on skills involving attention, shifting, discrimination, initiation, inhibition, making differential responses, visuomotor integration, visuoperceptual processing and visuomotor skills, verbal and spatial memory, auditory tone discrimination, and problem solving. Bracy's (Psychological Software Services, 1983) and Gianutsos (1981) microcomputer exercises were selected because of their theoretically based structure, their extensive use by clinicians, their ecological and face validity, and because they provided presentation flexibility (see Ethier, et al., 1989a,b, for a detailed description).

Procedure

There were four phases in this study.

Phase one - Each patient was invited to attend a private interview during which a neuropsychological questionnaire was completed. A parent or custodian answered the same questionnaire in the waiting room. If the patient met all the inclusion criteria (s)he was informed about the nature of the study, the remediation therapy, and what his/her participation involved. Once given his/her signed consent to participate, the patient was scheduled for neuropsychological assessment. The interview lasted approximately one and a half hours in most cases.

Phase two - This phase involved neuropsychological assessment (i.e., pretest) which lasted between two to three days depending on the patient's capacity to perform. In most cases testing began at 9:30 A.M. until 4 P.M. with intermittent rest periods including an one hour lunch period. If the patient appeared tired testing stopped and recommenced on the following work day. The order of neuropsychological tests was arranged in such a way that there was a balance between hemi-lobes, in the difficulty, and duration of effort. Patient instructions and test administration were standardized in accordance with test manuals. All tests were scored following standardized procedures by persons other than those giving the cognitive-perceptual remediation, in order to control for experimenter bias. Most tests provided objective measures (e.g., means) that did not require blind scoring. There were a few tests, however, for which scoring was complicated and/or required expertise. For these tests a blind scorer was trained and then an interscorer (blind/nonblind) reliability was calculated. Reliability coefficients for these analyses ranged between .96 and .99, suggesting very high interscorer reliability (see Table 4).

A neuropsychological profile was drawn up for each patient by comparing his/her test score against the norms and by using the following psychometric scale: A score was considered superior if it was beyond two standard deviations above normative mean performance, high average when above one standard deviation to two standard deviations, average when the score was between +/- one, low average when it was less than minus one and no greater than minus two standard deviations, deficient when the score was beyond minus two but not greater than minus three standard deviations, and profoundly deficient when the score was beyond minus three standard deviations. Based on this profile, percentage deficits were calculated. This score was then used as one of the pairing variables to match the two groups. The group matched patients were then randomly assigned to either

Table 4

Reliability coefficients between blind and nonblind scorers.

	Pre	Post
Design Fluency	.99	.99
Russell delayed recall (design)	.96	.98
Tactual performance test (block memory)	.97	.96
Vocabulary	.99	.99
Wechsler Memory test (visual reproduction)	.96	.96
Wisconsin card sorting test		
perseverative responses	.99	.99
nonperseverative errors	.97	.98
perseverative errors	.98	.99

the experimental or control group. Note that the control patients were also offered the cognitive remediation program which would then be administered at the end of phase four. In addition to the ethical reasons, this offer served to elicit similar motivation and interest from these patients.

Phase three - Phase three involved the treatment condition. Each experimental patient received two sessions of two hours each of cognitive remediation, weekly for a period of six months. The time of day at which therapy was given was counterbalanced to control for fatique (e.g., morning sessions versus afternoon sessions). Briefly, all patients began with simple reaction time (RT) exercises and proceeded with more complex choice RT exercises, visual-spatial exercises, memory exercises, auditory exercises, and finally problem solving exercises. The presentation of exercises followed Bracy's standard procedure. The rationale was that more fundamental skills (e.g, simple reaction time) must be improved before more complex skills (e.g., memory) that require higher level abilities (e.g., initiation, inhibition, selection, etc.). Each exercise was performed a minimum of 10 times. For a more detailed description of exercises, of counterbalanced practice schedules and time of day effects see Ethier, et al., 1989a,b. To ensure that any treatment effect on the experimental group was not due to the mere increase in personal attention during cognitive remediation therapy, and to make sure that the two groups received equal personal contact and encouragement, the control group also participated in the regular programs given to all patients at the remediation center biweekly (e.g., physical education, family, occupational, recreational therapies, etc.). The control group was also encouraged to visit and to communicate with the cognitive-perceptual remediation therapists at any time. Maximal performance was encouraged equally in all patients.

Phase four - In this final phase (i.e., post-test) all the patients (experimental and control) were again neuropsychologically assessed by repeating the test battery used during pre-test. Six months must have elapsed between pre and post testing.

Rationale and Strategies for Statistical Analyses and presentation of Results

This was the first time that this neuropsychological battery has been used to assess CHI patients. Hence, descriptive statistics on raw scores for all tests were necessary for normative purposes as well as for future research.

Validity and normative studies were not always available for each and every measure used, hence correlational analyses between tests were computed to get an idea of which tests correlated strongest with which other tests. It was expected that a test that is supposedly related primarily to the functioning of a specific lobe would tend to correlate strongest with other tests believed to relate to the same lobe.

Since the unit of measurement for each dependent variable was not necessarily equivalent, to answer the experimental hypothesis, univariate ANOVAs were calculated. Multivariate ANOVA was not possible given the nature and design of this study. Univariate ANOVAs permitted to determine, for each measure, whether there was a carry-over of treatment effect.

Given that the unit of measurement for each measure was not necessarily equivalent in the neuropsychological battery it was not possible to make comparisons between tests. Hence, transformation of the data to standardized scores permitted inter-test comparisons. More importantly however, through these transformations, it was possible to have an overall view of each groups' performance over the entire experiment.

Although small changes on individual tests may result in statistically nonsignificant findings, it is possible that these small changes may have an additive effect. Hence, one ANOVA will be calculated for the entire experiment on summed standardized scores in order to get an overall view of the group by treatment condition interaction.

Although a measure may not be 'experimentally' statistically significant, clinically, small gains or deteriorations are sometimes meaningful and give the clinician an idea of whether to persist in an approach with a specific patient. Hence, analyses of pre- to post-test changes (difference scores) will give the clinician an idea of which types of tests (s)he might expect changes on and in which direction.

Previous research has indicated the impact that certain variables have on therapeutic outcome. It was important therefore, to evaluate the relationship between these variables (i.e., coma duration, chronicity, age, education, and the symptoms reported by the patient at pre-test) and their effects on outcome. Hence, correlations between these variables and difference scores were calculated.

Since the two groups were matched on these variables, these variables were not used as covariates (i. e., covariates usually permit post hoc statistical control when an uncontrolled variable is found to influence the dependent variable in a linear fashion). As well it was not appropriate to use these as factors in the ANOVA design. Finally, given the great number of correlations calculated it was necessary to find a simplified way of presenting these data. Hence, for this purpose only, summary figures were prepared on percentages.

Results

A: Descriptive analyses for all patients combined prior to remediation

1: Descriptive statistics on raw scores

Descriptive statistics on raw scores were calculated using BMDP (BMDP Statistical Software Inc., 1983). Table 5a-d presents, for all patients combined, the performance mean, standard deviation (SD), range for all the matching variables, subjective symptoms (according to category) reported by the patient, and all dependent measures separated according to lobe functioning (as per Table 3 in the method section). The N may differ because patients may have had one of the following problems: apraxia preventing performance on a manual test, or deafness in one ear, or visual field loss, or any other inability to perform. One test (Design Fluency) was not included at the beginning of the study. Hence, there were some missing data at pre-test. The norms can be found in the reference article for each test given in the method section (see Appendix 2). Note that normative data or cut-off data were not presented for the whole group since norms must be categorized according to sex, age, education, and/or left/right hand. Hence, norms can only be compared for each patient individually.

As expected there was much variability between patients on most tests. This was more prominent on the tremometer (right hand) (mean=29.76, SD=32.97, SE=6.12). This was also true for the tactual test (block location), stimulation, and the letter cancellation test (% errors) (see Tables 5a-5d).

To investigate differences between groups on summed scores a nonparametric Chi Square was calculated on number of tests for which there were improvements and/or deteriorations. That is, pre- and post-test raw score performance was compared for each dependent measure and improvements or deteriorations were tallied, irrespective of their significance. The results from these calculations showed that the experimental group (EG) improved on 44 of the 63 measures and their performance was lower on 18 of the 63 measures. The control group (CG) improved on 38 of the 63 measures and deteriorated on 25 of the 63 measures. The EG showed greater improvement and less deterioration than did the CG. There was only one measure (Memory scale-orientation) for which there was no change in the EG. Chi Square, calculated for these results, showed that the differences observed between groups was not statistically reliable (Chi Square (1,.05) = 1.57).

Attempts were made to look at the data in different ways with the hope of finding an informative and eloquent

Table 5a

Descriptive statistics of pre-test raw scores for all patients combined on demographic/medical variables and Frontal tests.

Variable Name	N	Mean	SD	Range
Coma duration (days)	34	59.32	55.65	7 - 270
Chronicity (months)	34	66.85	47.77	12 - 222
Age (years)	34	26.21	5.25	19 - 37
Education (years)	34	11.32	2.46	6 - 19
Symptoms reported motor	33	2.94	1.60	0 - 6
sensory	33	3.21	1.64	1 - 8
emotional	33	2.09	1.57	0 - 5
social	33	2.76	1.25	1 - 5
cognitive	33	3.33	1.69	0 - 6
autonomic/vegetative	33	2.09	1.38	0 - 5
FRONTAL TESTS				
Design fluency				
5 minutes	25	10.92	7.22	0 - 26
4 minutes	23	8.22	8.15	0 - 31
Dynamometer grip strength				
dominant hand	30	41.37	11.39	20 - 59
nondominant hand	31	37.00	12.46	9 - 59
Finger tapping				
right hand	31	38.52	10.45	16 - 59
left hand	32	35.00	11.40	8 - 59
Kolb hand praxia				
preferred hand	32	45.03	2.78	40 - 48
nonpreferred hand	31	44.65	4.18	28 - 48
Verbal fluency				
5 minutes	34	15.94	9.22	5 - 44
4 minutes	34	5.50	3.93	1 - 20
Wisconsin Card Sorting				
categories completed	33	5.30	2.86	0 - 10
nonperseverative errors	33	18.00	12.74	2 - 63
perseverative errors	33	19.27	13.97	4 - 60
perseverative responses	33	22.36	18.16	4 - 77

Table 5b

Descriptive statistics of pre-test raw scores for all patients combined on Temporal tests.

	N	Mean	SD	Range
TEMPORAL TESTS				
Dichotic digits				
left ear	32	42.48	17.42	7 - 71
right ear	32	44.50	20.73	0 - 76
Dichotic melodies				
left ear	30	8.18	3.21	1 - 20
right ear	30	7.62	3.06	1 - 20
Ekman facial affect				
hits	34	25.06	5.64	5 - 33
RT on hits (sec.)	34	91.59	67.82	15 - 373
Russell delayed recall (% score)				
semantic	33	60.91	30.99	0 - 105
designs	33	62.79	29.96	0 - 100
Verbal contextual affect				
hits	33	28.12	5.22	12 - 35
RT on hits (sec.)	33	60.73	4.92	16 - 148
Wechsler memory scale				
information	34	4.53	1.31	2 - 6
orientation	34	4.77	.43	4 - 5
mental control	34	6.24	1.88	3 - 10
logical memory	34	8.38	3.48	2 - 15
digits forward	34	5.97	1.09	4 - 8
digits backward	34	4.29	.87	3 - 6
visual reproduction	34	9.32	3.24	0 - 14
associative learning	34	12.74	4.96	4 - 20

Table 5c

Descriptive statistics of pre-test raw scores for all patients combined on Parietal tests.

	N	Mean	SD	Range
PARIETAL TESTS				
Aesthesiometer two point discrimination (cm)				
right hand - down	32	11.45	5.59	4 - 33
- across	32	10.53	4.62	2 - 25
left hand - down	31	11.64	5.53	5 - 30
- across	31	11.62	4.63	4 - 26
Benton Right-left orientation				
own body	34	11.85	.44	10 - 12
experimenter's body	34	7.27	.99	4 - 8
Semmes body placement	34	29.94	5.87	14 - 35
Single double simultaneous stimulation				
errors	34	1.21	3.05	0 - 17
Tactual performance				
dominant hand time (sec.)	31	557.29	246.35	240 - 1080
nondominant hand time	29	567.93	360.56	120 - 1495
memory for blocks	32	6.17	1.78	3 - 6
memory-block location	32	1.69	1.93	0 - 6

Table 5d

Descriptive statistics of pre-test raw scores for all patients combined for Occipital and Auxiliary tests.

	N	Mean	SD	Range
OCCIPITAL TEST				
Visual Field Perimetry				
Right (R) eye				
R superior quadrant	31	62.61	15.37	33 - 90
R inferior quadrant	31	78.71	15.54	40 - 90
L superior quadrant	32	53.72	10.52	33 - 73
L inferior quadrant	32	55.97	13.50	30 - 90
Left (L) eye				
L superior quadrant	29	48.69	13.75	15 - 68
R inferior quadrant	29	52.07	13.43	23 - 83
L superior quadrant	29	63.41	11.96	40 - 90
L inferior quadrant	30	80.23	13.90	40 - 93
AUXILIARY TESTS				
D2 letter cancellation				
% errors	34	6.87	6.93	0 - 36
hits	34	279.35	99.27	108 - 556
Humour appreciation	33	21.61	4.02	12 - 28
Reaction time (msec.)				
right hand	34	.43	.28	.22 - 1.75
left hand	33	.36	.14	.22 - .96
Token (language testing)	34	79.74	2.37	69 - 81
Tremometer				
right hand	29	29.76	32.97	3 - 132
left hand	31	23.87	16.73	4 - 74
WAIS Vocabulary subtest(%)	34	52.32	14.91	24 - 80

way of describing this sample of CHI patients. Although neuropsychological test profiles were drawn up for each patient at pre-test, the mean performance of the entire sample was compared to normative data in order. This permitted determination as to whether this sample showed any patterns with respect to deficits. These comparisons were however, not very informative (see Appendix 5). The effect of having averaged the performance score tended to obliterate individual differences, hence, camouflaging deficiencies.

2. Correlations between pre-test raw scores

In order to determine which tests associated most strongly with which other test(s), Pearson product moment correlation coefficients were calculated between all raw score measures at pre-test. To test the significance of the 63 measures correlated, the probability level was adjusted using the more stringent one-stage Bonferroni procedure (Larzeleri & Mulaik, 1977). That is, the significance level (p=.05) was divided by the number of correlations (63) which was .00079, rounded to .001. A correlation coefficient of .55 or greater would be significant at $p < .001$. Since a very stringent approach was taken, probabilities of .01 and .05 were regarded as trends toward significance (correlation coefficients of $\geq .44$ and $\geq .34$ respectively).

Table 6 presents the number of tests per lobe that either reached or tended to reach significance. So called "frontal" tests related significantly with frontal tests and decreasingly with auxiliary tests, with parietal tests and finally with temporal tests. There were no significant correlations observed between "frontal" tests and occipital tests.

So called "temporal" lobe tests correlated significantly primarily with other temporal lobe tests, then parietal, and finally with auxiliary tests. As had occurred with frontal tests, there were no significant correlations between temporal and occipital tests.

So called "parietal" lobe test correlated significantly with auxiliary and parietal tests. Again there were no significant correlations observed in parietal-occipital comparisons. The greatest number of significant correlation coefficients for parietal tests occurred with frontal and temporal comparisons (see Table 6).

Four significant correlation coefficients were obtained for occipital-occipital test comparisons, and only one between occipital-auxiliary tests. Occipital tests did not significantly correlate with frontal, temporal, or parietal tests.

In summary, overall, significant correlations between tests indicated that the expected tests tended to

Table 6

Number of tests per lobe that attained significant correlation coefficients or a trend toward significance for raw pre-test scores.

	Frontal	Temporal	Parietal	Occipital	Auxiliary
			$p < .001$ $r = \geq .55$		
Frontal	18	2	5	0	13
Temporal		7	5	0	5
Parietal			3	0	4
Occipital				4	1
Auxiliary					4
			$p < .01$ $.55 > r > .43$		
Frontal	14	12	7	1	9
Temporal		11	11	5	8
Parietal			4	0	4
Occipital				2	0
Auxiliary					3
			$p < .05$ $.44 > r > .33$		
Frontal	12	36	20	10	18
Temporal		20	22	3	22
Parietal			4	8	10
Occipital				1	6
Auxiliary					2

correlate mostly with the expected lobe. The only exception was for parietal tests which tended to correlate primarily with frontal and temporal tests. This may indicate that the latter tests are not related solely to the integrity of parietal lobe functioning. In addition, the auxiliary tests tended to correlate primarily with frontal lobe functioning and did not correlate primarily within each other.

3. Descriptive statistics on standardized scores

The variables used in this study did not all yield equivalent dependent measures. That is, the tests in this neuropsychological battery were all measured on a ratio scale of measurement but, they varied in units of measurement (e.g., a psychometric score of two on one test did not mean the same as a score of two on another since the number of items per test varied). To permit descriptive comparisons between tests, all measures were converted to standard scores (i.e., Z scores) using SPSS-X (Statistical Package for the Social Sciences, 1986). For the sake of consistency, some standardized measures were inverted. Hence, the higher and more positive the Z score the better the performance, conversely, the more negative the Z scores the poorer the performance.

Table 7a-d present Z score means and SDs per group and condition on each dependent measure (as subdivided in Table 3). Although the groups were not statistically different on percentage of neuropsychological deficits on pre-test, it is interesting to note that on pre-test the EG attained performances that were below the Z score mean (i.e., negative mean Z score) on 39 of the 63 measures. Roughly half (23) of these 39 negative standardized scores, were related to either motor or sensory test measures. In contrast, the CG had 24 negative Z score mean performances on pre-test. Only 4 of the 24 negative means related to motor/sensory functioning.

In summary, although the groups seemed similar there were variations between pre- and post-test. The differences between the groups were somewhat reversed on post-test. That is, the EG improved (with only 28 negative Z score means at post-test versus 39 at pre-test). In contrast, the CG's performance deteriorated at post-test (with 36 negative Z score means compared to 24 at pre-test) (see Table 7a-d).

4. Performance over the entire battery

In order to get an overview of how each group performed over the entire neuropsychological battery, standardized scores of the 63 dependent measures were summed for each group separately for each test, pre and

Table 7a
Standardized Z score means (M) and standard deviations (SD) per condition and group for Frontal tests.

FRONTAL TESTS	EXPERIMENTAL				CONTROL			
	Pre		Post		Pre		Post	
	M	SD	M	SD	M	SD	M	SD
Design fluency								
5 minutes	-.193	.870	-.113	.752	.409	1.191	.112	1.214
4 minutes	.104	1.111	-.126	.729	-.191	.787	.127	1.225
Dynamometer Grip Strength								
dominant hand	-.351	.941	-.265	.942	.401	.94	.218	1.021
nondominant hand	-.286	.977	.133	.957	.305	.963	-.133	1.057
sustained strength right	-.101	1.143	-.011	.779	.373	.759	.107	1.129
sustained strength left	-.240	.992	.056	.875	.320	.972	-.118	.851
Finger tapping								
right hand	-.247	1.129	-.193	1.161	.263	.796	.206	.782
left hand	-.124	1.086	-.108	1.005	.140	.909	.115	1.104
Kolb hand praxia								
preferred hand	.124	.938	.112	.536	-.124	1.074	-.112	1.322
nonpreferred hand	.043	.635	.129	.580	-.052	1.344	-.043	1.302
Verbal fluency								
5 minutes	-.064	.896	.104	.870	.064	1.118	.033	1.130
4 minutes	-.022	.903	.005	1.129	.022	1.115	-.004	.898
Wisconsin								
categories completed	.306	.795	.180	.812	-.230	1.141	-.179	1.156
nonperseverative errors	.065	.821	.139	.897	-.069	1.185	-.139	1.103
perseverative errors	.327	.642	.339	.665	.347	1.201	.339	1.173
perseverative responses	.331	.646	.330	.648	-.352	1.197	-.330	1.188

Table 7b
Standardized Z score means (M) and standard deviations (SD) per condition and group for Temporal tests.

TEMPORAL TESTS	EXPERIMENTAL				CONTROL			
	Pre		Post		Pre		Post	
	M	SD	M	SD	M	SD	M	SD
Dichotic digits								
left ear	-.191	.840	.115	.972	.191	1.133	-.122	1.047
right ear	-.241	1.026	-.226	1.051	.241	.944	.212	.933
Dichotic melodies								
left ear	.254	1.111	-.058	1.188	-.223	.866	.059	.805
right ear	.242	1.189	.008	1.185	-.212	.778	-.009	.813
Ekman facial affect								
hits	-.031	1.188	.069	.809	.279	.779	-.076	1.175
reaction time on hist	-.311	1.310	-.424	1.525	.277	.403	.225	.283
Russell delayed memory								
semantic	-.080	.879	-.155	.974	.075	1.124	.223	.996
designs	-.056	.925	.101	1.014	.059	1.102	-.095	1.009
Verbal contextual emotion								
hits	.174	1.230	.017	1.303	.180	.718	-.032	.635
reaction time on hits	-.256	1.183	-.004	1.080	.349	.702	.077	.825
Wechsler memory								
information	.045	.939	.103	.941	-.045	1.085	-.067	1.087
orientation	.136	.912	.296	.397	-.137	1.091	-.297	1.311
mental control	.063	.863	.017	.928	-.063	1.145	-.017	1.096
logical memory	-.0002	.936	-.125	.982	.012	.951	.126	1.032
digits forward	.027	.797	.210	.799	.010	1.144	-.209	1.154
digits backward	.135	.817	.208	1.057	-.135	1.164	-.214	.926
visual reproduction	-.173	.690	.203	1.328	-.173	1.234	-.140	.444
associative learning	.044	1.094	.051	1.319	-.038	.920	-.051	.563

Table 7c
Standardized Z score means (M) and standard deviation (SD) per condition and group for Parietal tests.

PARIETAL TESTS	EXPERIMENTAL				CONTROL			
	Pre		Post		Pre		Post	
	M	SD	M	SD	M	SD	M	SD
Aesthesiometer two point discrimination								
right hand - down	-.050	.878	.001	.969	.218	1.185	-.038	1.058
- across	-.172	1.009	-.048	1.128	.098	.991	-.061	.900
left hand - down	-.153	1.211	-.068	1.066	.186	.659	-.148	.967
- across	-.110	1.221	-.202	1.262	-.098	1.525	.018	.606
Benton Right-left orientation								
own body	.068	.763	.172	.001	-.067	1.213	-.171	1.414
experimentor's body	.207	.880	.235	.194	-.207	1.094	-.235	1.381
Semmes body placement	.170	.969	.237	.735	-.170	1.030	-.178	1.167
Single double stimulation	.144	.441	.230	.096	-.145	1.350	-.230	1.393
Tactual performance								
dominant hand time	-.078	1.159	-.213	1.321	.032	.861	.112	.576
nondominant hand time	-.156	1.218	-.120	1.241	.167	.705	.095	.699
memory for blocks	.053	.906	.014	1.206	-.052	1.114	-.013	.798
memory of block location	.422	1.039	.187	1.272	-.422	.779	-.176	.643

Table 7d
Standardized Z score means (M) and standard deviations (SD) per condition and group for Occipital and Auxiliary tests.

OCCIPITAL TESTS	EXPERIMENTAL				CONTROL			
	Pre		Post		Pre		Post	
	M	SD	M	SD	M	SD	M	SD
Visual Field Perimetry								
Right eye								
right superior quadrant	-.057	.890	-.452	1.178	.14	1.138	.452	.493
right inferior quadrant	-.156	.941	-.281	1.298	-.002	.947	.281	.462
left superior quadrant	-.050	1.031	-.218	1.052	.288	.833	.218	.927
left inferior quadrant	-.119	.926	.061	1.228	.256	1.061	-.061	.742
Left eye								
right superior quadrant	.057	1.068	-.194	1.213	.018	1.010	-.404	.906
right inferior quadrant	-.447	.708	.353	.897	.400	1.056	-.071	.855
left superior quadrant	-.365	.746	-.240	1.006	.284	1.107	.197	.980
left inferior quadrant	-.120	1.002	-.387	1.228	.105	1.019	.363	.550
AUXILIARY TESTS								
D2 letter cancellation								
% error	-.007	.832	-.059	.962	.007	1.170	.050	1.063
hits	-.030	1.006	-.043	1.079	.024	1.028	-.087	.865
Humour	-.269	1.029	-.080	.875	.285	.913	.305	1.100
Reaction time								
right hand	-.056	1.237	.054	.845	.061	.729	-.054	1.160
left hand	-.154	1.265	-.136	1.157	.204	.596	.114	.832
Token (language testing)	.212	.486	.209	.790	-.211	1.316	.040	.915
Tremometer								
right hand	-.142	1.197	-.192	1.221	.175	.694	.030	1.175
left hand	-.063	1.062	.255	.676	.035	.924	-.223	1.197
WAIS Vocabulary subtest	-.037	1.116	.023	.940	.032	.906	.062	.973

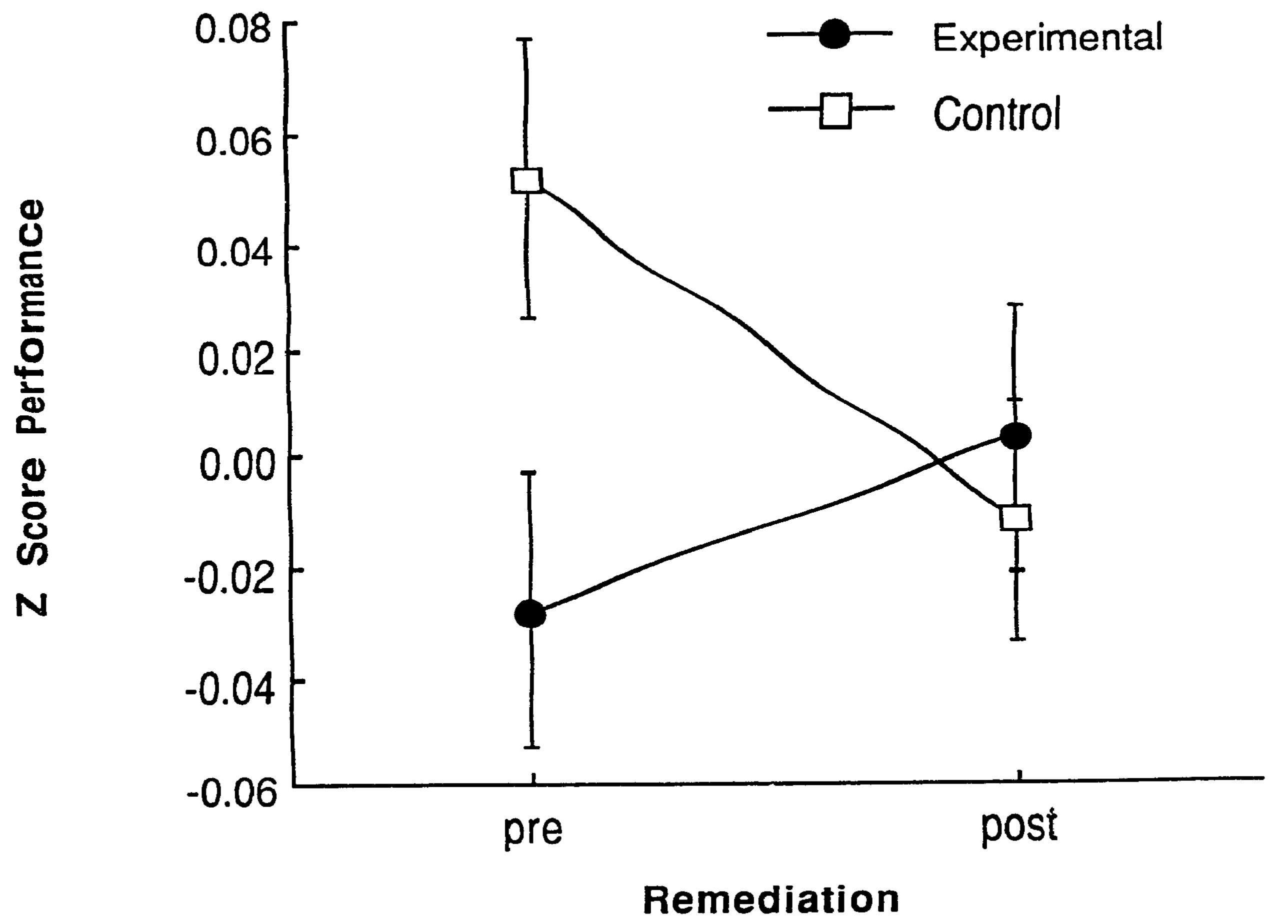
post remediation. Figure 1 indicates that the EG had lower performance compared to the CG at pre-test (Z = -.027 versus .051 respectively). This was however, reversed at post-test in that the CG's performance declined while the EG's performance increased (Z = .003 versus -.011 respectively) (see Figure 1). In order to determine whether these were significant differences these data were subjected to ANOVA. See section B.3 and B.4 of the results.

5. Performance according to lobe at post-test

For clinical purposes it was important to determine the patients' improvement for each measure as it related to lobe (i.e., as subdivided in Table 3). Hence, the following a posteriori questions were addressed: 1) Were there differences in performance, in terms of which tests related to which lobes? 2) Were the improvements and/or deteriorations dependent on the type of tests (i.e., cognitive, motor, or buffer tests); 3) Was this different depending on the group? Note that question 3 was implicit in questions one and two. This type of information was attained by comparing the pre- to post-test means for each group.

With respect to question one, (test improvement, deterioration, or no change) results were calculated in

Figure 1: Overall standardized performance per group.



terms of proportion in order to control for unequal number of measures per lobe. The number of tests was relatively comparable for most lobes, with six for the frontal lobe, six for the temporal, five for the parietal lobe, but only one for the occipital lobe. Improvements, in the EG, were greatest on auxiliary tests followed by parietal, temporal, occipital, and frontal tests (see Table 8). In contrast, CG's improvements were greatest on temporal tests followed by auxiliary, parietal, occipital, and frontal tests. The opposite happened for deterioration scores (i.e., 100 minus improvement) in each group, except for 5% of the temporal tests in the EG for which the dependent measure remained the same from pre- to post-test.

Regarding question 2, Table 9 may support the notion that there were some differences, with respect to improvement, between groups and type of tests (see Table 9). The EG improved equally on cognitive and buffer tests followed by motor tests. In contrast the CG did not show this bimodal distribution of improvement. Note that most performance deteriorations occurred on motor tests.

In summary, these analyses show that there were differences, although not statistically evaluated at this point, between the groups. However, these differences may be related to the type of tests (e.g., cognitive or

Table 8

Percentage of tests, according to the integrity of lobe function, that showed improvement (I), deterioration (D), or no change (Ch) in each group (experimental-E, control-C).

	Frontal		Temporal		Parietal		Occipital		Auxiliary	
	E	C	E	C	E	C	E	C	E	C
I	56	44	67	78	83	58	63	50	89	67
D	44	56	28	22	17	42	37	50	11	33
Ch	-	-	5	-	-	-	-	-	-	-

Table 9

Percentage of tests for which there was improvement (I) or deterioration (D) according to motor function, cognitive function, or buffer tests in each group (experimental-E, control-C).

	Cognitive		Motor		Buffer	
	E	C	E	C	E	C
I	75	69	58	42	75	50
D	25	31	42	58	25	50

motor). This cognitive-motor test subdivision will be analyzed further in section C2 of the results.

B: Analyses of Variance

The ANOVA comprised a 2 x 2 design, with a crossed group factor (experimental, control) and a repeated treatment condition factor (pre, post). The dependent variables (as noted above) did not yield the same dependent measures, since these tests are not conceptually the same and since our N was small due to the nature of the study we did not use the multivariate procedure. Rather, it was necessary to calculate multiple univariate ANOVAS (i.e., 57). The discrepancy on the number of ANOVAS (57) and other analyses (63) relates to the fact that in the ANOVAs, perimetric quadrants were combined to yield one measure per eye as opposed to eight. That is, there was no obvious a priori hypothesis regarding the differences between eye quadrants. The large number of tests again necessitated that the probability level of .05 be adjusted. Hence, a more stringent test-wise probability level was used (.001). Appendix 3 presents all the ANOVA summary tables for all dependent measures (see Appendix 3). Since a very stringent alpha level (.001) was used, the range of probabilities between .05 and .0015 was regarded to indicate at least a trend toward significance. Hence,

Table 10 presents all significant tests and trends.

1: Group main effects

The ANOVAs, on raw scores, did not demonstrate any significant group main effects. Hence, the EG did not differ significantly from the CG in terms of performance on individual test analysis. There were however. trends toward significance observed.

Tests related to the integrity of frontal lobe functioning: Grip Strength (dominant hand) showed a trend toward significance - F (1,25) = 3.93, p <.05. This was in favour of the CG (mean = 45 vs 37). Card sorting approached significance on perseverative errors - F (1,31) = 5.10, p <.03, and perseverative responses - F (1,31) = 5.02, p < .03. These were in favour of the EG (mean = 16 vs 27).

Tests related to temporal lobe functioning: There was a trend on facial affect (reaction time on hits) - F (1,32) = 4.75, p < .03. This was in favour of the CG (mean seconds = 72 vs 119).

Tests related to the integrity of parietal lobe functioning: Tactual (memory for block location) approached significant - F (1,30) = 5.43, p < .02. This was in favour of the EG (mean = 2 vs .9).

Tests related to the integrity of occipital lobe functioning: Perimetry (right eye) - F (1,30) = 4.90, $p <$ .03 and perimetry (left eye) - F (1,27) = 7.51, $p < .01$ approached significance. These were both in favour of the CG (mean = 65 vs 58 and 63 vs 56 respectively) (see Table 10).

In summary, these data show that it was mostly the CG that showed better performance at pre-test, although not significant on individual univariate ANOVAs.

2. Pre/Post main effects

Of the 57 ANOVAs calculated on raw scores only one demonstrated significant treatment condition main effect. There was a significant pre/post main effect demonstrated on letter cancellation (% errors) - F (1,32) = 13.93, $p <$ .0007. Percentage errors declined on post-test (mean = 6.87 vs 3.66).

There was a trend toward significance for treatment condition main effect on 11 of the 57 ANOVAs calculated (see Table 10).

Tests related to the integrity of frontal lobe functioning: Design fluency (5 minute condition) - ($p < .01$ performance improved at post-test (mean = 18 vs 22 designs). For verbal fluency (5 and 4 minute conditions) - $p < .003$ and .01 respectively, performance also

Table 10

Summary of probability levels and degrees of freedom (df) from ANOVA tables for group (G), Pre/Post condition (P), and group by condition interaction (GxP) effects for significant ($p < .001$) effects and trends ($p < .05$) toward significance.

		Probability		
	df	G	P	GxP
FRONTAL				
Design fluency - 5 min.	1,22	.38	.01	.84
Grip strength				
dominant hand	1,25	.05	.82	.55
nondominant hand	1,26	.30	.18	.04
Finger tapping - right hand	1,29	.19	.01	.46
Verbal fluency - 5 min.	1,31	.81	.003	.95
- 4 min.	1,31	.97	.01	.83
Card Sorting				
categories completed	1,31	.13	.02	.28
perseverative errors	1,31	.03	.67	.98
perseverative responses	1,31	.03	.60	.79
TEMPORAL				
Facial affect-RT hits (sec)	1,32	.03	.70	.82
Verbal affect-correct hits	1,31	.68	.01	.05
Memory Scale-digits backward	1,32	.23	.05	.45
PARIETAL				
Orientation				
experimenter's body	1,32	.14	.04	.62
Tactual				
memory for blocks	1,30	.82	.04	.81
memory for block location	1,30	.02	.57	.30
OCCIPITAL				
Perimetry				
right eye	1,30	.03	.79	.83
left eye	1,27	.01	.64	.52
AUXILIARY				
Letter cancellation-% errors	1,32	.88	.0007*	.85
Reaction time - right hand	1,30	.73	.01	.91
Tremometer - left hand	1,26	.78	.02	.40

improved at post-test (mean = 16 vs 19 words and for 5.5 to 6.7 words respectively). On finger tapping (right hand) - $p < .01$ performance was slightly lower on post-test (mean = 38 vs 36 taps). For the card sorting task (categories completed) - $p < .02$ there were more categories completed on post-test (mean = 6 vs 5 categories). This was more evident in CG (4.4 vs 5.7) than in EG (6.2 vs 6.6). Although the CG completed more categories, they made more perseverative errors and more perseverative responses. In contrast, the EG made less perseverative errors and perseverative responses than the CG at post-test (14.3 vs 23.7, 16 vs 28 respectively). These differences however, were not significant (see Appendix 3).

Tests related to the integrity of temporal lobe functioning: Verbal affect (hits) - $p < .01$, discrimination increased at post-test (mean = 28 vs 30 correct hits). This was primarily related to the EGs' performance (27 vs 30) at post-test. For the memory scale (digits backward) - $p < .05$, performance was slightly higher on post-test (mean = 5 vs 4 digits).

Tests related to the integrity of parietal lobe functioning: On the tactual (memory for blocks) - $p < .04$, patients reproduced slightly more blocks at post-test (mean = 6.1 vs 6.7). For orientation (experimenter's body) - $p <$ .0,4 patients' performance was greater at post-test (mean = 7 vs 8).

Auxiliary tests: For reaction time (right hand) - $p < .01$, patients reduced their reaction time at post-test (mean = 371 vs 327 msec.). For the tremometer (left hand) - $p < .02$, there were improvements (mean = 24 vs 16) (see Table 10).

In summary, Pre/Post main effect analyses showed that performance was in the expected direction (i.e., improvement but not deterioration for tests that showed a trend toward significance).

3. Group by Pre/Post interaction

Of the 57 ANOVAs calculated on raw scores, there were no significant group by pre/post interactions. Moreover, there were only two measures for which trends reached $p < .05$ (see Table 10). On frontal tests, there was a trend for grip strength (nondominant hand) - $p < .04$. For this test, the EG improved their performance (from 34 to 38) more than the CG, whose performance slightly deteriorated (from 41 to 40).

On temporal tests, there was a trend for verbal affect discrimination (hits) - $p < .05$. Performance improved in the EG (from 27 to 30 hits) while the CGs' performance remained the same (e.g., 29).

In summary, there were no significant group by pre/post interactions demonstrated by univariate ANOVAs on raw scores. The trends toward significance however, were always in the expected direction (i.e., improvement as opposed to deterioration) and in the expected group (i.e., experimental, not control). It is possible that if one ANOVA was calculated on overall performance, there may be a significant interaction on summed Z scores per group (i.e., on the entire neuropsychological battery).

4. <u>Summed Z score assessment of group differences</u>

One ANOVA on the entire neuropsychological battery was run due to the concern over multiple univariate ANOVAs and also due to the findings from Figure 1. Using standardized measures permitted such a statistical analysis.

The ANOVA of summed Z scores from Figure 1 demonstrated that there were no significant group or pre/post condition main effects. There was however, a significant interaction ($\underline{F}$ (1,124) = 7.18, $\underline{p} < .008$). No alpha adjustment was required here since only one ANOVA was calculated. Hence, the .05 level was considered for significance. Tukey's HSD tests indicated that the pre-test group means were significantly different from each other. CG (Z mean = .051) had a better performance than EG (Z mean = -.027). In addition the CGs' mean on pre-test was significantly greater than their post-test mean (Z score mean difference = -.062). The pre-post differences for the EG were nonsignificant. These results reflect the direction of trends observed on raw scores presented above and are possibly due to cumulative effects (i.e., in a negative direction for the CG and, non-significantly, in a positive direction for the EG) of all these changes.

C: Difference Z scores

1. Correlations between matching variables and difference Z scores.

Difference Z scores on dependent measures were obtained by subtracting pre- from post-test performance. These scores were then subtracted from zero so that improvements were in a positive direction whereas poorer performance on post-test was in a negative direction. Table 11a-d presents correlations of these measures between clinical variables (i.e., coma duration, chronicity, age, and education) and each dependent measure (according to lobe subdivisions from Table 3). The probability level was again adjusted to a more stringent one (i.e., a one-stage Bonferroni, $p = .001$).

Coma duration (which was reversed so that the longer the coma duration the more negative the Z score) was most "strongly" associated with parietal tests followed by those of temporal, frontal, and least with occipital and auxiliary tests (see Table 11a-d). The term "strongly" here relates to the cumulative number of absolute correlation coefficients (i.e., irrespective of direction) which were $\geq$ .34 in both groups.

The only significant correlation between coma duration and frontal tests was negative and was for grip strength (dominant hand) in the CG (r = -.56) (see Table 11a).

For so called "temporal" tests, on the memory scale (logical memory) there was a significant correlation observed (r = .56) in the EG (see Table 11b).

For parietal lobe functioning the two point sensation (right hand-across) reached significance in the EG (r = .59). Tactual (dominant hand time) attained a significant correlation (r = .57) in the EG (see Table 11c).

For occipital lobe functioning the perimetry (right eye - left inferior quadrant and left eye - right inferior quadrant) significant correlations (r = .60 and .56 respectively) were observed in the CG (see Table 11d).

Figure 2 presents a summary of the above correlations. That is, the proportion of tests that have a positive or negative correlation coefficient as they

Table 11a
Correlation coefficients for pre minus post-test Z score performance by group (experimental=E, control=C) on Frontal tests.

FRONTAL TESTS	Coma		Chronicity		Age		Education	
	E	C	E	C	E	C	E	C
Design fluency								
5 minutes	-.07	-.43	.15	-.59	-.07	.71	-.08	-.44
4 minutes	-.18	.42	-.24	.09	-.11	-.46	.13	.06
Dynamometer Grip Strength								
dominant hand	.09	-.56	-.03	-.16	.22	-.02	-.32	-.31
nondominant hand	-.33	.24	.13	.68	-.27	.55	.15	-.12
sustained strength right	.15	.01	-.32	.32	.21	.04	-.17	.78
sustained strength left	.40	.14	.35	.12	-.47	-.23	-.22	.39
Finger tapping								
right hand	-.24	-.18	-.31	-.14	.37	-.03	-.02	.04
left hand	-.21	-.06	.12	-.23	.14	-.13	-.43	-.04
Kolb hand praxia								
preferred hand	.18	.19	-.65	.74	.32	-.09	.33	.11
nonpreferred hand	.18	.18	-.18	.11	.05	.40	.13	.12
Verbal fluency								
5 minutes	.08	-.32	-.24	-.15	.46	.01	.23	.27
4 minutes	.14	-.08	.02	.26	.06	-.23	-.11	-.04
Wisconsin Card Sorting								
categories completed	.14	.33	.28	.22	.07	-.10	.10	.15
nonperseverative errors	.25	.37	-.20	-.03	.29	-.12	.06	.30
perseverative errors	-.16	.21	.20	.35	-.10	-.43	-.14	.39
perseverative responses	-.06	.21	.17	.29	-.02	-.44	-.08	.38

Note: Significant correlation coefficients at:
$p < .001 = \geq \pm .55$
$p < .01 = \geq \pm .44 < .55$
$p < .05 = \geq \pm .34 < .44$

Table 11b
Correlation coefficients for pre minus post-test Z score performances by group (experimental=E, control=C) on Temporal tests.

TEMPORAL TESTS	Coma		Chronicity		Age		Education	
	E	C	E	C	E	C	E	C
Dichotic digits								
left ear	.05	.22	-.01	-.10	.09	-.28	.44	.28
right ear	.10	.29	-.20	-.22	-.12	-.10	.07	.07
Dichotic melodies								
left ear	.24	.32	-.26	.15	.21	-.10	-.05	.07
right ear	-.15	-.21	-.07	.26	-.31	-.24	-.32	.01
Ekman facial affect								
hits	.05	-.20	.27	-.21	-.43	-.07	-.02	-.52
reaction time on hits	-.03	.02	-.24	-.48	.45	.18	-.20	-.33
Russell delayed memory								
semantic	-.02	-.07	-.27	.11	.12	.10	-.17	-.11
designs	.17	.21	.07	-.10	.25	-.01	-.05	-.17
Verbal contextual affect								
hits	.01	-.21	-.15	-.35	.35	-.29	.37	-.45
reaction time on hits	-.18	-.09	.02	-.83	.17	.32	.16	-.45
Wechsler Memory Scale								
information	-.17	-.23	.41	.08	-.42	.17	-.31	-.04
orientation	.24	.54	.16	.13	.10	.15	.18	.09
mental control	.38	-.30	.07	.18	-.04	.27	.19	-.02
logical memory	.56	-.11	-.05	-.19	.07	-.17	-.01	-.15
digits forward	.36	-.41	-.17	-.12	-.25	.01	.10	.14
digits backward	-.10	-.30	-.36	.18	.37	-.13	.31	-.04
visual reproduction	-.25	-.43	.13	-.66	.03	.07	.23	-.56
associative learning	-.46	-.15	-.20	-.42	.33	.22	.05	-.40

Note: Significant correlation coefficients at: $p < .001 = \geq \pm .55$
$p < .01 = \geq \pm .44 < .55$; $p < .05 = \geq \pm .34 < .44$

Table 11c
Correlation coefficients for pre minus post test Z score performances by group (experimental = E, control = C) on Parietal tests.

PARIETAL TESTS	Coma		Chronicity		Age		Education	
	E	C	E	C	E	C	E	C
Aesthesiometer two point discrimination								
right hand - down	.33	-.34	.66	.59	-.55	-.48	-.36	.27
- across	.59	-.27	.19	.13	-.15	.03	.11	.07
left hand - down	-.35	-.02	.49	.35	-.33	.12	-.32	.04
- across	-.40	.17	.26	-.61	-.06	.37	-.42	-.38
Benton Right-left orientation								
own body	.01	.43	.01	.09	.24	-.05	.47	.16
experimentor's body	.05	-.38	.32	.42	-.31	.06	-.01	.45
Semmes body placement	.32	.02	-.02	-.04	-.14	-.03	-.13	.03
Single double stimulation	.30	-.34	.32	.12	-.19	.16	-.46	.08
Tactual performance								
dominant hand time	.57	-.28	.33	.08	-.11	-.17	-.57	.25
nondominant hand time	.26	.15	.24	.46	-.08	-.28	-.45	.67
memory for blocks	.17	-.22	.10	.06	-.07	-.29	-.46	.35
memory of block location	-.24	-.01	.08	-.21	-.01	-.28	-.14	-.14

Note: Significant correlation coefficients at: $p < .001 = \geq \pm .55$
$p < .01 = \geq \pm .44 < .55$
$p < .05 = \geq \pm .34 < .44$

Table 11d
Correlation coefficients for pre minus post test Z score performances by group (experimental = E, control = C) on Occipital and Auxiliary tests.

OCCIPITAL TESTS	Coma		Chronicity		Age		Education	
	E	C	E	C	E	C	E	C
Visual Field Perimetry								
Right eye								
right superior quadrant	.06	-.12	.26	.10	-.45	-.06	-.08	-.06
right inferior quadrant	.30	-.36	-.12	.05	-.27	-.56	-.54	-.08
left superior quadrant	.24	-.11	.30	-.07	.09	.68	.35	.20
left inferior quadrant	.17	.60	.08	-.10	.06	-.05	-.11	.12
Left eye								
right superior quadrant	.25	.28	.70	-.26	-.76	.17	-.33	.26
right inferior quadrant	.03	.56	-.14	.11	-.09	-.12	.08	.33
left superior quadrant	.10	-.10	.02	-.24	.19	-.04	.06	.11
left inferior quadrant	-.14	-.32	.64	-.40	-.30	-.28	-.63	-.31
AUXILIARY TESTS								
D2 letter cancellation								
% error	.11	.52	-.06	-.10	.25	.26	-.32	-.20
hits	-.16	.04	-.19	.03	-.07	.48	.08	.01
Humour	-.09	-.16	.15	-.37	-.32	-.02	.03	-.20
Reaction time								
right hand	-.02	-.05	.08	.08	.30	.03	-.16	.40
left hand	-.09	-.24	-.11	.44	-.16	-.07	.13	.48
Token (language testing)	-.12	.37	-.01	-.77	-.09	.16	-.31	-.44
Tremometer								
right hand	.21	.01	.65	.19	-.14	-.34	-.27	-.16
left hand	-.47	-.18	.14	.55	.32	.32	-.05	.42
WAIS-Vocabulary subtest	-.54	.11	.14	.34	.20	.18	-.44	.41

Note: Significant correlation coefficients at: $p < .001 = \geq \pm .55$
$p < .01 = \geq \pm .44 < .55$
$p < .05 = \geq \pm .34 < .44$

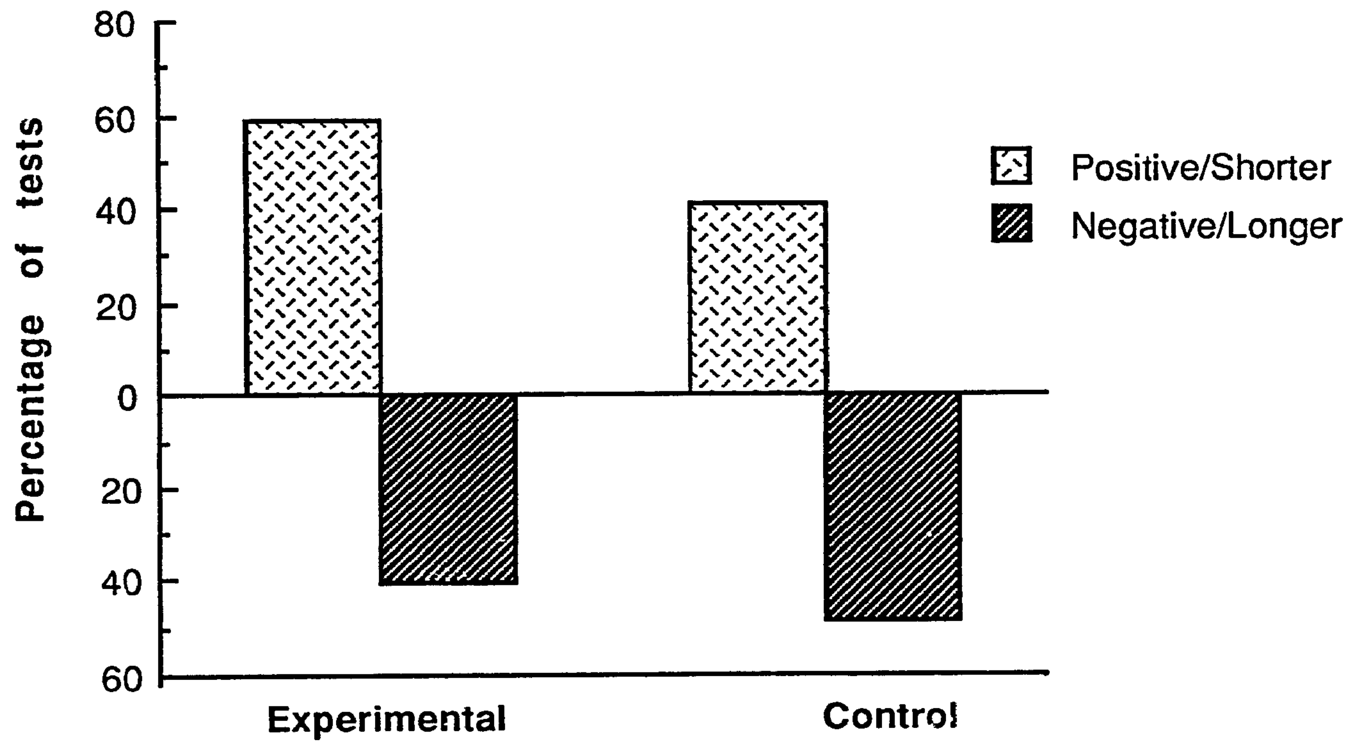
relate to coma duration and improvement. Negative correlations indicate greater improvement by those patients with longer coma duration. In contrast, positive correlations indicate greater improvements by patients with shorter coma duration (see Figure 2). The dependent measure was always positive at post-test if there was an improvement in performance. This figure shows that the proportion of positive correlations was greater than the proportion of negative correlations in the EG. The reverse was true in the CG although not to the same extent (see Figure 2).

Chronicity was strongly correlated to parietal tests, followed by tests related primarily to frontal lobe functioning, temporal lobe functioning, and least with those tapping occipital lobe functioning.

In the EG significant correlations were observed between chronicity and frontal lobe functioning - (preferred) hand praxia ($r = -.65$), a parietal sensory test - two point sensation (right hand-down) ($r = .66$), one test related to occipital lobe functioning - perimetry (left eye-right superior quadrant and left inferior quadrant) ($r = .70$, $.64$ respectively), and an auxiliary test - tremometer ($r = .65$).

For the CG significant correlations occurred between chronicity and tests related to frontal lobe functiong - design fluency (5 minute condition) (r = figure 2

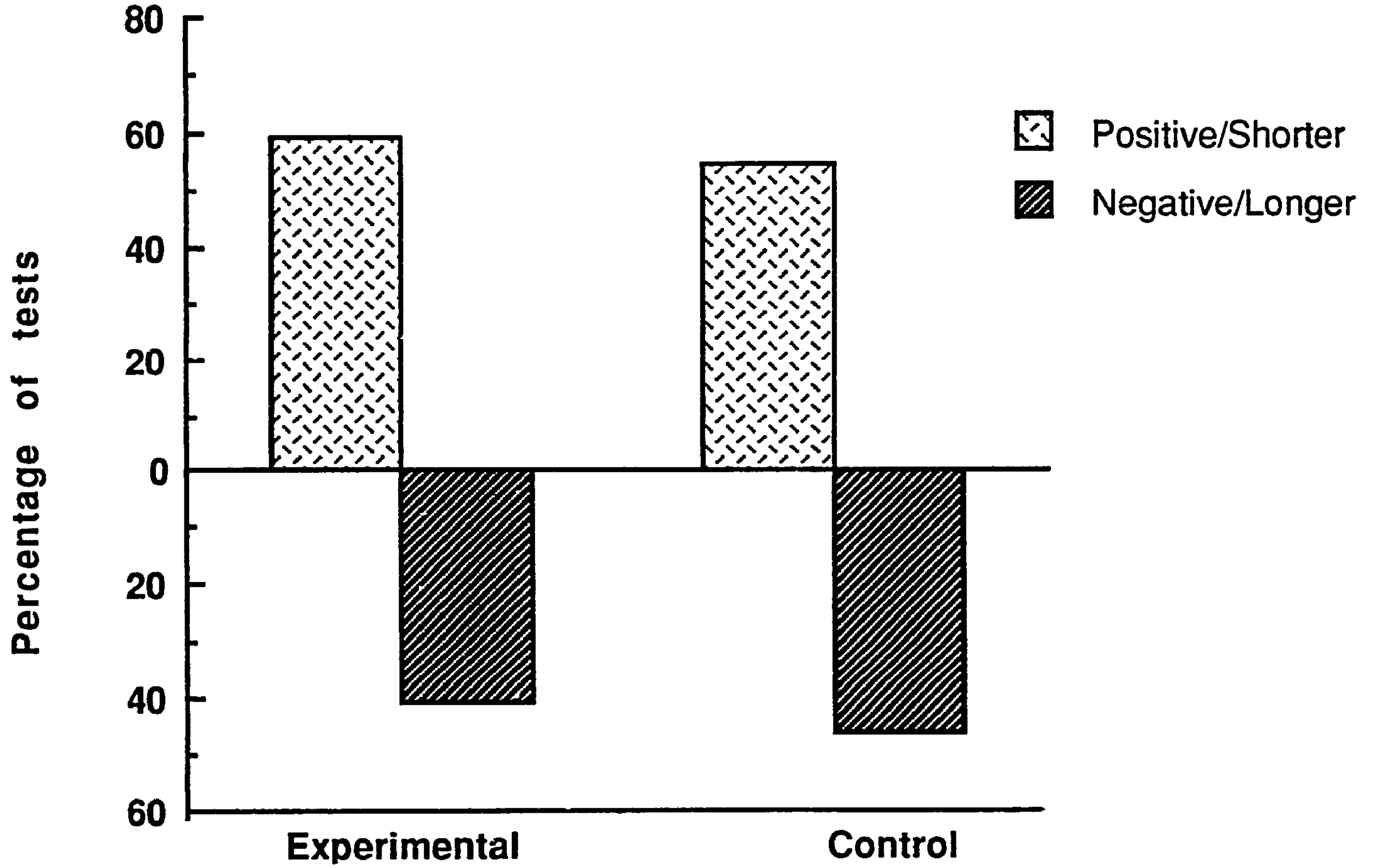
Figure 2: Percentage of tests that attained Positive or Negative Correlation Coefficients on Coma Duration.



- .59), grip strength (nondominant hand) (r = -.68), hand praxia (preferred hand) (r = .74). Significant correlations on temporal lobe tests for the memory scale (visual reproduction) (r = -.66) and verbal affect (reaction time on hits) (r = -.83). Only one significant correlation was obtained on a test related to parietal lobe functioning, two point sensation (right hand-down and left hand-across) (r = .59, -.61 respectively). Significant correlations for auxiliary tests were obtained for language (r = -.77) and tremometer (left hand) (r = .55).

Similar to coma duration, negative correlations indicate poorer performance at post-test by patients with longer chronicity. In contrast, positive correlations indicate that patients with lower chronicity had better performance at post-test. Figure 3 summarizes the proportion of tests that were positive or negative in each group for chronicity. In the EG it showed similar proportions (i.e., 59% positive and 41% negative) to those found for coma duration. In the CG the proportions of positive correlations were greater than negative correlations, similar to the EG. That is, in this group patients with longer chronicity (negative correlations) showed greater improvement. The proportion of tests that showed positive correlation coefficients were however, greater than for negative correlation coefficients (see Figure 3).

Figure 3: Percentage of tests that attained Positive or Negative correlation coefficients on Chronicity.



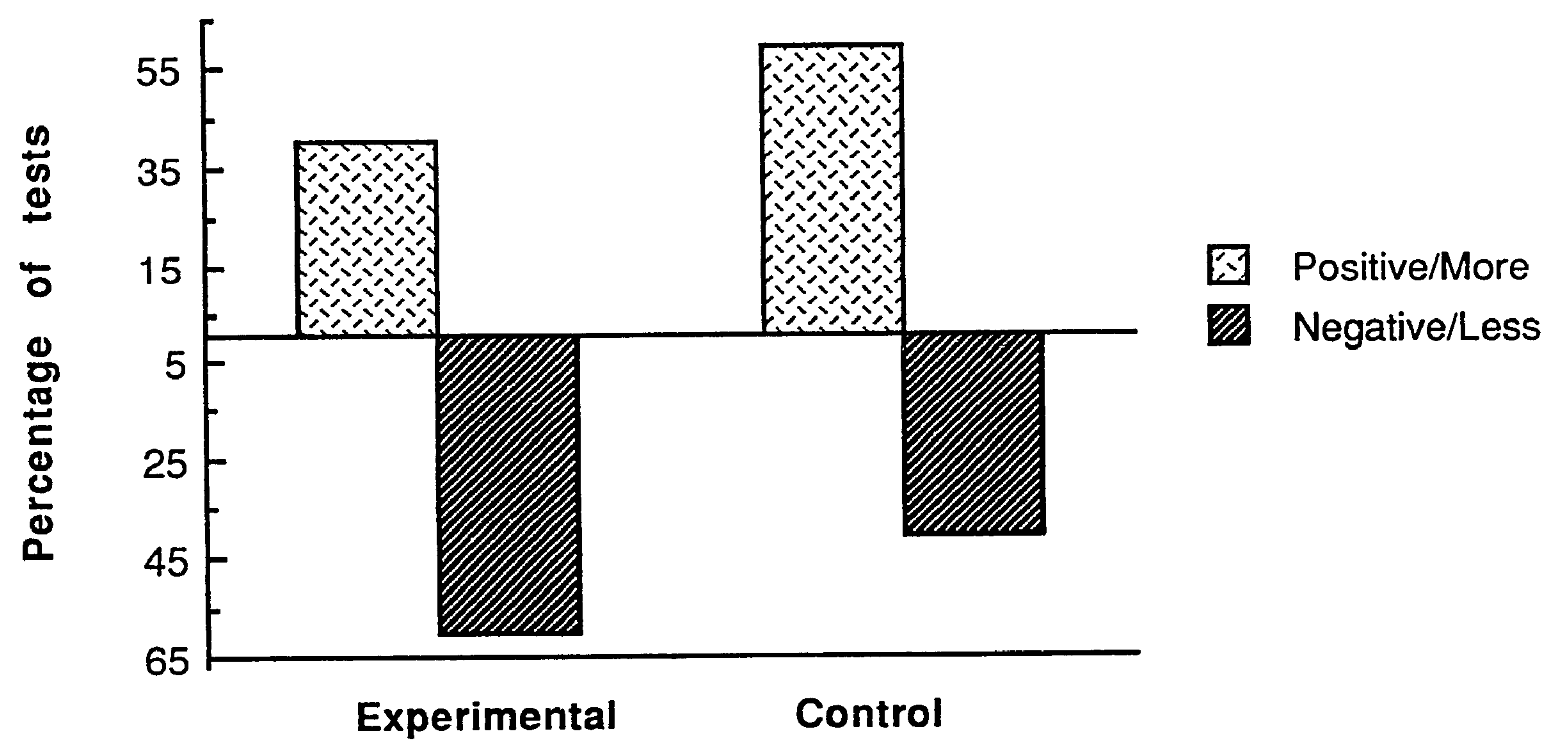
Similar to coma duration and chronicity, education correlated strongest with tests primarily of parietal lobe functioning followed by tests of temporal lobe functioning, frontal lobe functioning, and least with occipital lobe functioning.

Significant correlations were calculated in the EG between education and only one test related to parietal lobe function - tactual performance (dominant hand time) (r = -.57). In the CG significant correlations were calculated for this variable and a test related to frontal lobe functiong - grip strength (right hand sustained strength) (r = .78), a temporal lobe test - memory scale (visual reproduction) (r = -.56) and a test related to parietal lobe functioning - tactual performance (nondominant hand time) (r = .67).

Figure 4 presents a summary of the proportion of tests that were either positive or negative in each group for education. Positive correlations, the higher the educational level the greater was improvement. In contrast, for negative correlations the lower the educational level the greater was improvement. There was a higher proportion of tests that were negative in the EG compared to the CG (60% vs 41%) (see Figure 4).

In contrast to coma duration, chronicity, and

Figure 4: Percentage of tests that attained Positive or Negative Correlation Coefficients on Education.

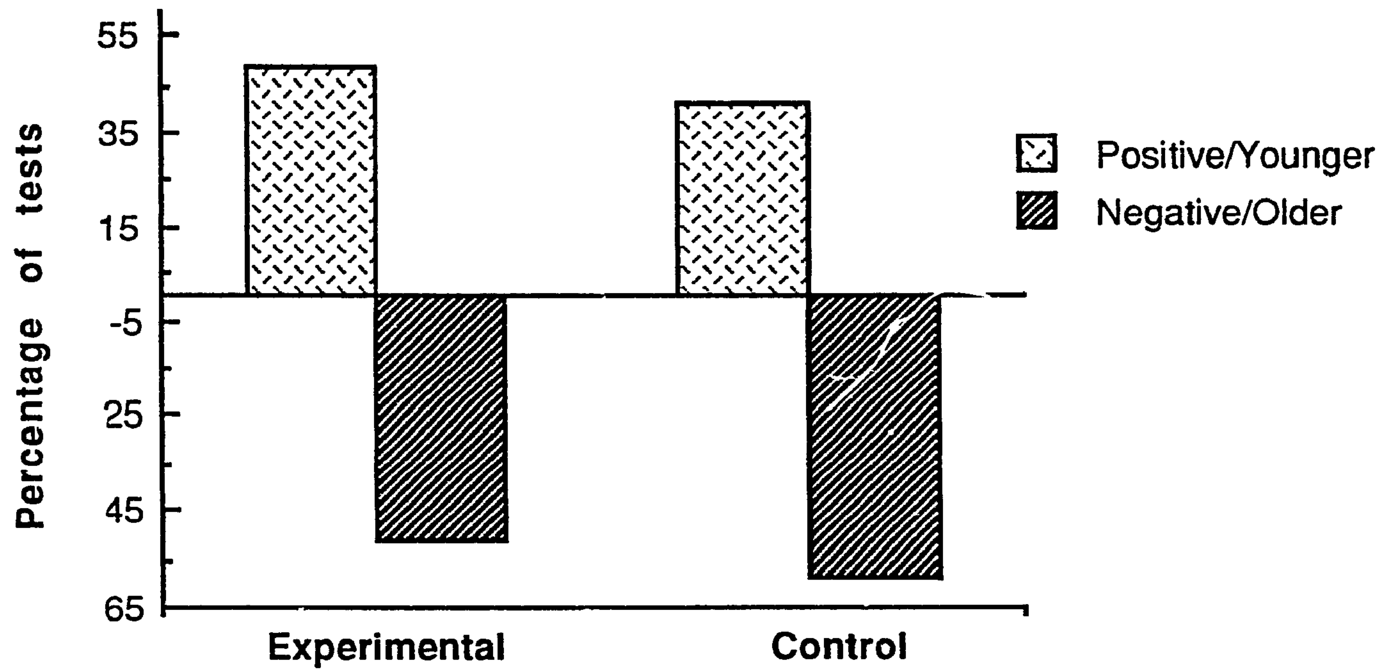


education, age correlated most strongly with tests related primarily to the frontal lobes followed by tests tapping primarily parietal functioning, occipital functioning and least with those tapping temporal functioning.

Significant correlations in the EG were calculated between age and sensory tests - one related to parietal lobe functioning on two point sensation (right hand-down) ($r = .66$) and one related to occipital lobe functioning - perimetry (left eye-right superior quadrant) ($r = -.76$). In the CG significant correlations were calculated for tests related to frontal lobe functioning on design fluency (five minute condition) ($r = .71$), grip strength (nondominant hand) ($r = .55$), and on a test related to occipital lobe functioning for perimetry (right eye - right inferior and left superior quadrants) ($r = -.56$, $.68$ respectively).

Figure 5 summarizes the proportion of tests that were positive or negative in relation to age for each group. This Figure shows that there was a greater proportion of tests that were negative than positive in the EG whereas, the reverse was true in the CG (see Figure 5). Note that negative correlations indicate that older patients tended to have better post-test performance whereas, positive correlations indicate that younger patients manifest greater performance at post-figure 5

Figure 5: Percentage of tests that attained Positive or Negative Correlation Coefficients on Age.



test.

In summary, one common pattern was observed for coma duration and education. Parietal tests correlated strongest (i.e., $\geq$ .34) with these variables. Additionally, the tactual and the two point sensation tended to result in significant correlations.

2. Correlations between symptoms and difference Z scores.

Table 12 presents a summary of the percentage of tests, according to lobe, that attained a positive or negative correlation coefficient (calculated from Appendix 4) between the patients' subjective pre-test self-reported symptomatology (which were subdivided into categories- motor, sensory, emotional, social, cognitive, and vegetative/autonomic) and standardized difference Z scores (i.e., post-test performance). The grouping of the questions that attributed to the total score in each category, selected from the neuropsychological questionnaire answered by the patient during the initial interview, were the same as those used by Braun and colleagues (1988) (see last page of Appendix 1 for the questions that comprised each category). Note that the more symptoms reported, the more positive the Z score. Hence, negative correlations imply that the lower the reported symptomatology (i.e., defined here as mild cases) the greater the post-test performance. In contrast for positive correlations, the more symptoms reported (i.e., defined here as severe cases) the better was post-test performance. Note however, that this terminology (i.e., mild, severe) is arbitrary since it is not based on any specific cut-off points rather, symptoms are on a sliding scale.

Table 12 shows that in the CG, performance at post-test was negatively correlated with the number of symptoms reported at pre-test in most instances. Hence, in the CG, the patients with the least symptoms manifested more improvement than the patients with more symptoms. The reverse was true in the EG. Patients with more symptoms manifested greater improvements than the "milder" cases in this group (see Table 12).

Figure 6 presents a summary of Table 12 correlations. That is, it presents the percentage of tests, in each group, that attained a positive or negative correlation coefficient on collapsed symptom categories. The EG had a greater percentage of positive correlation coefficients compared to the CG. In contrast the CG had more negative correlation coefficients compared to the EG (see Figure 6).

An attempt was made to subdivide as many neuropsychological tests into a cognitive or motor

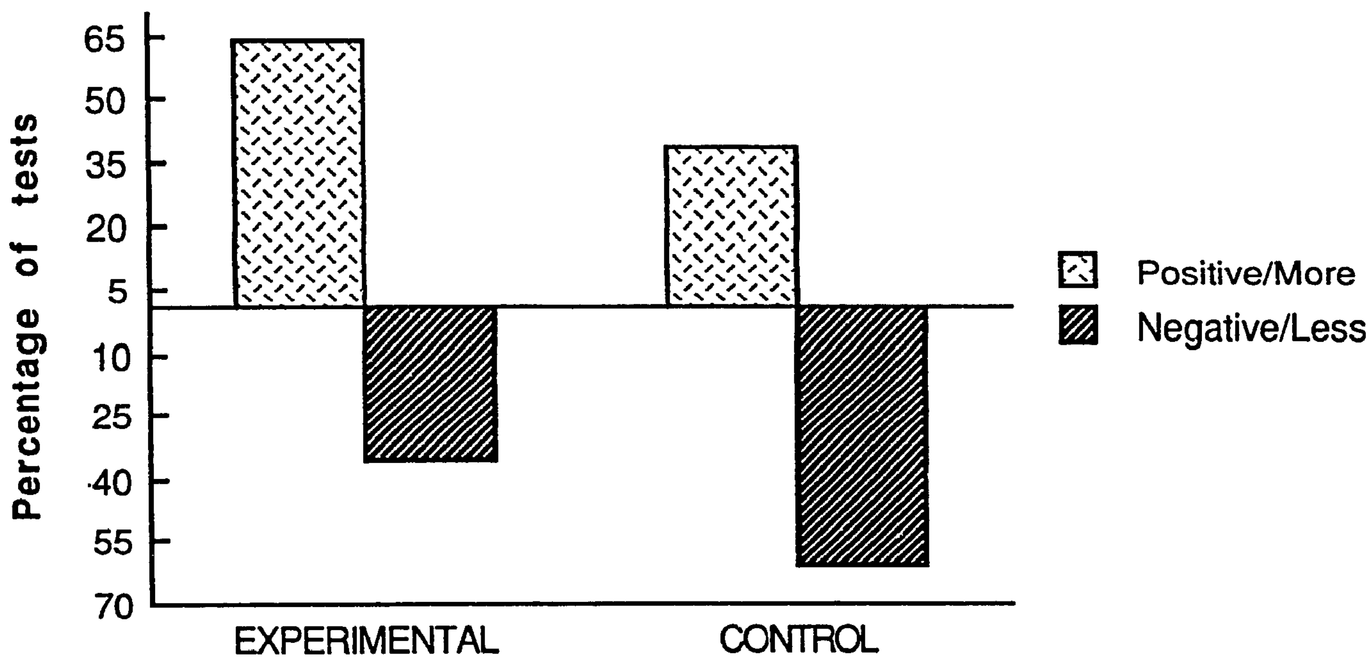
Table 12

Percentage of tests that attained negative or positive correlation coefficients between difference score and pre-test patient reported symptom category per lobe and per group.

	Negative correlations					Positive correlations				
	F	T	P	O	A	F	T	P	O	A
CATEGORY										
Motor										
E	50	33	8	25	89	50	67	92	75	11
C	56	61	50	75	67	44	39	50	25	33
Sensory										
E	38	50	8	50	25	62	50	92	50	75
C	56	50	75	63	50	44	50	25	37	50
Emotional										
E	44	50	17	11	33	56	50	83	89	67
C	75	61	75	100	78	25	39	25	0	22
Social										
E	38	44	8	63	30	62	56	93	37	70
C	69	56	32	50	56	31	44	68	50	44
Cognitive										
E	25	44	33	50	44	75	56	67	50	56
C	38	72	58	75	50	62	28	42	25	50
Vegative/ Autonomic										
E	50	50	25	25	33	50	50	75	75	67
C	56	39	67	50	89	44	61	33	50	11

Note: F (Frontal), T (Temporal), P (Parietal), O (Occipital), and A (Auxiliary) tests. E (Experimental), C (Control) group.

Figure 6: Percentage of Tests that attained Positive or Negative Correlation Coefficients on Collapsed Symptoms Categories per Group.



subgrouping since we wanted to determine whether there were any differences between improvement and subgroup (i.e., cognitive versus motor). This a posteriori analysis was based on the rationale that the two groups may differ based on the training (e.g., cognitive remediation or other remediation training).

Tests that were categorized into the cognitive subgroup were the following: design fluency (2 measures), verbal fluency (2 measures), card sorting (4 measures), delayed recall (2 measures), memory scale (8 measures), tactual (2 "memory" measures), language, and vocabulary.

The motor subgroup comprised the following tests: grip strength (4 measures), finger tapping (2 measures), tactual (2 measures on manual time to complete the task), reaction time (2 measures), and tremometer (2 measures). The balance of the correlations (29) were not classifiable into either of these categories.

To simplify correlational analyses, scores were reversed so that the more reported symptoms the more negative the Z score. A global measure of patient-reported subjective symptoms was obtained irrespective of category (e.g., motor, sensory, etc). Correlations were then calculated between this global measure (as opposed to correlations for each category as presented in Table 12) and individual neuropsychological tests. Table 13a-d presents these correlations according to group (see Table

13a-d). The reader is reminded that positive correlations here, indicate that the lower the reported global symptoms were, the greater was improvement. In contrast, negative correlations here mean that the greater the reported global symptoms were, the greater was the improvement.

Although both groups had roughly equal positive (7) and negative (9) correlation coefficients on frontal tests, the distribution of these correlations was different. In the CG roughly half (4) of the negative correlations were observed for grip strength. This suggests that heavier cases improved more on motor related tasks whereas, milder cases (positive correlations) improved most on cognitively related tests. In the EG, negative correlations tended to occur primarily on cognitively related tests. This suggests that milder cases improved more on these tests whereas, heavier cases tended to show more improvements on motor tasks (as reflected by positive correlations) (see Table 13a).

On both temporal and occipital tests both groups had roughly the same positive and negative correlation coefficients. There was no consistent pattern observed for severe and mild cases or cognitive/motor comparisons per group for these tests (see Table 13b, 13d).

Table 13a

Correlations between global subjective reported symptoms with difference scores on Frontal tests.

FRONTAL TESTS	Experimental	Control
Design fluency		
5 minutes	-.40	-.09
4 minutes	.38	.09
Dynamometer grip strength		
dominant hand time	.23	-.42
nondominant hand time	-.06	-.32
Sustained strength right	.19	-.41
Sustained strength left	.27	-.42
Finger tapping		
right hand	.06	-.20
left hand	.32	.02
Kolb hand praxia		
preferred hand	-.04	.42
nonpreferred hand	.23	-.30
Verbal fluency		
5 minutes	-.03	.31
4 minutes	-.04	-.19
Wisconsin Card Sorting		
categories completed	-.03	.04
nonperseverative errors	-.09	-.05
perseverative errors	-.13	.15
perseverative responses	-.18	.19

Note: Significant correlation coefficients at:

$p < .001$ $r > \pm .55$

$p < .01$ $.55 > r > \pm .44$

$p < .05$ $.44 > r > \pm .33$

Table 13b

Correlations between global subjective reported symptoms at pre-test with difference scores on Temporal tests.

TEMPORAL TESTS	Experimental	Control
Dichotic digits		
left ear	.39	.08
right ear	-.23	-.12
Dichotic melodies		
left ear	.28	-.59
right ear	.19	-.26
Ekman facial affect		
hits	-.16	-.44
reaction time on hits (sec.)	.21	.35
Russell delayed recall (% score)		
semantic	-.04	-.06
designs	.37	.40
Verbal contextual affect		
hits	-.39	-.28
reaction time on hits (sec.)	.01	-.12
Wechsler memory scale		
information	-.16	-.19
orientation	-.10	-.21
mental control	-.07	.02
logical memory	-.25	-.15
digits forward	.18	.03
digits backward	.13	.02
visual reproduction	.33	.13
associative learning	.30	.26

Note: Significant correlation coefficients at:

$p < .001 \quad r > \pm .55$

$p < .01 \quad .55 > r > \pm .44$

$p < .05 \quad .44 > r > \pm .33$

Table 13c

Correlations between global subjective reported symptoms at pre-test with difference score on Parietal tests.

	Experimental	Control
PARIETAL TESTS		
Aesthesiometer two point discrimination (cm)		
right hand - down	.53	.14
- across	.62	.06
left hand - down	.33	.73
- across	.48	-.22
Benton Right-left orientation		
own body	.32	.05
experimenter's body	.01	-.26
Semmes body placement	-.54	.27
Single double simultaneous stimulation		
errors	-.50	.09
Tactual performance		
dominant hand time (sec.)	.66	-.10
nondominant hand time	.47	.01
memory for blocks	-.65	.53
memory of block location	-.40	-.02

Note: Significant correlation coefficients at:

$p < .001$ $r > \pm .55$

$p < .01$ $.55 > r > \pm .44$

$p < .05$ $.44 > r > \pm .33$

Table 13d

Correlations between global subjective reported symptoms at pre-test with difference scores on Occipital and Auxiliary tests.

	Experimental	Control
OCCIPITAL TEST		
Visual Field Perimetry		
Right eye		
right superior quadrant	-.13	.43
right inferior quadrant	-.15	-.03
left superior quadrant	.28	-.35
left inferior quadrant	-.41	-.22
Left eye		
right superior quadrant	-.02	.35
right inferior quadrant	.36	.16
left superior quadrant	.29	.23
left inferior quadrant	-.38	-.42
AUXILIARY TESTS		
D2 letter cancellation		
% errors	-.17	.39
hits	-.13	.04
Humour appreciation	-.06	-.10
Reaction time (msec.)		
right hand	-.05	.48
left hand	.05	-.11
Token (language testing)	-.07	-.39
Tremometer		
right hand	.61	-.17
left hand	-.04	.05
WAIS Vocabulary subtest(%)	.01	-.01

Note: Significant correlation coefficients at:

$p < .001$ $r > \pm .55$

$p < .01$ $.55 > r > \pm .44$

$p < .05$ $.44 > r > \pm .33$

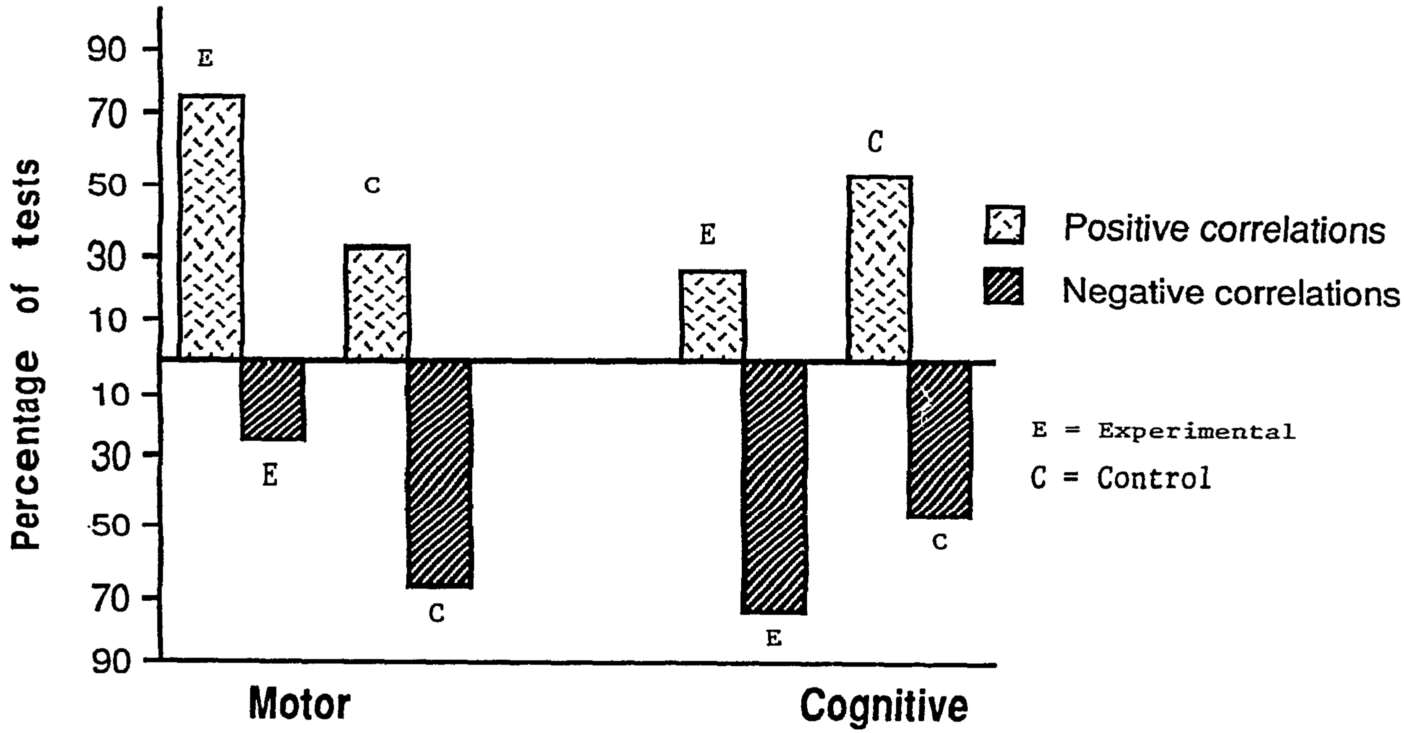
In contrast to the temporal tests, for parietal tests there was a marked contrast between the number of positive and negative correlation coefficients. There were twice as many positive correlations (8) as there were negative correlations (4) and this was equally true for both groups. Similar to temporal tests, however, there were no obvious consistent patterns observed for cognitive/motor tests. Nevertheless, milder cases showed the greatest improvements, as reflected by the number of positive correlations.

Similar to parietal tests, for auxiliary tests there were more negative (6) than positive (3) correlations but, this was mostly true for the EG. Again, this suggests that heavier cases showed better performance at post-test.

In summary, on frontal and auxiliary tests the heavier cases appeared to manifest greater improvement as reflected by negative correlation coefficients. Contrary to mild cases, severe cases appeared to improve least on the parietal tests as reflected by positive correlation coefficients.

Figure 7 presents a summary of the proportion of tests from the above analysis for which there were positive or negative correlations. The proportion of negative or positive correlations in these two subdivisions of tests varied dependent on the group (see Figure 7). Positive correlations indicate that the lower the global reported

Figure 7: Percentage of tests that attained a Positive or Negative Correlation coefficient on Global symptom reports.



symptoms the greater the improvement. In contrast negative correlations mean that the more global reported symptoms the greater the improvement.

In summary this figure shows that for cognitively related tests, in the EG, the heavier cases had better post-test performance (negative correlations) whereas, milder cases had better post-test performance on motor tests (positive correlations). In contrast, in the CG heavier cases had greater improvements on motor related tests (negative correlations) and milder cases had greater improvements on cognitively related tests (positive correlations).

Discussion

A: Efficacy of computer-driven cognitive remediation

The findings do not support the hypothesis that computer-driven cognitive remediation therapy has benefits in severe traumatic CHI patients long after spontaneous recovery. Previous literature has suggested that spontaneous recovery occurs primarily within the first year post-injury. Memory functions, however, have been reported to continue improving beyond this period (Squire, 1986). The present results do not support the notion that memory functions continue to recover beyond a five year chronicity level since there were no significant interactions on various memory tests. These findings may suggest that computer-driven cognitive remediation may be overrated, given the "subminimal" gains which were statistically below limen. Since patients were, on average, five years beyond their trauma, these nonsignificant findings suggest that these CHI patients may have reached a plateau.

The issue of carry-over of treatment effects (i.e., level two generalization) was addressed in this study by using a pre-post design and looking at improvements on neuropsychological tests that differed from the training exercises. The lack of significant interactions on individual ANOVAs is sobering. Since this study systematically controlled for many methodological limitations found in previous research (Miller, 1980; Robertson et al., 1986; Scholberg & Mateer, 1987)), the findings may suggest that CHI patients are indeed limited in their ability to benefit beyond the immediate training exercises (i.e., level two generalization) even though the exercises were similar to the training tasks in terms of cognitive structure.

Previous studies that investigated "low" level generalization abilities (i.e., level one) in head injured patients found that these patients are able to improve and maintain learning over time (e.g., Ethier et al., 1989a,b; Glisky & Schacter, 1989; Glisky et al, 1986a,b; Miller, 1980). It is well known however, that performance gets disrupted with minuscule changes in the task in CHI patients (i.e., beyond level one generalization). Indeed, when head injured patients are required to perform on "higher" level tasks (i.e., level two generalization) they show poor performance (Glisky et al, 1986b; Malec, et al., 1984; Ragain, 1983) and no generalization according to the present findings.

The finding that CHI patients are unable to generalize (i.e., at a higher conceptual level - level two generalization) was alluded to in previous literature that reported a "rigidity" in problem solving approaches used by these patients (Glisky et al., 1986b). These convergent findings, taken together, suggest that traumatic CHI individuals may require well controlled environments for optimal functioning. It is not surprising therefore, that clinicians have reported that considerable time and effort are required for minimal performance gains in CHI. Perhaps future research can address this question by investigating the effects of very fundamental skill training as opposed to higher order learning (e.g., simple as opposed to complex tasks in a controlled non changing learning situation) in severe traumatic CHI patients.

Since this study used different outcome variables than those used during remediation, it permitted one to investigate the differences between practice effects and "true" improvements. There were no significant improvements found. Hence, these results suggest that previous studies that employed similar tasks to those used during training to evaluate remediation (i.e., level one generalization) and that reported improvements following remediation, may be dealing primarily with practice effects.

This study controlled for spontaneous recovery effects, that occur during the first year following head trauma, which was often a confounding variable in previous studies that reported improvements following computer-driven remediation (e.g., Finlayson, et al., 1987). Previous research that attempted to control for it, similar to this study, did not find improvements (e.g., Batchelor et al., 1988; Vignolo, 1964). The present results concur with Ponsford and Kinsella's (1988) findings, who controlled for both spontaneous recovery and practice effects yet, found little response to computer remediation. The question then, arises as to when during the person's rehabilitation program might cognitive remediation be best implemented?

Using a convergent approach, the present study indirectly addressed the issue related to when treatment may best be implemented (i.e., before or after the spontaneous recovery period of brain function). Both the study by Vignolo (1964) and the study by Kertesz and McCabe (1977) found no significant differences between treated and untreated groups during the spontaneous recovery period. This suggests that brain function improves independent of intervention during the spontaneous recovery period. What these studies, together with the present findings, have in common is that they all address the issue related to "when is treatment most beneficial". On the average five years following head trauma, there were no statistically significant test results found between treated and untreated patients on the basis of univariate analyses in this study. Taken together, the results of these three studies suggest that treatment may be most beneficial following spontaneous recovery and possibly before a five year chronicity.

The most cautious conclusion that can be drawn given these findings, is that computer-driven cognitive remediation does not help severe traumatic CHI patients to improve late beyond spontaneous recovery, as measured by each test separately. Hence, similar to Robertson et al. (1986), the present findings do not permit widespread endorsement of computer-assisted remediation in clinical practice. The computer training in this study was not tailored to meet the individual's needs. Had it been, a different picture might have emerged.

Perhaps future research should consider using a multivariate approach since non-significant results on univariate analyses appear to be meaningless. This is especially true given the finding that there was a significant interaction on summed Z scores in which the control group demonstrated a significant decline in performance but the experimental group did not. Most measures were in an ascending direction in the experimental group although not significantly so. Hence, the absence of cognitive remediation may result in cognitive decline. Future research should verify if it is the absence of cognitive remediation which is the significant variable. There may however, be alternate explanations for the non-significant results.

Most of the measures used in this study were chosen because their clinical validity had been well established in the neuropsychological literature. Although, a test may be clinically sensitive in detecting brain function, it does not follow that it would be equally able to detect possible changes (in a positive or negative direction) following cognitive remediation. Given the non-significant findings, one would want to consider whether the measures used were sufficiently sensitive in detecting differences.

Post-hoc power determination of well established measures can help to determine if the sensitivity of the measures used was sufficient (i.e., how much variance can be explained by differences) to reject the null hypothesis. Post-hoc analyses indicated that there was a zero percent chance (i.e., power) that the two group means were large enough to be statistically significant (see Appendix 5 for these calculations).

Power was severely affected probably due to the very extreme variability within patients. Many attempts were made in this study to reduce error variance (e.g., by matching patients on variables reported to influence remediation, using repeated measures). Nevertheless, extreme variability was observed in this sample of CHI patients, which is commonly reported in the literature, and points to difficulties in doing research with this population. This may have had serious effects on the sensitivity of the measures used. Given the stringent alpha level used and the low sensitivity it is possible that real differences went unrecognized.

An alternate way of reducing error variance is by using covariance. Indeed, covariance can produce a reduction in error variance by adjusting estimates of error and of treatment effects for the linear effects of a control variable (i.e., a variable that is correlated with the dependent variable, in this case the pre-test score with the post-test performance). Given the finding that there were group differences at pre-test on averaged Z scores, using pre-test performance as a covariate might have equalized the two groups and a different picture might have emerged.

Alternately, another statistical issue to consider relates to how should "change" be measured? In this study changes in pre-post performance was taken to imply possible carry-over of treatment effects in the experimental group. Hence, changes in post-test performance may be related to the treatment effect. However, carry-over of performance from pre- to post-test may equally occur in the control group. How can these results be explained? It is possible that when repeated measures are used the variance from pre-test may be systematically affecting post-test results.

Cronbach and Furby (1970, p.68) state that "Raw change or raw gain scores formed by subtracting pretest scores from posttest scores lead to fallacious conclusions, primarily because such scores are systematically related to any random error of measurement." These authors further argue that such change scores are useless no matter how they may be adjusted or refined. This implies that covarying pre-test measures would not adequately control for systematic error that may occur by using repeated measures.

Other researchers hold that the best way to deal with change scores is by residualizing post-test performance with pre-test performance (Woody & Costanzo, 1990). That is, the post-test performance is expressed as a deviation from the post-test on pre-test regression line. This approach has the effect of partialling out the portion of the post-test information that is linearly predictable from the pre-test. Hence, residualizing removes from post-test performance the portion that could have been predicted linearly from pre-test status.

Cronback and Farly (1970) argue that the residualized score is not simply a corrected measure of gain. They hold that corrected measures (e.g., covariance adjusted scores) have the effect of discarding portions of genuine and important change. They argue that "The residualized score is primarily a way of singling out individuals who changed more (or less) than expected." (p74). This issue related to the best statistical approach to analyze change scores however, is very controversial. Nevertheless, the possibility exists that the two groups may have had different baselines. Depending on pre-treatment baseline the change score may have a different significance, hence, a different meaning or interpretation. Consequently, the pre-test baseline differences may explain the lack of significance.

B: Discussion of trends for clinical and future research purposes

Normally one would not analyze trends, because non-significant results on univariate analyses are meaningless. However, since trends referring to group and treatment effects reported here were all in the same direction (i.e., in an ascending direction for the experimental group), perhaps it is worthwhile to discuss them. Moreover, the direction of these trends was consistent with the hypothesis. Additionally, this was also an exploratory study which was designed to maximize any improvements in CHI patients. Finally, perhaps practitioners and future researchers will find here clues for future research.

Overall, the results indicate that computer-dispensed cognitive remediation produced very subtle nonsignificant benefits. Trends indicated that, despite the extreme performance variability often seen in this population (i.e., instability in behavioral performance over time even in static situations) (Ethier, 1987), the experimental group occasionally manifested improvement in the expected direction, whereas, the control group occasionally showed decline.

The finding that the experimental group's performance was inferior to that of the control group's on pre-test might perhaps have reduced the chance of finding a significant improvement on univariate ANOVAs. Despite the attempt to match patients on percentage of neuropsychological test deficits at pre-test, after having standardized and tallied all test performance, the experimental group's cumulative performance on the entire neuropsychological battery was significantly inferior to the control group. Despite this, the experimental group tended to show minimal, although not statistically significant, consistent gains in comparison to the control group who showed statistically significant deterioration.

It may be possible that in patients treated with only "standard" rehabilitation, a "spontaneous" performance decline on neuropsychological tests may occur. Indeed, the significant pre-test performance superiority in the control group, relative to the experimental group, was not maintained at post-test. Whether this "spontaneous" decline was due to mental inactivity, and/or motivation, and/or physiological deterioration, and/or alterations in lifestyle is not immediately obvious. The fact remains that the control group's overall performance deteriorated without cognitive remediation while the experimental group's performance was maintained. The question of whether "real" improvement or deterioration occurs as a result of therapy versus no therapy should be addressed more systematically by using a staggered double cross-over design (i.e., neuropsychological assessment of all patients, followed by six months of no therapy for randomly chosen or matched one-half of the group, followed by neuropsychological assessment of all patients, followed by six months of therapy for the other half of the untreated patients while the treated patients discontinue therapy, followed by neuropsychological testing of all patients). Although there was a statistically significant decline in the control group, it was observed that not all patients in the control group showed decline.

1. Predictors of remediation outcome

"Mainstreaming" approaches provide therapy not tailored to the individual's needs, but rather, where everyone receives the same treatment. In this study cognitive remediation appears to be beneficial for some patients and not others using this approach. Hence, this approach is limited and not very efficient with all CHI patients. Indeed, correlations between patients' global subjective symptom reports (at pre-test) and difference scores, on tests primarily tapping cognitive functions, indicated that in the experimental group severe cases (i.e., patients with many subjective symptoms reported at pre-test) benefit more from this approach than milder cases (see Figure 6).

Similarly, Van Zomeren and Deelman (1978) found that a mild group (mild was defined as level of CNS severity) appeared to reach a plateau in performance sooner post injury. In contrast a more severely injured group kept improving information processing capacity (as indexed by reaction time) two years post injury. The experimental group, who reported less symptoms at pre-test (i.e., mild cases) also appeared to manifest the least improvements (as indexed by the percentage of tests that attained a negative correlation coefficient). Hence, cognitive remediation therapy may help patients that were classified as severe prior to remediation. It is concluded therefore, that the number of symptoms reported by patients at pre-test (categorized post hoc as "mild" or "severe") may be a useful predictor of who will benefit most from computer-dispensed cognitive remediation.

Correlations obtained in the present study for the control group, also suggest that the "mild" cases with less symptomatology actually improved more than "severe" cases (positive correlations). Hence, not all control patients showed neurobehavioral decline. A "spontaneous" cognitive decline does not occur systematically in all untreated patients. Rather, only certain patients show this decline.

With respect to the cognitive-motor subdivision, "mild" cases in the experimental group showed minimal benefits on cognitively related tests. C motor related neuropsychological tests, an opposite effect ocurred in mild cases (i.e., milder cases showed greater improvements on motor tests) in the experimental group. Alternately, severe cases in the experimental group improved less on motor related neuropsychological tests than did mild cases. The opposite was true for the control group. In the control group, the severe cases showed more improvements compared to the milder cases on motor related tests.

This double dissociation between the groups on cognitive and motor performance in relation to reported subjective symptoms is a very interesting finding. The severe cases in the experimental group improved most on cognitively related measures whereas the severe cases in the control group improved most on motor related neuropsychological measures. Perhaps this occurred because the majority of the patients in the control group participated in an intensive exercise program during the six months during which time the experimental group received cognitive remediation. What these observations suggest is that severe cases (as indexed by the number of reported symptoms at pre-test) tend to show performance benefits on tests that relate closely to the treatment modality (cognitive versus motor). Conversely, treatment modality is not related to outcome in mild cases. More systematic research on treatment modality (e.g., cognitive versus motor) and its effects on neurobehavioral functioning would be a worthwhile effort.

2. <u>Neuropsychological test results, their relation to previous anatomical findings, and their significance for rehabilitation</u>

Pre-test measures indicated that, overall, the patients showed deficiencies primarily on frontal and temporal tests. Moreover, the post-test results indicated that patients showed least improvement on frontally related neuropsychological tests irrespective of group. This finding supports the anatomical literature in traumatic CHI stating primarily a fronto-temporal distribution of cortical damage (Jennett & Teasdale, 1981).

The greatest performance improvement in the experimental group occurred on auxiliary tests followed by parietal tests. Sixty seven percent of the auxiliary tests related closely to the training exercises used in cognitive remediation therapy, hence it is not surprising that the experimental group showed most improvement on these tests compared to the control group (89% vs 67%).

The experimental group may have improved, although not significantly, on cognitive tests because most of the exercises used during remediation focused on cognitive functions. This group improved more than the control group on all tests (i.e., cognitive, sensory, motor), although these improvements were subtle and nonsignificant on univariate analyses. These findings suggest involvement of brain sites other than the expected fronto-temporal lesion distribution. These findings point to the residual functions of less damaged lobes. If these CHI patients had manifested improvement primarily on "frontal" and "temporal" neuropsychological tests, then the results would support a "training of dysfunction" hypothesis (Crain, 1982) as the best approach for remediation of cognitive function. However, the contrary having occurred, it is more likely that these results are best explained by the "residual function" hypothesis (Luria, 1963).

3. Attention and memory hypothesis

The trend toward significance in the pre/post effect for digits backward was mostly attributed to the experimental group's improved performance as opposed to the control group's performance decline. For Digits forward the experimental group improved their performance more than the contro group (increases of .59 vs. 06 respectively). However, Digits forward has been shown to primarily reflect attention as opposed to memory function per se. For Digits backward, working memory as well as the ability to actively manipulate digits (i.e., mental rotation) must be intact in order to perform this task. CHI patients have been reported to show mental slowing (Lezak, 1983). This slowing would by necessity interfere with the person's ability to maintain and perform at an adequate level. Hence, these results suggest that cognitive remediation helped the experimental group to perhaps be "more" attentive and alert and to process this information mentally more effectively since they outperformed (although not significantly) the control group.

On the Memory scale there were improvements in performance, although not significant, in the experimental group on various subtests. On the Orientation subtest the experimental group maintained their performance while the control group's performance deteriorated. Similarly on Visual reproduction the experimental group improved more than the control group (mean = 2.41 vs 1.35). This same improvement was also observed on Associative learning in favour of the experimental group (mean = 1.3 vs .8). This improvement on Associative learning lends support to previous ideas that this group's attentional capacity was enhanced following cognitive remediation compared to the untreated control group. There were no obvious differences on the other subtests (i.e., Mental control and Logical memory).

Neurophysiological investigations by Baribeau and her colleagues (1989) revealed that following cognitive remediation CHI patients showed improved attentional effort, better capacity to follow instruction, improved stimulus processing, and better motivation. These researchers concluded however, that improvements in various indexes of the event related potential (e.g., Nd-200 amplitude) were not due to improved attentional selectivity per se. Hence, some very basic selective mechanisms remain unaffected by remediation, and an exaggerated case for remediating attentional selectivity per se cannot be supported.

4. Other variables related to outcome

Positive correlations between coma duration and post-test performance were indicative of greater performance improvements by the patients with the shortest coma duration. Fifty-nine percent of these correlations in the experimental group were positive suggesting that patients with shorter coma duration gained most from cognitive remediation compared to patients with longer coma duration. Two of the six statistically significant measures - Logical memory and Tactual (time), were very closely related to the cognitive exercises on which the experimental patients with shorter coma duration improved most. The reverse was true in the control group. This is counter intuitive. That is, patients with longer coma duration had better performance. This suggests that, in the control group, the patients with the shortest coma duration showed no change with regular rehabilitation. Patients with longer coma duration still show some cognitive changes even without cognitive remediation! An immediate explanation is not forthcoming for these findings. It is possible that they resulted from random error sometimes found in small N studies.

With respect to correlations between chronicity and post-test performance, the results indicated that patients with the shortest chronicity in both groups improved more than those with longer chronicity. This was however, more pronounced in the experimental group. These findings suggest that prolonging remediation long after the spontaneous recovery period may not be in the best interest of the patient. They also suggest that as time elapses patients plateau and hence it becomes more difficult to remediate these individuals. Indeed, only five percent of these correlations in the experimental group indicated that patients with the longest chronicity improved. In contrast 13% of the correlations in the experimental group indicated that the patients with the shortest chronicity tended to improve on certain tests. In summary, this suggests that remediation is more beneficial in the earlier stages following injury but after spontaneous recovery.

In general correlations between age and post-test performance indicated that younger patients seemed to perform slightly better (negative correlations) than older patients following remediation. However, for the measures that attained statistical correlational significance related with age, younger and older patients in the experimental group appeared comparable (52% negative correlations, 48% positive correlations). These findings suggest that cognitive remediation therapy may be beneficial at all ages.

The pattern for education on post-test performance was somewhat different. Since, the proportions of negative correlations were greater than for positive, the results suggest that the lower the education the greater the benefits of cognitive remediation therapy (60% vs 40% respectively). These findings may suggest that lower educated patients "reap the greatest rewards" in cognitive remediation therapy whereas the reverse is true for those not in therapy.

In summary, these findings support previous literature that patients with shorter chronicity improve most (Ethier et al., 1989a,b; Levin et al., 1982; Lezak, 1983; Miller, 1984; Williams et al., 1984). With respect to education, perhaps lower educated patients benefit more from therapy because they have "more" to learn.

5. Sensory functioning in CHI

It is not surprising that there were group trends on the Perimetry test. This suggests, simply, that some patients nad more or less visual field loss. We would not have expected this to change following therapy since the therapy cannot change pure sensory loss. It is important to discuss such findings because sporadic changes in "pure" sensory assessment should not occur, since sensory function cannot be remediated. There are other sensory tests however, that are not "pure" and may involve other functions. These tests may also have low localizing abilities. For example, in two-point discrimination the testee may show "deficits" that may be related to real sensory deficits or what appears to be a sensory deficit may in fact be an attentional deficit parading as a sensory deficit. Hence, sensory performance improvements following cognitive remediation is taken here to imply improvement in attention or motivation to perform at the time rather than a "true" sensory change.

6. <u>Information processing in CHI as it relates to cognitive remediation therapy</u>.

The experimental group practiced on various reaction time exercises (simple and complex) for a period of approximately two months at the beginning of the remediation therapy. This group subsequently was trained on other exercises for a further four months. At post-test, which occurred four months following training on reaction time exercises, patients were required to perform on the same reaction time exercise used during cognitive remediation therapy. Although their performance improved it did not differ significantly from the control group's performance. These findings suggest various possibilities: 1) cognitive remediation therapy may not be the crucial factor in shortening reaction time, hence limited in improving information processing capacity in CHI patients; 2) perhaps improvements in reaction time are not maintained over time in CHI patients suggesting that we are measuring practice effects and therefore that information processing capacity may not be remediable; 3) the remoteness of the task to that of the cognitive remediation therapy exercises may not be an important issue in the way future data are considered (i.e., investigating whether improvements are greatest for similar or dissimilar tasks to those that were being trained); 4) real improvements were camouflaged since hand analysis per se was performed as opposed to analysis by functional hand. Possibilities 2, 3, and 4 may be important theoretical and clinical issues that deserve some attention.

Since reaction time analyses, per hand, of the 17 matched experimental patients was not significant, it was decided that addressing possibility number four would be of interest. Consequently, additional post hoc analyses focused on the functional hand. Functional hand was defined as the patient's "better" functioning or preferred hand. These analyses showed that there were statistically significant improvements in these patients. Hence, there is persistence over time in trained patients but this becomes obvious only with functional hand analyses. This issue of persistence will be further investigated by comparing the two groups according to functional hand (manuscript in preparation).

Training residual functions therefore, may be more beneficial than attempting to train or ameliorate dysfunctions. This issue and the benefits of such an approach were extensively discussed by A.R. Luria (1963).

Conclusions

The results indicated that computer-driven cognitive remediation may be overrated given the nonsignificant findings on the basis of univariate test analysis. However, there were trends indicating benefits, although non-significant, following therapy in the treated patients whereas the untreated patients showed significant decline. Mental inactivity in some of the untreated patients may have led to reduced attentional effort. Finally, it was found that higher level generalization abilities in traumatic CHI patients are limited and nonsignificant.

Post-hoc power analyses however, suggested that treatment effects were not necessarily completely absent or too small but rather, the measures used to detect change were insensitive. Hence, small differences could not be detected using these measures. Consequently it cannot be concluded that treatment effects were probably not present in this specific comparison. Additionally, the possibility exists that the differences between the groups at baseline may have had the effect of showing non-significant results.

Using a mainstreaming approach, cognitive remediation helped some patients and not others. Hence, this approach is limited and not very efficacious with all CHI patients.

Future research should, therefore, attempt to isolate the most effective components in cognitive remediation therapy. To accomplish this, sub-groups of head injured patients must be identified. It is important to address the question of which patients benefit from specific techniques which are superfluous in other patients. In this regard chronicity and global patient's reported symptoms may be important predictor variables.

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Appendix 1

NEUROLOGICAL QUESTIONNAIRE

1. Name of respondent ______________________
2. Phone number ______________________
3. Relation of respondent to patient __________
4. Present date ______________________
5. Duration of coma ______________________
6. Duration of post traumatic amnesia __________
7. Name of patient ______________________
8. Date of birth of patient ________________
9. Date of trauma ______________________
10. Education of patient ________________
11. Highest diploma attained ________________
12. Address of patient ______________________
13. Patient's phone number ________________
14. Name of patient's medical doctor __________
15. Phone number of doctor ________________
16. Skull fracture Yes ____ No____
17. Surgical intervention following injury ______
18. Presently employed Yes ___ N ___
19. Type of work at present

    a) same as pre-injury
    b) less demanding
    c) sheltered
    d) unemployed
    e) homemaker
    f) don't know

20. Status of present job

a) full
b) part
c) unemployed
d) don't know

Income

a) patient	21) primary
b) spouse	
c) children	22) secondary
d) extended family	
e) private insurance	23) tertiary
g) unemployment	
h) court award	24) fourth
i) investment	
j) don't know	

Position /dates/status

25. Prior to injury

26. Prior to injury

27. Prior to injury

28. Since injury

29. Since injury

30. Current

31. Occupation of father

32. Occupation of mother

33. Disability/Compensation Type ____ Amount ___

a) yes
b) no
c) don't know

Marital status

a) single	34) pre-traumatic
b) married/cohabiting	
c) separated	35) Post-traumatic
d) divorced	
e) widowed	36) Since last questionnaire

Psychiatric history

a) none
b) yes, did not seek help
c) outpatient treatment
d) hospitalization
e) don't know

37) Pre-traumatic

38) Post-traumatic

39) Since last questionnaire

40. Transportation

a) alone
b) accompanied
c) none
d) don't know

41. Pre-injury arrest   Type
Sentence

42. Post-injury arrest   Type
Sentence

43. Previous cerebral commotion

Yes   Date
No

44. Previous trauma

Yes   Date
No

45. Treatment received for present brain trauma

a) hospital
b) clinic
c) rehabilitation center
d) other institution
e) individual treatment
f) psychology, MD etc

46. Previous central nervous system damage of disease:

47. Present Medical complaints:

48. Neurological diseases of family members:

Compared to: pre-injury since last questionnaire

---

49. Dizziness

a) no changes
b) mild increase
c) marked decrease
d) improvement
e) don't know

50. Coordination

a) no change
b) mild increase
c) marked decrease
d) improvement
e) don't know

51. Headaches

a) no change
b) mild increase
c) marked decrease
d) improvement
e) don't know

52. Vision

a) no change
b) mild increase
c) marked decrease
d) improvement
e) don't know

53. Gait (walking)

a) no change
b) mild increase
c) marked decrease
d) improvement
e) don't know

54. Fainting

a) no change
b) mild increase
c) marked decrease

d) improvement
e) don't know

55. Sleep

a) no change
b) mild increase
c) marked decrease
d) improvement
e) don't know

56. Trembling (hands)

a) no change
b) mild increase
c) marked decrease
d) improvement
e) don't know

57. Pronunciation of words

a) no change
b) mild increase
c) marked decrease
d) improvement
e) don't know

58. Muscle twitching

a) no change
b) mild increase
c) marked decrease
d) improvement
e) don't know

59. Bladder control

a) no change
b) mild increase
c) marked decrease
d) improvement
e) don't know

Compared to: pre-injury | since last questionnaire

---

60. Bowel control

a) no change
b) mild increase
c) marked decrease
d) improvement
e) don't know

61. Sense of balance

a) no change
b) mild increase
c) marked decrease
d) improvement
e) don't know

62. Pain (other than headache)

a) no change
b) mild increase
c) marked decrease
d) improvement
e) don't know

63. Handwriting

a) no change
b) mild worsening
c) marked worsening
d) improvement
e) don't know

64. Reading

a) no change
b) mild worsening
c) marked worsening
d) improvement
e) don't know

65. Feeling of numbness in a part of the body

a) no change
b) mild increase
c) marked decrease
d) improvement
e) don't know

Compared to: pre-injury | since last questionnaire

66. Muscular weakness

a) no change
b) mild increase
c) marked decrease
d) improvement
e) don't know

67. Stability of Mood

a) no change
b) mildly unstable
c) marked instability
d) more stable
e) don't know

68. Speech

a) no change
b) mild worsening
c) marked worsening
d) improvement
e) don't know

69. Ability to live independently

a) no change
b) mild worsening
c) marked worsening
d) improvement
e) don't know

70. Ability to dress

a) no change
b) mild worsening
c) marked worsening
d) improvement
e) don't know

71. Hearing

a) no change
b) mild disturbance
c) marked disturbance
d) improvement
e) don't know

Compared to: pre-injury | since last questionnaire

---

72. Taste and smell

a) no change
b) mild increase
c) marked decrease
d) improvement
e) don't know

73. Seizures

a) none
b) pre-injury disorder
c) at time of impact
d) after initial hospitalization
e) c and d
f) don't know

74. Thinking

a) no decline
b) mild decline
c) marked decline
d) improvement
e) don't know

75. Concentration

a) no decline
b) mild decline
c) marked decline
d) improvement
e) don't know

76. Recent memory

a) no decline
b) mild decline
c) marked decline
d) improvement
e) don't know

77. Remote memory

a) no decline
b) mild decline
c) marked decline
d) improvement
e) don't know

	Compared to: pre-injury	since last questionnaire

78. Depression

    a) none
    b) mild
    c) marked
    d) improved
    e) don't know

79. Appetite

    a) no change
    b) increased
    c) decreased
    d) don't know

80. Sleeping

    a) no change
    b) increased
    c) sleep disturbance
    d) don't know

81. Energy level

    a) no change
    b) increased
    c) decreased
    d) don't know

82. Sexual functioning

    a) no change
    b) mild decrease activity/arousal
    c) no marked decrease
    d) increase
    e) don't know

83. Anxiety

    a) no change
    b) mild increase
    c) no marked increase
    d) decrease
    e) don't know

Compared to: pre-injury | since last questionnaire

---

84. Patience

a) no change
b) mild decrease
c) no marked decrease
d) increase
e) don't know

85. Temper/impulse control

a) no change
b) increased
c) decreased
d) don't know

86. Hallucinations

a) none
b) auditory
c) visual
d) auditory and visual
e) don't know

87. Managing household chores

a) no change
b) mild decrease
c) no marked decrease
d) improvement
e) don't know

88. Legal dispute

a) none
b) patient initiated
c) against patient
d) b and c
e) don't know

89. How getting along with spouse?

a) as well as before
b) better than before
c) not as well
d) does not apply

	Compared to: pre-injury	since last questionnaire

90. How getting along with family/friends?

    a) as well as before
    b) better than before
    c) not as well
    d) does not apply

91. Social activities

    a) as much as before
    b) more than before
    c) less than before
    d) hardly at all

92. Sports/recreation

    a) as much as before
    b) more than before
    c) less than before
    d) hardly at all

GENERAL IMPROVEMENT

93. Physical

    a) improved
    b) no change
    c) decline
    d) don't know

94. Mental

    a) improved
    b) no change
    c) decline
    d) don't know

	95.	96.	97.
	pre-injury	post-injury	since last questionnaire

DRUG USE

__ Marijuana

	95. pre-injury	96. post-injury	97. since last questionnaire
__ Hallucinogens			
__ Stimulants (Cocaine, amphetamines)			
__ Sedatives/hypnotics (Quaaludes, barbiturates)			
DRUG USE continued			
__ Narcotics			
__ Minor tranquilizers			
__ Prescription			
__ Other			

	98. pre-injury	99. post-injury	100. since last questionnaire
ALCOHOL USE			
a) none			
b) occasional			
c) less than 2 drinks/day			
d) more than 2 drinks/daily			
e) drinking interfering with job/social functioning			

101. Medication used in the past ____________________

102. Medication presently used ________________________

Break-down of uestions used in each category

Category	Corresponding question number
Motor problems	2, 7, 26, 28, 29, 30, 38
Sensory problems	1, 3, 4, 5, 6, 33, 34, 37
Primary emotional problems	12, 17, 18, 19, 39
Psychosocial problems	21, 22, 23, 24, 25, 40, 41, 42
Cognitive-perceptual problems	8, 9, 10, 11, 20, 35, 36
Vegetative and autonomic problems	13, 14, 15, 16, 27, 31, 32

Appendix 2

Description of the neuropsychological test battery with normative and validation references where available ....

TESTS RELATED PRIMARILY TO INTEGRITY OF THE FRONTAL LOBE SYSTEMS

Design fluency (design fluency)

This is a paper and pencil test that assesses the ability to generate nonsense designs on command. In the first part of this test the individual is given five minutes in which to draw as many nonsense designs as possible. The second part of the test requires that as many nonsense designs comprising only four lines each be drawn during four minutes (Jones-Gotman & Milner, 1977). This test is believed to be an analoque of verbal fluency. The number of hits in each condition were recorded. Apraxic patients were unable to do this test.

In a validation study, Jones-Gotman and Milner (1977) found that the right frontal group produced less total nonsense designs than did other lesion groups. The validity of this test however, is somewhat questionable due to its scoring criteria. Kolb and Wishaw (1985) reported that 38% of right frontals showed deficits on design fluency while only 10% of left frontals had deficits on this test.

Benton Verbal Fluency (verbal fluency)

This test, most often referred to as "verbal fluency", is also a paper and pencil test. This assesses the ability to spontaneously generate words on command. During a five minute period the individual is required to write down as many words as possible that begin with the letter "S". The second part of this test requires the subject to write down in four minutes as many words as possible that begin with the letter "C" but each word has only four letters (Benton, Hamsher, Varney & Spreen, 1983). The examiner recorded the words for apraxic patients. Hits for each condition were recorded.

The localization abilities of this test are well established in the neuropsychological literature. Ramier and Hecaen (1970), for example, found that the left frontal lesioned group demonstrated significantly lower performance than the right frontal lesioned group on this test. Milner (1964) also found that left frontal lesioned patient's verbal productivity was lower than that of left temporal and/or right frontal (35, 58, 57 words respectively).

Finger Tapping (finger tapping)

This test assesses the individual's ability to initiate and inhibit a motor response (i.e., index finger) as rapidly as possible. The individual is given five 10 seconds trials in which (s)he is to tap as quickly as possible. The mean number of hits was calculated for analyses.

Bornstein (1985) provides standardization of these measures. The initiation and inhibition of motor response is uncontroversially a function related to frontal lobe functioning. Lateralized lesions usually results in slowing of the tapping rate of the contralateral hand (Finlayson & Reitan, 1980).

Dynamometer Grip Strength (grip strength)

This test measures motor strength of the upper extremities. Two trials are given for each hand, provided that trials do not overlap in excess of five kilograms (Bornstein, 1985). The mean motor strength per hand was collected.

Kimura, 1977 provides standardization measures in brain damaged patients for this test.

Kolb Sequential Praxia (praxia)

Tests the individual's ability to sequence and execute arm movements that are demonstrated by the experimenter (Kolb & Milner, 1981). Total hits were collected.

Kolb and Milner (1981) found that frontal lobe patients are impaired on the sequencing aspect of this test compared to other lesioned groups (see also Kolb and Whishaw, 1985).

Wisconsin Card Sorting (card sorting)

This test assesses conceptualization, the ability to use feedback to correct the response, perseveration, and inefficient learning across stages of the test. The stimulus cards (n=4) and response cards (n=128) display figures of varying forms (i.e., crosses, squares, triangles, or circles), numbers (i.e., one, two, three, or four forms), and colors (i.e., yellow, green, red, or blue) (Heaton, 1981). The total categories completed, perseverative responses, perseverative errors, and nonperseverative errors were considered for analyses.

Milner (1964) in a validation study found that the dorsolateral frontal group completed significantly less categories and had more total errors than patients with posterior lobe damage or those patients with orbitofrontal involvement. These errors were mainly perseverative in the dorsolateral group.

Drewe (1974) found that the frontal lesioned group made significantly more total errors (this measure includes perseverative and nonperseverative errors) than the other patient groups. Hence, based on this study's findings we decided to include nonperseverative errors with frontal lobe measures, although perseverative errors is by far a more sensitive measure to frontal lobe dysfunction.

Heaton (1981) in a normative study also found that the frontal groups made more perseverative responses and nonperseverative errors than did nonfrontal groups.

TESTS RELATED PRIMARILY TO INTEGRITY OF THE TEMPORAL LOBE

Audiometer test (audiometry)

The individual's hearing threshold is assessed using a Fechnerian method. The individual is tested at intensities of 500, 1000, 2000, 4000, and 8000 decibels with frequency ranging from -10 to 70 Hertz (Jerger, 1963). Since this test is included simply to determine the patients hearing, it will not be included in the analyses. The threshold intensity was recorded.

Dichotic test (dichotic digits/melodies)

This tests left-right aural differences in the perception of digits (Kimura, 1961,1964). Total hits per ear were collected.

Unilateral temporal lobectomy impairs recognition of dichotic digits arriving at the ear contralateral to the removal (i.e., right ear)(Kimura, 1961). In contrast, unilateral right temporal lobectomy impairs recognition of dichotic melodies arriving at the contralateral ear of excision (i.e., left ear)(Kimura, 1964, Shankweiler, 1966, see also Kolb & Whishaw, 1985).

Ekman Facial Affect (facial affect)

This test was designed to test the individual's ability to descriminate primary facial emotional expressions. The stimulus slides (N=36) include male (n=3) and female (n=3) faces each expressing a primary emotion (i.e., happy, sad, fear, anger, surprise, or disgust) (Ekman & Friesen, 1975). Total hits and reaction time on hits were collected.

In an electrical stimulation study with patients undergoing surgery for epilepsy, Fried, Mateer, Ojeman, Wohns, and Fedio (1982) found that errors occurred when the posterior part of the middle temporal gyrus was stimulated (disrupting the activity of this area). Hence, visual affective perception is handled by the temporal lobe.

Russell delayed recall (delayed recall)

This test investigates the individual's ability to retain verbal (i.e., short stories) and spatial (i.e., designs) material half an hour post presentation (Russell, 1975). The percentage of semantic and design recall were calculated for analyses.

Russell (1975) found that the split-half reliability of these measures ranged from .88 for the long-term verbal score to .51 for the figural score.

Delaney, Rosen, Mattson & Novelly (1980) found that the Russell adaptation of the Wechsler Memory Scale (logical and figural memory) were more sensitive in discriminating persons with left versus right unilateral temporal-lobe seizure foci.

Verbal contextual affect test (verbal affect)

This test is an analogue of Ekman's Facial Affect test. It comprises 36 emotional situational sentences (6 each of happy, sad, fear, anger, surprise, or disgust) presented to the subject by a tape recorder (Ethier, 1985). Total hits and reaction time on hits were collected.

Auditory presentation of emotinal stimuli have also been found to be sensitive to right hemispheric damage due to prosodic disturbances (Weintraub, Mesulam & Kramer, 1981). For both visual and auditory presentation of emotion stimuli and their localization see Ethier (1988) for a complete discussion.

Wechsler Memory Scale (memory scale)

This memory scale taps into the person's-information, orientation, mental control, logical memory, digit span forward and backward, visual reproduction, and associative learning abilities (Wechsler, 1955). In each subtest scoring was in accordance with the test manual.

This test has been somewhat controversial in its construct validity. Moreover, all the subtests have not been validated and research on each of the subtest's localization ability is incomplete.

Fedio, Martin, and Brouwers (1984) investigated logical memory, verbal paired associates, and visual reproduction. The left temporal group's performance was significantly lower than that of the right temporal group on logical memory and verbal paired associates. The reverse was true for visual reproduction.

Delaney et al. (1980) also found that the left temporal group retained less of the logical memory story than other groups. The right temporal group, however, retained less of the visual reproduction stimuli than did other groups. Frontal patients did not differ on either measure relative to controls.

Larrabee, Kane, Schuck, and Francis (1985), based on their findings, suggested that the immediate visual reproduction stimuli load primarily on a visual-perceptual-motor factor and secondarily on memory. One can argue however, that a person must perceive and remember these stimuli if he is to reproduce them.

The test-retest reliability of the Mental Quotient (MQ) is reasonable (.75 for normal samples and .89 in patient populations). For individual subtests, however, the internal consistency ranged from .37 (on associative learning) to .81 (for logical memory (see Franzen, 1989).

The MQ has been found to be sensitive to temporal lobe (especially medial) dysfunction. This test apparently assesses memory as a whole, although it is weighted toward verbal ability and verbal memory with the exception of visual reproduction (Franzen, 1989). The temporal amnesia literature found temporal amnesics to have very low MQs. These findings suggest that most of the subscales (since they make up the total MQ score) contribute to the temporal lobe effect. This argues for keeping the WMS in temporal lobe functioning. However, there is no garauntee that each and every subscale would contribute to temporal lobe dysfunction since no one has looked at each and every subtest.

The digit span subtest from the Wechsler Adult Intelligence Scale (WAIS) is very similar to the digit span subtest form WMS except that different digits are used. Warrington, James and Maciejewski (1986) investigated the localization ability of this measure from the WAIS. They found that right hemisphere lesioned groups (both temporal and parietal) showed better mean performance than the left lesioned group (temporal or parietal). This may be related to the better attentional abilities of the right hemisphere. However, the left temporal lesioned group had slightly better mean performance (9.33) than the left parietal group (9.29).

In contrast the right temporal lesioned group had slightly lower mean performance (11.58) compared to the right parietal group (11.79). It appears, therefore, that the differences are minimal between temporal and parietal groups. Overall digit span measures may not be as sensitive a measure in its localization ability. So left-right hemispheric comparisons may be more meaningful in discrimination differences than temporal-parietal comparisons on this measure.

As for General Information, Orientation, and Mental Control, intuitively it seems that if one has huge bitemporal lesions the long term memory for this information (e.g., the alphabet in mental control) will likely be affected. There is, however, no research evidence to support this idea.

TESTS RELATED PRIMARILY TO INTEGRITY OF THE PARIETAL LOBES

Aesthesiometer two point discrimination (two point sensation)

This is a sensory test designed to measure the individual's perception of the cutaneous two point threshold. Horizontal or vertical palm stimulation of various two point centimetric distances are applied and the person must indicate whether he or she feels one or two points (Semmes, Weinstein, Ghent & Teuber, 1960). The two point threshold at horizontal (across) and vertiacl (down) were recorded.

Parietal lobe patients demonstrated significantly poorer two-point discrimination than did frontal or temporal lesioned patients (Corkin & Milner, 1970).

<u>Benton Right-Left orientation</u> (right-left orientation)

This test, also known as right-left orientation, comprises 20 items challenging the individual's ability to discriminate right from left by indicating various right or left body (own and examiner's) parts (Bornstein, 1985). In each instance the total hits were calculated.

Semmes, Weinstein, Ghent, and Teuber (1963) found that unilateral left anterior lesioned group performance significantly worse than unilateral left posterior or unilateral right anterior and posterior groups on personal orientation. In contrast the right anterior/posterior and left posterior group's performance was worse than the left anterior group's performance on extrapersonal orientation. This study permits only left-right and anterior-posterior comparisons rather than lobe per se.

Semenza and Goodglass (1985) showed that posterior lesioned patients made significantly more errors than anterior lesioned groups. The localization abilities of this test appears to have produced mixed findings. Aphasia will most certainly influence the test results.

Given the spatial nature of this test we decided to include it with parietal test rather than frontal or temporal because of the verbal comprehension component. Kolb and Whishaw (1985 and Benton (1959) also atribute such tasks to parietal lobe functioning.

Semmes Body Placement (Semmes)

This test investigates autostereognosia and employs five body parts diagrams (Semmes, Weinstein, Ghent & Teuber, 1963). The number of hits are recorded.

Although disorientation of personal space tends not to be associated with localization problems and likely to occur with frontal lesions (Teuber, 1964), tests of disorientation require the patient to make right-left discrimination that may be disrupted with posterior rather than anterior lesions. Hence, we included this test with parietal tests although it could have just as easily been included with frontal tests.

Single and Double Simultaneous Stimulation (stimulation)

This test examines the accuracy with which one can identify single or double tactile stimulation to the cheek and/or hand and is sensitive to "extinction" in bilateral presentation (Centofani & Smith, 1979). Total errors are recorded.

It was found that 93% of patients with chronic brain lesions were correctly identified with this test (Centofani & Smith, 1979). Although these results were not specific in identifying subgroups of neurologic patients, sensory perception would necessarily have to be intact for normal perception. Hence, since the sensory strip may likely be involved this test was placed with parietal lobe tests.

Tactual Performance test (tactual)

This tests psychomotor problem-solving ability and reproduction. Blocks of varying sizes and shapes are to be placed into their respective spaces on a formboard by the blindfolded individual. The person uses the dominant hand first then the opposite hand and then both hands. In each instance the time to complete the task is recorded. The individual is also required to reproduce the forms (i.e., blocks) and their location on the board upon completion of the test. (Heaton, Grant & Mathews, 1986). The number of blocks reproduced and their location were recorded as well as task completion time per hand.

Weinstein (1954) found that posterior lesioned patients made significantly more errors in block location, had lower block reproduction and took longer to complete the task than anterior lesioned patients. The parietal patients had the longest task completion time followed by temporal while the frontal patients had the shortest task completion time. With respect to block reproduction, frontal and temporal patients had significantly higher block reproductin scores than did parietal patients. This finding suggests that intact somosthetic perception (a parietal lobe function) may primarily be contributing to the better performances of frontal and temporal patients. Although the error rate is a more controversial measure regarding its localization abilities, it was decided to include it with the other two measures (i.e., parietal functioning) since the patient was able to "feel" the blocks throughout the test (which most did, since they were searching with their fingers throughout the completion of the test). Hence, this measure may not be a 'pure' measure of memory for block location, but Reitan's terminology would make one think that it is and it may not be. We will nevertheless, retain Reitan's terminology in this study.

TESTS RELATED PRIMARILY TO INTEGRITY OF THE OCCIPITAL LOBES

Perimetry (Perimetry)

This test investigates possible visual field loss or visual field shrinkage. The four visual quadrants of each eye are separately tested while the person keeps her or his gaze centered on a mirror. The point at which the stimulus is perceived is recorded. There are no validation studies on this test, to my knowledge.

Visual Acuity

Investigates the individual's visual acuity using a visual chart from a 20 feet distance. This test, similar to the Audiometry test, will not be included in the analyses.

AUXILIARY TESTS

The following tests are included here because their successful completion may not depend on the adequate functioning of any one specific brain site. Rather, they may require the orchestrated functioning of different systems in the CNS. For this reason, localization studies were not presented here.

<u>D2 letter cancellation</u> (letter cancellation)

This test is a paper and pencil visual-motor letter cancellation test of attention. The individual is given 20 seconds per line in which to cross out all the letters "d" which have two primes. There are a total of 14 lines (Brickenkamp, 1962). The number of hits and the percentage of errors were recorded.

<u>Vocabulary</u> (vocabulary)

This test is a subtest from the Wechsler Adult Intelligence Scale-Revised. It purports to investigate the person's vocabulary level (Wechsler, 1981) and is believed to be a good measure of premorbid functioning. The total vocabulary score was calculated.

<u>Token Test</u> (language testing)

This test is a shortened version (16 items) of the Token Test and investigates possible aphasia. It comprises small and large tokens of various colors (i.e., yellow, blue, green, red, and white) and shapes (circles or squares) (Spellacy & Spreen, 1969). The number of hits were recorded. The internal consistency of this test was .79 (Franzen, 1989). This test classified 93% of aphasic patients correctly.

<u>Tremometer</u> (tremometer)

This test investigates hand stability. The individual is given 10 seconds per circle (i.e., there are 3 circles varying in circumferance from one inch to 1/4 on an inch). The person is required to insert a stylus into the hole and keep it centered during 10 seconds without touching the sides (Braun, 1985). The number of errors were recorded. Braun (1985) provides norms in normals while Haaland, Cheland and Can (1977) provide standardization measures in tumor patients.

<u>Humour appreciation test</u> (humour appreciation)

This test measures appreciation of humour, the individual's response consistency, and the ability to make connections between (non)connected image-test (i.e., funny picture-funny text, funny picture-neutral text, etc.). This test comprises 30 such cards divided into 5 subcategories (Braun, Lussier, Baribeau & Ethier, 1989). Only the number of correct hits were analysed here since, most other data were already reported elsewhere.

<u>Reaction time</u> (reaction time)

This tests information processing as indexed by the person's speed of manual response. The individual is asked to button press upon detection of a yellow square (n-15) presented by the computer at varying inter-stimulus intervals. This task is performed with the left and the right hand given that the person has two functional hands (Braun, Ethier, Baribeau, 1987). The reaction time per hand was collected.

Appendix 3

ANOVA Summary tables

Source	Sum of Squares	df	Mean Square	F	p
FRONTAL TESTS					
Design fluency - 5 minute condition					
Group	114.84	1	114.84	.77	.38
Error	3263.46	22	148.33		
Pre/Post	412.51	1	412.51	7.23	.01
Group x Pre/Post	2.34	1	2.34	.04	.84
Error	1255.46	22	57.06		
Design fluency - 4 minute condition					
Group	12.08	1	12.08	.12	.73
Error	1974.21	20	98.71		
Pre/Post	.83	1	.83	.06	.80
Group x Pre/Post	32.46	1	32.46	2.43	.13
Error	267.46	20	13.37		
Dynamometer grip strength - dominant hand time					
Group	918.19	1	918.19	3.93	.05
Error	5840.17	25	233.60		
Pre/Post	.82	1	.82	.05	.82
Group x Pre/Post	6.15	1	6.15	.36	.55
Error	423.17	25	16.92		
Dynamometer grip strength - nondominant hand time					
Group	297.16	1	297.16	1.09	.30
Error	7086.46	26	272.55		
Pre/Post	36.16	1	36.16	1.86	.18
Group x Pre/Post	90.01	1	90.01	4.63	.04
Error	505.32	26	19.43		
Dynamometer grip strength - sustained strength right hand					
Group	91.12	1	91.12	.49	.49
Error	2618.87	14	187.06		
Pre/Post	55.12	1	55.12	.44	.51

Source	Sum of Squares	df	Mean Square	F	p
FRONTAL TESTS - continued					
Group x Pre/Post	24.50	1	24.50	.20	.66
Error	1736.37	14	124.02		
Dynamometer grip strength - sustained strength left hand					
Group	120.12	1	120.12	.60	.45
Error	2798.87	14	199.91		
Pre/Post	50.00	1	50.00	.46	.50
Group x Pre/Post	6.12	1	6.12	.06	.81
Error	1508.87	14	107.77		
Finger tapping - right hand					
Group	333.60	1	333.60	1.76	.19
Error	5506.36	29	189.87		
Pre/Post	82.80	1	82.80	6.32	.01
Group x Pre/Post	7.31	1	7.31	.56	.46
Error	377.87	29	13.03		
Finger tapping - left hand					
Group	160.80	1	160.80	.73	.39
Error	6616.94	30	220.56		
Pre/Post	2.11	1	2.11	.13	.71
Group x Pre/Post	.43	1	.43	.03	.87
Error	485.31	30	16.17		
Kolb hand praxia - preferred hand					
Group	19.14	1	19.14	1.06	.31
Error	539.96	30	17.99		
Pre/Post	13.14	1	13.14	.98	.32
Group x Pre/Post	2.64	1	2.64	.20	.65
Error	400.72	30	13.35		
Kolb hand praxia - nonpreferred hand					
Group	13.25	1	13.25	.29	.59
Error	1279.68	28	45.70		
Pre/Post	4.65	1	4.65	.60	.44

Source	Sum of Squares	df	Mean Square	F	p
FRONTAL TESTS - continued					
Group x Pre/Post	2.05	1	2.05	.27	.61
Error	215.68	28	7.70		
Verbal Fluency - 5 minute condition					
Group	10.20	1	10.20	.05	.81
Error	5997.73	31	193.47		
Pre/Post	131.08	1	131.08	9.88	.003
Group x Pre/Post	.05	1	.05	.01	.95
Error	411.40	31	13.27		
Verbal Fluency - 4 minute condition					
Group	.04	1	.04	.00	.97
Error	1127.98	31	36.38		
Pre/Post	24.33	1	24.33	6.83	.01
Group x Pre/Post	.15	1	.15	.04	.83
Error	110.60	31	3.56		
Wisconsin card sorting - categories completed					
Group	31.41	1	31.41	2.41	.13
Error	403.70	31	13.02		
Pre/Post	13.10	1	13.10	5.22	.02
Group x Pre/Post	2.92	1	2.92	1.16	.28
Error	77.83	31	2.51		
Wisconsin card sorting - nonperseverative errors					
Group	103.22	1	103.33	.43	.51
Error	7417.75	31	239.28		
Pre/Post	3.05	1	3.05	.08	.77
Group x Pre/Post	10.68	1	10.68	.28	.59
Error	1172.40	31	37.81		
Wisconsin card sorting - perseverative errors					
Group	1454.55	1	1454.55	5.10	.03
Error	8844.93	31	285.32		
Pre/Post	11.88	1	11.88	.18	.67
Group x Pre/Post	.01	1	.01	.01	.98
Error	2065.11	31	66.62		

Source	Sum of Squares	df	Mean Square	F	p
FRONTAL TESTS - continued					
Wisconsin card sorting - perseverative responses					
Group	2276.65	1	2276.65	5.02	.03
Error	14052.43	31	453.30		
Pre/Post	27.52	1	27.52	.27	.60
Group x Pre/Post	6.86	1	6.86	.07	.79
Error	3186.40	31	102.78		
TEMPORAL TESTS					
Dichotic digits - left ear					
Group	283.25	1	283.25	.67	.41
Error	12233.83	29	421.85		
Pre/Post	115.68	1	115.68	1.05	.31
Group x Pre/Post	351.81	1	351.81	3.21	.08
Error	3183.11	29	109.76		
Dichotic digits - right ear					
Group	795.70	1	795.70	1.22	.27
Error	18256.33	28	652.01		
Pre/Port	434.70	1	434.70	3.33	.07
Group x Pre/Post	7.70	1	7.70	.06	.80
Error	3659.96	28	130.71		
Dichotic melodies - left ear					
Group	8.45	1	8.45	1.07	.30
Error	220.92	28	7.89		
Pre/Post	2.82	1	2.82	.58	.45
Grop x Pre/Post	9.06	1	9.06	1.86	.18
Error	136.60	28	4.87		
Dichotic melodies - right ear					
Group	11.08	1	11.08	1.40	.24
Error	221.33	28	7.90		
Pre/Post	1.81	1	1.81	.37	.54
Group x Pre/Post	4.14	1	4.14	.85	.36
Error	137.27	28	4.90		

Source	Sum of Squares	df	Mean Square	F	p
TEMPORAL TESTS - continued					
Ekman facial affect - hits					
Group	.72	1	.72	.01	.90
Error	1604.41	32	50.13		
Pre/Post	9.19	1	9.19	1.12	.29
Group x Pre/Post	5.30	1	5.30	.65	.42
Error	263.00	32	8.21		
Ekman facial affect - reaction time on hits (Sec)					
Group	38689.47	1	38689.47	4.75	.03
Error	260393.58	32	8137.29		
Pre/Post	1395.05	1	1395.05	.14	.70
Group x Pre/Post	508.76	1	508.76	.05	.82
Error	313520.17	32	9797.50		
Russel delayed recall - semantic					
Group	617.78	1	617.78	.48	.49
Error	33474.57	26	1287.48		
Pre/Post	41.14	1	41.14	.06	.81
Group x Pre/Post	126.00	1	126.00	.18	.67
Error	18539.85	26	713.07		
Russel delayed recall - designs					
Group	36.00	1	36.00	.02	.88
Error	47888.93	30	1596.29		
Pre/Post	540.56	1	540.56	1.32	.25
Group x Pre/Post	380.25	1	380.25	.93	.34
Error	12295.18	30	409.83		
Verbal contextual affect - hits					
Group	6.82	1	6.82	.16	.68
Error	1299.93	31	41.93		
Pre/Post	41.39	1	41.39	6.09	.01
Group x Pre/Post	27.45	1	47.45	4.04	.05
Error	210.63	31	6.79		
Verbal contextual affect - reacting time on hits (sec)					
Group	1364.33	1	1364.33	1.43	.24
Error	29616.60	31	955.37		

Source	Sum of Squares	df	Mean Square	F	p
Pre/Post	547.47	1	547.47	1.51	.22
Group x Pre/Post	1101.59	1	1101.59	3.04	.09
Error	11225.52	31	362.11		
Wechsler memory scale - Information					
Group	.52	1	.52	.22	.64
Error	76.52	32	2.39		
Pre/Post	.52	1	.52	.76	.39
Group x Pre/Post	.05	1	.05	.08	.77
Error	22.41	32	.70		
Wechsler memory scale - Orientation					
Group	2.11	1	2.11	3.32	.07
Error	20.41	32	.63		
Pre/Post	.94	1	.94	1.99	.16
Group x Pre/Post	.94	1	.94	1.99	.16
Error	15.11	32	.47		
Wechsler memory scale - Mental Control					
Group	.36	1	.36	.06	.80
Error	188.64	32	5.89		
Pre/Post	.36	1	.36	.51	.47
Group x Pre/Post	.13	1	.13	.18	.67
Error	23.00	32	.71		
Wechsler memory scale - Logical Memory					
Group	7.77	1	7.77	.32	.57
Error	775.23	32	24.22		
Pre/Post	.36	1	.36	.15	.70
Group x Pre/Post	1.19	1	1.19	.48	.49
Error	79.94	32	2.49		
Wechsler memory scale - digits forward					
Group	1.77	1	1.77	.90	.35
Error	63.52	32	1.98		
Pre/Post	1.77	1	1.77	1.52	.22
Group x Pre/Post	1.19	1	1.19	1.02	.32
Error	37.52	32	1.17		
Wechsler memory scale - digits backward					
Group	2.48	1	2.48	1.45	.23
Error	55.00	32	1.71		

Source	Sum of Squares	df	Mean Square	F	p
Pre/Post	2.48	1	2.48	3.85	.05
Group x Pre/Post	.36	1	.36	.57	.45
Error	20.64	32	.64		
Wechsler memory scale - Visual Reproduction					
Group	46.11	1	46.11	1.29	.26
Error	1145.11	32	35.78		
Pre/Post	60.23	1	60.23	3.18	.08
Group x Pre/Post	4.76	1	4.76	.25	.61
Error	607.00	32	18.96		
Wechsler memory scale - Associative Learning					
Group	7.11	1	7.11	.09	.76
Error	2461.11	32	76.90		
Pre/Post	17.00	1	17.00	.69	.41
Group x Pre/Post	.94	1	.94	.04	.84
Error	784.05	32	24.50		

PARIETAL TESTS

Aesthesiometer two point discrimination - right hand down					
Group	1.65	1	1.65	.04	.84
Error	1246.46	29	42.98		
Pre/Post	1.85	1	1.85	.04	.84
Group x Pre/Post	3.36	1	3.36	.07	.78
Error	1313.70	29	45.30		
Aesthesiometer two point discrimination - right hand across					
Group	20.81	1	20.81	.75	.39
Error	806.69	29	27.81		
Pre/Post	3.03	1	3.03	.11	.74
Group x Pre/Post	5.13	1	5.13	.19	.66
Error	793.46	29	27.36		
Aesthesiometer two point discrimination - left hand down					
Group	51.26	1	51.26	1.09	.30
Error	1366.46	29	47.11		

Source	Sum of Squares	df	Mean Square	F	p
<u>PARIETAL TESTS</u> - continued					
Pre/Post	87.72	1	87.72	3.41	.07
Group x Pre/Post	.03	1	.03	.00	.96
Error	746.77	29	25.75		
Aesthesiometer two point discrimination - left hand across					
Group	25.92	1	25.92	1.07	.30
Error	700.55	29	24.15		
Pre/Post	76.07	1	76.07	2.35	.13
Group x Pre/Post	.42	1	.42	.01	.90
Error	938.76	29	32.37		
Benton Right - Left Orientation - own body					
Group	.72	1	.72	.74	.39
Error	31.00	32	.96		
Pre/Post	.06	1	.06	.05	.82
Group x Pre/Post	.36	1	.36	1.29	.26
Error	9.11	32	.28		
Benton Right - Left Orientation - experimenter's body					
Group	4.25	1	4.25	2.19	.14
Error	62.11	32	1.94		
Pre/Post	2.48	1	2.48	4.45	.04
Group x Pre/Post	.13	1	.13	.24	.62
Error	17.88	32	.55		
Semmes body placement					
Group	62.13	1	62.13	1.26	.27
Error	1582.64	32	49.45		
Pre/Post	1.77	1	1.77	.16	.69
Group x Pre/Post	.13	1	.13	.01	.91
Error	353.58	32	11.04		
Single double simultaneous stimulation					
Group	70.01	1	70.01	1.50	.22
Error	1493.47	32	46.67		
Pre/Post	6.48	1	6.48	.71	.40
Group x Pre/Post	22.36	1	22.36	2.45	.12
Error	292.64	32	9.14		

Source	Sum of Squares	df	Mean Square	F	p
PARIETAL TESTS - continued					
Tactual Performance - dominant hand time (sec.)					
Group	34271.40	1	34271.40	.15	.69
Error	5979231.07	27	221453.00		
Pre/Post	51211.05	1	51211.05	.57	.45
Group x Pre/Post	39863.81	1	39863.81	.45	.50
Error	2404958.46	27	89072.53		
Tactual Performance - nondominant hand time (sec.)					
Group	158450.28	1	158450.28	.48	.49
Error	8283990.04	25	331359.60		
Pre/Post	4183.32	1	4183.32	.07	.79
Group x Pre/Post	176.21	1	176.21	.00	.95
Error	1532027.15	25	61281.08		
Tactual Performance - memory for blocks					
Group	.25	1	.25	.05	.82
Error	149.50	30	4.98		
Pre/Post	5.06	1	5.06	4.35	.04
Group x Pre/Post	.06	1	.06	.05	.81
Error	34.87	30	1.16		
Tactual Performance - memory for block location					
Group	23.76	1	23.76	5.43	.02
Error	131.34	30	4.37		
Pre/Post	.76	1	.76	.31	.57
Group x Pre/Post	2.64	1	2.64	1.08	.30
Error	73.09	30	2.43		
OCCIPITAL TESTS					
Perimetry - right eye					
Group	3073.31	1	3073.31	4.90	.03
Error	18811.52	30	627.05		
Pre/Post	14.53	1	14.53	.07	.79
Group x Pre/Post	9.37	1	9.37	.04	.83
Error	6408.71	30	213.62		

Source	Sum of Squares	df	Mean Square	F	p
Perimetry - left eye					
Group	2646.09	1	2646.09	7.51	.01
Error	9510.24	27	352.23		
Pre/Post	61.30	1	61.30	.22	.64
Group x Pre/Post	113.85	1	113.85	.41	.52
Error	7466.28	27	276.52		

AUXILIARY TESTS

Source	Sum of Squares	df	Mean Square	F	p
D2 letter cancellation - % errors					
Group	1.16	1	1.16	.02	.88
Error	1608.39	32	50.26		
Pre/Post	175.04	1	175.04	13.93	.0007
Group x Pre/Post	.44	1	.44	.04	.85
Error	402.06	32	12.56		
D2 letter cancellation - hits					
Group	606.01	1	606.01	.03	.85
Error	573361.47	32	17917.54		
Pre/Post	2317.77	1	2317.77	.75	.39
Group x Pre/Post	2436.01	1	2436.01	.79	.38
Error	98455.70	32	3076.74		
Humour appreciation					
Group	31.00	1	31.00	2.02	.16
Error	475.75	31	15.34		
Pre/Post	.01	1	.01	.00	.97
Group x Pre/Post	11.88	1	11.88	1.16	.29
Error	319.11	31	10.29		
Reaction time - right hand (msec.)					
Group	.002	1	.002	.12	.73
Error	.58	30	.01		
Pre/Post	.03	1	.03	6.32	.01
Group x Pre/Post	.00006	1	.00006	.01	.91
Error	.14	30	.004		

Source	Sum of Squares	df	Mean Square	F	p
AUXILIARY TESTS - continued					
Reaction time - left hand (msec.)					
Group	.03	1	.03	1.01	.32
Error	.97	31	.03		
Pre/Post	.01	1	.01	.97	.33
Group x Pre/Post	.00	1	.00	.00	.99
Error	.39	31	.01		
Token (language testing)					
Group	2.11	1	2.11	.19	.66
Error	357.76	32	11.18		
Pre/Post	21.23	1	21.23	2.58	.11
Group x Pre/Post	7.11	1	7.11	.86	.35
Error	263.64	32	8.23		
Tremometer - right hand					
Group	735.17	1	735.17	.45	.51
Error	40473.15	25	1618.92		
Pre/Post	513.28	1	513.28	1.78	.19
Group x Pre/Post	4.83	1	4.83	.02	.89
Error	7219.86	25	288.79		
Tremometer - left hand					
Group	34.57	1	34.57	.08	.78
Error	11664.14	26	448.62		
Pre/Post	787.50	1	787.50	5.83	.02
Group x Pre/Post	97.78	1	97.78	.72	.40
Error	3513.71	26	135.14		
WAIS-Vocabulary subtest					
Group	42.88	1	42.88	.09	.76
Error	15691.00	32	490.34		
Pre/Post	8.47	1	8.47	.37	.54
Group x Pre/Post	3.76	1	3.76	.16	.68
Error	734.76	32	22.96		

Appendix 4

Correlations between post-test performance and patients' reported symptoms at pre test...

Correlations on Frontal tests between post-test performance and patients' reported symptomatology on motor, sensory, and emotional categories.

	Motor		Sensory		Emotional	
	E	C	E	C	E	C
FRONTAL TESTS						
Design fluency						
5 minutes	.01	-.11	.60	.50	.40	-.17
4 minutes	-.30	-.24	-.04	.04	-.39	-.01
Dynamometer grip strength						
dominant hand	-.45	-.25	.08	-.15	.60	.19
nondominant hand	.13	-.26	.15	-.20	-.32	-.12
sustained strength right	.49	.64	.06	-.83	.25	-.87
sustained strength left	-.19	-.46	.44	-.60	.44	-.71
Finger tapping						
right hand	.20	-.15	-.13	.05	-.30	.12
left hand	-.24	.20	.32	-.01	.51	-.28
Kolb hand praxia						
preferred hand	.40	.47	-.18	.07	-.40	.17
nonpreferred hand	.13	-.16	.22	.01	-.11	-.31
Verbal fluency						
5 minutes	-.23	-.43	-.36	-.01	-.03	-.20
4 minutes	-.20	-.13	-.23	.32	-.12	.08
Wisconsin card sorting						
categories completed	-.16	.09	.18	-.13	.39	-.43
nonperseverative errors	-.32	.19	-.13	.02	.41	-.07
perseverative errors	.24	.06	.19	-.05	.33	-.13
perseverative responses	.22	.06	.21	-.10	.41	-.11

Correlations on Temporal tests between post-test performance and patients' reported symptomatology on motor, sensory, and emotional categories.

	Motor		Sensory		Emotional	
	E	C	E	C	E	C
TEMPORAL TESTS						
Dichotic digits						
left ear	-.39	-.03	-.18	-.04	-.24	.01
right ear	.59	.11	.22	.11	.08	-.11
Dichotic melodies						
left ear	.12	-.39	.11	-.30	.28	-.37
right ear	.22	-.27	-.05	-.29	-.13	-.52
Ekman facial affect						
hits	.06	-.45	-.05	-.37	-.13	-.39
reaction time on hits	.24	.23	-.19	.31	.15	.25
Russell delayed recall						
semantic	.14	.05	-.27	-.14	-.07	.16
designs	.16	-.62	.22	-.47	.17	.17
Verbal contextual affect						
hits	.24	-.46	-.56	-.14	-.27	-.30
reaction time on hits	-.20	-.12	.10	.12	.12	-.05
Wechsler memory scale						
information	-.05	.03	.14	.07	.32	.23
orientation	-.19	.38	.09	-.05	.17	.05
mental control	.42	-.03	.29	.09	.26	-.13
logical memory	.03	.20	.27	.17	.46	-.11
digits forward	.45	.02	.02	.07	-.32	-.17
digits backward	.17	-.22	-.23	.03	-.34	-.25
visual reproduction	-.18	-.24	-.22	.08	-.31	.12
associative learning	-.13	-.34	-.41	-.19	-.40	-.14

Correlations on Parietal tests between post-test performance and patients' reported symptomatology on motor, sensory, and emotional categories.

	Motor		Sensory		Emotional	
	E	C	E	C	E	C
PARIETAL TESTS						
Aesthesiometer two point discrimination						
right hand - down	.16	.20	.50	.08	.44	-.08
- across	.20	-.07	.40	.15	.31	-.14
left hand - down	.12	-.23	.35	-.21	.37	-.15
- across	.25	-.51	.35	-.47	.09	-.15
Benton Right-left orientation						
own body	-.17	.09	-.04	-.02	-.22	-.32
experimenter's body	.04	.25	.22	-.14	-.11	.14
Semmes body placement	.41	-.30	.25	-.19	.26	-.17
Single double stimulation	.46	.09	.43	-.17	.40	.02
Tactual performance						
dominant hand time	.13	.15	.40	-.15	.62	-.06
nondominant hand time	.01	.01	.36	-.08	.61	.12
memory for blocks	.44	-.23	.60	-.53	.53	-.27
memory of block location	.14	-.11	.64	.15	.05	-.31

Correlations on Occipital and Auxiliary tests between post-test performance and patients' reported symptomatology on motor, sensory, and emotional categories.

	Motor		Sensory		Emotional	
	E	C	E	C	E	C
OCCIPITAL TESTS						
Visual Field Perimetry						
Right eye						
right superior quadrant	.22	.30	-.07	.42	-.04	.44
right inferior quadrant	-.19	-.15	-.27	.60	.01	.08
left superior quadrant	-.08	-.02	-.22	.30	.17	-.22
left inferior quadrant	.22	.17	.34	-.22	.44	.30
Left eye						
right superior quadrant	.14	-.30	.03	-.20	.01	-.22
right inferior quadrant	.10	-.18	.31	-.31	.01	.08
left superior quadrant	.17	-.22	-.23	-.05	-.17	-.01
left inferior quadrant	.06	-.40	.26	-.25	.46	-.33
AUXILIARY TESTS						
32 letter cancellation						
% errors	-.01	-.27	.01	-.60	.47	-.24
hits	-.01	.05	.15	-.05	-.30	-.27
Humour appreciation	-.14	-.48	.13	-.30	-.07	-.25
Reaction time (msec.)						
right hand	-.17	-.27	.22	-.27	.29	-.53
left hand	.22	-.02	-.06	-.28	-.15	-.15
Token (language testing)	-.16	-.25	.03	-.29	.31	-.25
Tremometer						
right hand	-.07	-.25	.46	-.27	.69	.33
left hand	-.34	.25	.03	-.06	.03	.19
WAIS Vocabulary subtest (%)	-.13	.04	.10	-.11	.04	-.17

Correlations on Frontal tests between post-test performance and patients' reported symptomatology on social, cognitive, and vegetative/autonomic categories.

	Social		Cognitive		Veg./Aut.	
	E	C	E	C	E	C
FRONTAL TESTS						
Design fluency						
5 minutes	.41	-.52	.27	-.14	.14	.62
4 minutes	-.05	-.19	-.52	.42	-.32	-.44
Dynamometer grip strength						
dominant hand	-.05	-.19	.52	-.34	.33	.22
nondominant hand	.08	-.30	-.15	-.53	-.07	-.03
sustained strength right	.15	-.70	.76	-.47	.25	-.54
sustained strength left	.09	-.15	.48	-.27	.20	-.69
Finger tapping						
right hand	.35	-.04	.13	-.10	-.19	.07
left hand	.36	.14	.52	.07	.43	-.17
Kolb hand praxia						
preferred hand	.01	.62	-.03	.30	-.09	.15
nonpreferred hand	-.02	.06	.14	.33	-.01	.21
Verbal fluency						
5 minutes	-.18	-.65	.02	.08	.11	-.12
4 minutes	.21	-.18	.25	.39	.01	.36
Wisconsin card sorting						
categories completed	-.06	.11	-.01	.02	-.07	.10
nonperseverative errors	-.02	.11	.03	.03	.29	-.07
perseverative errors	.29	-.03	.17	.21	-.15	-.63
perseverative responses	.28	-.07	.23	.15	-.10	-.70

Correlations on Temporal tests between post-test performance and patients' reported symptomatology on Social, Cognitive, and Vegetative/Autonomic categories.

TEMPORAL TESTS	Social E	Social C	Cognitive E	Cognitive C	Veg./Aut. E	Veg./Aut. C
Dichotic digits						
left ear	-.31	.16	-.39	-.07	-.15	-.29
right ear	.39	.16	.20	.31	.12	-.08
Dichotic melodies						
left ear	.17	-.02	.36	-.40	.27	.01
right ear	.09	.20	-.07	-.09	.05	-.04
Ekman facial affect						
hits	.12	-.45	-.25	-.19	.17	-.12
reaction time on hits	.11	.24	.37	-.06	-.01	.46
Russell delayed recall						
semantic	.07	.26	-.19	-.13	.20	.13
designs	.08	-.29	.58	-.23	-.25	-.16
Verbal contextual affect						
hits	-.42	-.27	-.30	-.21	-.27	.13
reaction time on hits	.12	-.27	.01	-.30	.19	.08
Wechsler memory scale						
information	.42	.16	.15	-.01	.20	.39
orientation	.14	.44	.09	.07	.16	-.01
mental control	-.03	-.19	.06	-.22	-.14	.32
logical memory	-.05	.18	.25	.14	.15	-.02
digits forward	-.09	-.31	.01	.15	-.29	.02
digits backward	-.32	-.02	-.15	.05	-.25	.27
visual reproduction	-.12	-.43	-.13	-.28	-.21	.13
associative learning	-.08	-.35	-.08	-.24	-.20	.11

Correlations on Parietal tests between post-test performance and patients' reported symptomatology on Social, Cognitive, and Vegetative/Autonomic categories.

	Social		Cognitive		Veg./Aut.	
	E	C	E	C	E	C
PARIETAL TESTS						
Aesthesiometer two point discrimination						
right hand - down	.28	.40	.14	.18	.13	-.14
- across	.35	.18	.51	-.03	.16	.15
left hand - down	.24	.47	-.02	-.18	-.04	.20
- across	.42	-.20	-.08	-.52	-.08	.16
Benton Right-left orientation						
own body	-.20	-.07	-.27	.13	-.29	-.06
experimenter's body	.12	.37	-.39	.50	.01	-.10
Semmes body placement	.54	-.03	.44	-.26	.29	-.16
Single double stimulation	.37	-.05	.43	-.21	.07	-.05
Tactual performance						
dominant hand time	.17	.16	.57	-.25	.25	-.24
nondominant hand time	.26	.22	.61	.06	.46	-.22
memory for blocks	.41	-.35	.64	-.25	.25	-.54
memory of block location	.60	.02	.16	.18	.07	.10

Correlations on Occipital and Auxiliary tests between post-test performance and patients' reported symptomatology on Social, Cognitive, and Vegetative/Autonomic categories.

	Social		Cognitive		Veg./Aut.	
	E	C	E	C	E	C
OCCIPITAL TESTS						
Visual Field Perimetry						
Right eye						
right superior quadrant	-.15	.26	-.46	.03	.07	.40
right inferior quadrant	-.40	-.20	.15	.24	.12	.11
left superior quadrant	-.20	.09	-.39	-.24	-.29	.01
left inferior quadrant	.37	.22	.14	-.03	.37	.33
Left eye						
right superior quadrant	-.09	-.19	-.14	-.47	.01	-.10
right inferior quadrant	.27	.13	.38	-.37	.45	-.18
left superior quadrant	-.44	-.26	-.12	-.34	-.54	-.12
left inferior quadrant	.17	-.29	.11	-.40	.04	-.14
AUXILIARY TESTS						
D2 letter cancellation						
% errors	-.03	-.01	.15	-.51	.06	-.02
hits	-.02	.08	-.32	-.34	-.17	.21
Humour appreciation	.02	-.03	-.21	-.42	.20	-.02
Reaction time (msec.)						
right hand	.07	-.58	.34	.01	.04	-.51
left hand	-.02	.05	.14	.05	-.02	-.12
Token (language testing)	.05	-.35	.24	-.50	.57	-.02
Tremometer						
right hand	.54	.04	.55	.06	.29	-.05
left hand	.16	.12	-.21	.27	.20	-.22
WAIS Vocabulary subtest (%)	.26	-.01	-.07	.41	-.03	-.23

Appendix 5

Deviation (SD) of patient's performance relative to available norms and the classification.

FRONTAL TESTS	SD from norm	Classification
Design fluency		
5 minutes	>1<2	Low average
4 minutes	-	-
Dynamometer grip strength		
dominant hand	<1	Average
nondominant hand	<1	Average
Sustained strength right	-	-
Sustained strength left	-	-
Finger tapping		
right hand	>1<2	Average
left hand	>2<3	Deficient
Kolb hand praxia		
preferred hand	-	-
nonpreferred hand	-	-
Verbal fluency		
5 minutes	>3	Profound deficiency
4 minutes	-	-
Wisconsin Card Sorting		
categories completed	-	-
nonperseverative errors	-	-
perseverative errors	<1	Average
perseverative responses	-	-

TEMPORAL TESTS		
Dichotic digits		
left ear	-	-
right ear	-	-
Dichotic melodies		
left ear	-	-
right ear	-	-
Ekman facial affect		
hits	>1<2	Low Average
reaction time on hits (sec.)	-	-

	SD. from norm	Classification
Russell delayed recall (% score)		
semantic	>3	Profound deficiency
designs	>1<2	Low Average
Verbal contextual affect		
hits	<1	Average
reaction time on hits (sec.)	-	-
Wechsler memory scale		
information	>3	Profound deficiency
orientation	>3	Profound deficiency
mental control	<1	Average
logical memory	<1	Average
digits forward	<1	Average
digits backward	<1	Average
visual reproduction	<1	Average
associative learning	>1<2	Low Average

PARIETAL TESTS

Aesthesiometer two point discrimination (cm)		
right hand - down	<1	Average
- across	<1	Average
left hand - down	<1	Average
- across	<1	Average
Benton Right-left orientation		
own body	<1	Average
experimenter's body	<1	Average
Semmes body placement	<1	Average
Single double stimulation	<1	Average
Tactual performance		
dominant hand time (sec.)	-	-
nondominant hand time	-	-
memory for blocks	-	-
memory of block location	-	-

	SD from norm	Classification
OCCIPITAL TEST		
Visual Field Perimetry		
Right eye		
right superior quadrant	-	-
right inferior quadrant	-	-
left superior quadrant	-	-
left inferior quadrant	-	-
Left eye		
right superior quadrant	-	-
right inferior quadrant	-	-
left superior quadrant	-	-
left inferior quadrant	-	-
AUXILIARY TESTS		
D2 letter cancellation		
% errors	-	-
hits	>1<2	Low Average
Humour appreciation	>1<2	Low Average
Reaction time (msec.)		
right hand	>3	Profound Deficiency
left hand	>3	Profound Deficiency
Token (language testing)	<1	Average
Tremometer		
right hand	>2<3	Deficient
left hand	<1	Average
WAIS Vocabulary subtest(%)	-	-

Note: Dashes indicate the inability to compare the group mean to the normative mean.

POWER ANALYSES

	E	C	Power	Mean* Difference
Verbal fluency (5 min.)				
MD (meandifference)	2.875	2.765	0%	6.49
SD	4.349	5.804		
Russell delayed recall				
Logical memory				
MD	- 1.710	1.286	0%	53.12
SD	33.260	42.040		
Design memory				
MD	10.688	.938	1%	36.91
SD	14.310	37.876		
Degits Span				
Forward				
MD	.471	.176	0%	2.02
SD	1.375	1.845		
Semmes (experimentor's body)				
MD	.471	.294	0%	1.31
SD	.799	1.263		
Wisconsin Card Sorting				
Perseverative errors				
MD	.824	.875	0%	14.67

* Mean difference required between group means in order to have 80% power (i.e., .80 or to explain 64% of the variance at alpha .001).

Note: The mean difference was calculated by taking the difference score, of pre- post-test performance, and then calculating the mean and standard deviation of these difference scores.