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Reaction time characteristics after minor head injury: Evidence for slowing, variability, and attentional lapses

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REACTION TIME CHARACTERISTICS AFTER MINOR HEAD INJURY: EVIDENCE FOR SLOWING, VARIABILITY, AND ATTENTIONAL LAPSES

by

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Abstract

REACTION TIME CHARACTERISTICS AFTER MINOR HEAD INJURY:

EVIDENCE FOR SLOWING, VARIABILITY, AND ATTENTIONAL LAPSES

by

Bonnie Jill Newman

Advisor: Professor Gad Hakerem

Reaction time (RT) speed, intra-individual variability and lapses of attention were explored after minor head injury (MHI) using two methodologies. A conventional discrete trial test and a twelve minute continuous RT were administered whereby subjects were required to respond to a target stimulus when it appeared on the computer screen, and ignore an irrelevant foil stimulus. Two subgroups of MHI patients (labeled as dysfunctional and functional) were identified based on differences in functional impairment post injury ($\underline{M}$ = 2.5 years), and compared to a group of matched controls. Time on task decrements as a function of fatigue and the effects of varying inter-stimulus interval (ISI) were evaluated on the continuous RT test (CRT).

RT latency scores discriminated between dysfunctional and functional MHI patients on both tests. Dysfunctional patients were slower and more variable in speed than both functional patients and controls. Performance differences between the two MHI subgroups were consistent in direction with differences in number and severity of postconcussional symptoms, emotional symptoms, vocational status, and attentional complaints in every day life. Dysfunctional

patients evidenced significantly more response omissions indicative of lapses of attention on the CRT than functional patients. The presence of lapses of attention was pathognomonic to MHI supporting the CRT as a potential screening test.

While all subjects demonstrated increased latency as a function of fatigue and decreases in ISI, dysfunctional patients demonstrated progressively more lapses of attention as a function of time on task (an interaction). The usefulness of the CRT as an assessment tool was strengthened by the finding that a greater number of subjects in all groups were correctly classified by CRT performance criteria than by discrete trial performance criteria. The increase in RT latency for the dysfunctional group could not be solely accounted for by their increased intra-individual variability. Even their fastest RT's were significantly slower than control and functional subjects'. There were no differences between groups in false alarm speed or error rate indicating that MHI subjects were no more impulsive than control subjects, and were equally able to inhibit responding to distracting information.

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Table of Contents

List of Tables

List of Tables (cont.d)

page

List of Figures

page

List of Appendices

Glossary Of Frequently Used Abbreviations

Abbreviation	Term
ADL	Activities of Daily Living
BD	Brain Damaged
BDI	Beck Depression Interview
CHI	Closed Head Injury
CNS	Central Nervous System
CRT	Continuous Reaction Time Test
CT	Computer-Assisted Tomography
CVA	Cerebrovascular Accident
EEG	Electroencephalogram
EP	Evoked Potential
GCS	Glasgow Coma Scaled Score
LOC	Loss of Consciousness
HI-FI	Head Injury Family Interview
HIVE	Head Injury Vigilance Evaluation
HT1	Dysfunctional Head Trauma Subgroup
HT2	Functional Head Trauma Subgroup
ISI	Inter-Stimulus Interval
MHI	Minor Head Injury
MRI	Magnetic Resonance Imaging
MTBI	Minor Traumatic Brain Injury
MAACL-R	Multiple Affect Adjective Checklist-Revised
MVA	Motor Vehicle Accident
ORM	Orientation Remedial Module
PCL	Problem Check List
PI	Preparatory Interval
PTA	Post Traumatic Amnesia
RT	Reaction Time

INTRODUCTION

Reaction time (RT) testing has gained considerable respect over the past 50 years as a methodology capable of evaluating reductions in response speed after moderate to severe head injury (Conkey, 1938; Dencker & Lofving, 1958; Gronwall & Sampson, 1974; Klensch, 1973; Miller, 1970; Norrman & Svahn, 1961; Ruesch, 1944b). It is well established that severe head injury produces a generalized mental slowing and reduces central information processing speed (Gronwall, 1987; Gronwall & Sampson, 1974; Van Zomeren, 1981). The traditional RT paradigms (e.g. simple, choice, discrete trial) have not, however, always proven effective in demonstrating impairment in milder head injured patients (Klensch, 1973; Van Zomeren & Deelman, 1976, 1978). The lack of sensitivity of these traditional RT methodologies in detecting deficits in minor head injury (MHI) months post injury may be the result of insufficient task challenge. This possibility has led several researchers to increase complexity by increasing stimulus - response choices or by introducing paradigms requiring divided or distributed attention (Gentilini et al., 1985; Gentilini, Nichelli & Schoenhuber, 1989; Lee Teng, 1990). These approaches have not been consistently successful at demonstrating reductions in speed beyond the first few months post MHI. One major criticism of these paradigms is that they are too complex to permit an understanding of the underlying processes which are impaired after MHI (Buchtel, 1987; Gronwall, 1987).

Variables such as fatigue effects, intra-individual variability, and lapses of attention have rarely been explored after MHI. Yet these phenomena are highly consistent with self reported symptoms after MHI. Indeed, based on clinical complaints, it would appear that there is a deficit in processing when information is presented in rapid sequence, and the task requires prolonged maintenance of a high level of vigilance. Performance is often adequate on information processing tasks which are not paced, and where information is presented slowly over discrete trials. Deficits in sustained attention would be most likely demonstrated under test conditions which more closely approximate real life demands. It is under such conditions that MHI patients experience fatigue effects resulting in slowing, performance inconsistency, inaccuracies, and lapses of attention. It is predicted that these phenomena will be observable using RT paradigms requiring sustained attention (Dencker and Lofving, 1958; Gentilini et al, 1989; MacFlynn, Montgomery, Fenton, & Rutherford, 1984; Van Zomeren, Brouwer, & Deelman, 1984).

Current research is focused on the development of sensitive diagnostic measures intended to characterize the subtle attentional deficits which often remain in MHI patients long after their injury (current research at the Research and Training Center, New York University (N.Y.U.) Medical Center, 1987 to present). However, few methodologies exist to measure the effects of fatigue on continued performance, or the impact of intra-individual variability on RT performance. Performance is usually within normal limits when the usual brief structured tests, which minimize distraction and

maximize focused attention (most conventional neuropsychological tests), are employed (Prigatano, 1986; Rosenthal, 1987). Furthermore, performance is usually described in terms of total number of errors or average speed, measures which tend to mask the influence of intra-subject variability.

A recent clinical case clearly illustrates these problems. A 31 year old engineer who was evaluated after sustaining a MHI in an assault could not focus his attention and complained that his "mind went blank" while trying to concentrate. His attentional wandering caused him to miss important elements of conversation and information he had just read. He complained of great difficulty in performing his job, not because of a lack of skill or knowledge, but due to his periodic inattention and distractibility. This was eliminated when he was allowed to control the rate of information presented in his environment, and take rest breaks between tasks. Neuropsychologically, while brief focused attention (e.g. measured by letter cancellation tests) was adequate, RT was extremely variable, and the ability to maintain attention on continuous performance tasks was significantly impaired. Speed was reduced on complex RT tests involving divided and split attention. However, inspection of performance indicated that his primary deficit was in sustained and focused attention (attentional lapses were common), a problem evident only on continuous RT testing. This demonstrates the importance of using tasks sufficiently simple so as to permit an interpretation of the causes of failure.

This patient's complaints and performance deficits typify the nature of attentional difficulties which are often observed in the

absence of other neuropsychological deficits. As a consequence of variability and the occurrence of problems only under certain conditions, many patients experience a sense of unpredictability about their performance at work and fear about their continued job success. Patient's complaints that attentional and performance problems appear unexpectedly at different times (and a lack of awareness of the operation of these variables at any given time), probably reflect the influence of the variables described above. Too often, the standardized evaluation demonstrates average intellectual functioning and intact simple focused attention, further contributing to the lack of validation of a deficit. A methodological approach which requires a high level of continuous or sustained attention is the experimenter paced continuous reaction time (CRT) task. It is a sensitive monitor of performance variability, lapses of attention, and failure to maintain an efficient level of performance speed and stability. The experimenter paced form of the CRT has high ecological validity in so far as it mimics real life situations where information processing demands are high due to the temporal rate of presentation of information which cannot be controlled by the subject. In this approach, stimuli are presented at pre-programmed intervals with no warning signal and independent of the subject's response pattern (the conditions of a subject paced task). The subject must maintain vigilance during a rather monotonous task of several minutes during which rapid and irregularly spaced stimuli are presented and rapid response is required.

Post head injury assessment with the experimenter paced CRT has been surprisingly under utilized relative to its extensive use with heterogeneous brain damaged patients. Attentional deficits and impaired speed of responding after closed head injury have been widely investigated using discrete trial reaction time paradigms. In these RT studies, the stimulus to which the subject must respond is usually preceded by a warning signal presented at randomized or constant foreperiod or preparatory intervals, and the latency score is based on averaging over a number of temporally isolated trials. This methodology maximizes subject readiness and minimizes attentional wandering. When the subject is able to control the rate of presentation of each stimulus (a feature of many discrete trial tests), he/she can regulate its presentation to coincide with moments when attention is maximal. With temporally isolated trials he/she is allowed and often encouraged to rest between trials.

On a CRT, if MHI patients show RT's comparable to control subjects on certain trials, then what has previously been conceptualized as an impairment in level of functioning can instead be conceptualized as an impairment in effecting a <u>consistent</u> level of functioning. Conceptually, increases in RT latency for MHI patients as compared to normal controls could be the result of a general slowing of central nervous system processing, or a deficit in regulating attention indicated by high variability throughout the test. However, if the fastest reaction times of MHI patients were as rapid as those produced by normal controls, then a capacity, even if limited, for normal response speed would be indicated. This would argue in favor of a deficit in the regulation of attention;

high variability could explain an inability to perform at a consistently high level of quality especially when fatigued or under stress or time pressure.

If on the other hand, the fastest RT's of MHI patients were slower than normal controls, then a general slowing of response speed could be described as the primary deficit after MHI, in spite of elevations in variability. Response omissions on a CRT (a failure to respond to a relevant stimulus) can be an objective measure of lapses of attention indicating a breakdown in focused attention. Fatigue effects may interact with variability and RT speed as a function of time on a task. An increase in standard deviation and mean RT for MHI patients over time can be indicative of a deficit in sustained attention. This would indicate a failure to maintain an initial level of speed of response time associated with a tendency to become progressively more irregular with time on a test after MHI.

REVIEW OF THE LITERATURE ON REACTION TIME AFTER HEAD INJURY

Reaction time has been used extensively in classical experimental psychology for studying such constructs as attention, speed of information processing, vigilance, and state of arousal at the time of stimulus onset (Woodworth & Schlosberg, 1955). Indeed, use of RT tasks has always been quite popular in clinical studies due to its ability to demonstrate mental slowing and reliably differentiate performance between patient and non-patient groups (psychotic vs. non-psychotic patients, Huston, Shakow, & Riggs, 1937; mentally retarded vs. non-retarded children, Berkson, 1960;

and brain damaged vs. non-brain damaged adults, Blackburn & Benton, 1955). In studies with severely head injured clients, RT has often revealed deficits where other methods have failed, leading to the convincing conclusion that head injury produces mental slowing and reduces central processing speed (Conkey, 1938; Dencker & Lofving, 1958; Gronwall & Sampson, 1974; Klensch, 1973; Miller, 1970; Norrman & Svahn, 1961; Ruesch, 1944b).

Most of the RT literature after HT has focused on differences between simple and complex RT tasks to assess differences between groups of varying severity at different stages in the recovery process (Klensch, 1973; Miller, 1970; Van Zomeren & Deelman, 1976). Complexity in these studies has been defined variously as increases in task length, number of response choices, and number of stimuli (Miller, 1970, Van Zomeren & Deelman, 1976, 1978). It is well established that as a group, moderate to severely head injured patients show significantly slower RT latencies than normal adults. The differences between these two groups increase with task complexity and remain stable over time, post injury (Miller, 1970; Van Zomeren & Deelman, 1976, 1978). In contrast, milder head injured patients often recover to perform as well as controls within the first few months post injury on complex RT tasks (Gronwall & Sampson, 1974; Klensch, 1973; MacFlynn et al., 1984; Van Zomeren & Deelman, 1976, 1978). Indeed, Van Zomeren has attempted to explain the absence of a disproportionate increase in RT with complexity on the discrete trial RT task after minor head injury as evidence for a deficit in a more fundamental stage of processing: that of response

initiation or execution, rather than a deficit in a higher level of cognitive processing i.e. decision making, or S-R selection.

Susceptibility to response interference after head injury has also been assessed with Go/ No-Go type RT paradigms. These paradigms present distracting stimuli which must be ignored or not responded to (Bruhn & Parsons, 1971). These paradigms have been used in head trauma patients and normal controls to enhance between group differences (Klensch, 1973, Van Zomeren, 1981). Van Zomeren (1981) found an interaction between group and task using a brief four choice RT test with and without distraction. Head injured patients displayed longer RT's than normal controls under situations involving distraction and response interference (Van Zomeren, 1981; 1984). This distraction effect, however, was attributed to severe head injured patients in the first few months post injury only.

STUDIES WITH MINOR HEAD INJURY

Macflynn, Montgomery, Fenton, and Rutherford (1984) explored RT within a minor head injury sample (subject selection and neurological status undefined) on a ten minute four choice RT with constant inter-stimulus interval (ISI) delays. Mean RT latency was compared as well as a variability computation consisting of a comparison of Mean RT between the first and second half of the session between control and MHI patients. The patient group was tested 24 hours post injury, 6 weeks post injury, and a smaller subgroup of the original sample was followed at 6 months post injury. Using this test, mean RT was significantly slower for the MHI group at 24 hours and 6 weeks only. The coefficient of

variability differentiated between groups only at 24 hours post injury. Based on the lack of difference between performance in the first and second halves of the test, fatigue was discounted as a major contributing factor in the results. Patients did not differ from controls in number of errors, or Mean RT of errors, however, number correct and total number of responses were significantly different at day one. The results of this study are consistent with other studies using choice RT to compare MHI patients to controls. Macflynn et al. (1984) concluded that MHI results in deficits which are demonstrated early post injury and recover over a period of six months to levels comparable to controls.

Recently, several well controlled studies by Gentilini, Nichelli and Schoenhuber (1989) have focused on exploring the evidence for a sustained versus divided attentional (DA) deficit after MHI. MHI was defined strictly by a Glasgow Coma Score (GCS) of 13-15, loss of consciousness less than 20 minutes, and negative CT scan. Patients and matched controls were compared on a simple CRT. The sustained attention task involved the presentation of a 100 msec stimuli (a square) presented laterally on the screen followed by a warning signal triggered after each response (a subject paced task where the interval between tone and stimulus was varied from .5 to 2.5 secs.). Two trial sets consisting of 25 test stimuli each were presented. One set required a right handed response to a right sided stimulus, the next required a left handed response to a left sided stimulus. A DA component entailed the additional instruction to count backwards from 100 by two's while performing the RT test. In this way, subjects were required to

divide attention between two concurrent tasks. Results supported the hypothesis of a sustained attentional deficit. While patients were slower than controls independent of task, and while both groups were slower on the DA task, MHI and control subjects were equally slower on the more complex DA task (a lack of interaction). These findings of a lack of disproportionate increase between groups in RT with complexity had previously been demonstrated by Blackburn and Benton (1955), Bruhn and Parsons (1971), De Renzi and Faglioni (1965), and Hicks and Birren (1970) in brain damaged adults. In their study, Gentilini et al. (1989) concluded that MHI patients have a generalized deficit in the area of sustained attention or maintaining attention, a deficit which was still evident at three months post MHI.

RESEARCH WITH THE EXPERIMENTER PACED CRT

The experimenter paced CRT has been used to measure aspects of attention, especially variability and lapses of vigilance with heterogeneous brain damaged populations. In their seminal study, Benton and Blackburn (1957) investigated a failure to maintain an initial level of response speed and stability with a CRT task in a BD group composed of mostly CVA patients. It was hypothesized that the slower RT may not reflect diminished capacity per se: initial RT's may be within normal limits with a lengthening of RT and an increase in variability with time on task (Goldstein, 1942). Results indicated that while mean RT latency did not increase due to fatigue, there was a significant increase in mean intra-individual SD in patients over controls as a function of trial block (an

interaction) on the simple CRT. These results were described as a progressive failure to maintain a consistent level of response efficiency for brain damaged patients. The methodology of comparing mean RT across blocks of trials on a CRT is believed to be a valid way to measure the effects of fatigue and time on task performance decrements (Jeffcoate, Herbert, Cullen, Hastings & Walder, 1979).

Sanders and Hoogenboom (1970) found a significant increase in mental blocks (Bills, 1931) defined as incidental long RT's or lapses, as a function of time at work over a 30 minute period on a CRT while mean RT across all 2 minute work periods remained largely constant.

Researchers using the experimenter paced CRT with brain damaged patients demonstrated the usefulness of a method for determining the influence of frequent lapses of attention on average RT (Bruhn, 1970). By comparing extreme RT scores (eg., the mean of the 10 fastest RT's) between groups, these experimenters tried to determine whether slowing was the major deficit, or whether slowing was due to frequent periods of inattention. In the latter case, slowing would be secondary to attentional lapses. In his 1970 experiment, Bruhn demonstrated that the slower average RT performance of a group of centrencephalic epileptics was primarily due to frequent lapses of vigilance or attention. For the fastest RT scores, the performance of the epileptics were as rapid as controls indicating a capacity, however limited, for normal central nervous system (CNS) processing. This methodology of calculating extreme scores to establish an estimate of the fastest RT within an individual's distribution was

used by Berkson & Baumeister (1967, 1972) in mentally retarded individuals.

Bruhn and Parsons (1971) investigated the ability to maintain a consistent level of attention and vigilance, and transient lapses of attention, on a four minute discriminative CRT test with one constant ISI value by looking at trial by trial variability. One of the tasks chosen presented stimuli in relatively equal proportions in a Go/ No-Go type paradigm: instructing the subject to respond to only one of the stimuli while ignoring the other. Brain damaged subjects were found to be more variable and slower than normal control subjects, however, even the fastest RT's were slower than controls (the slowed mean was not restricted to the slow end of the distribution). While a specific time on task decrement was not demonstrated for brain damaged patients versus controls, further inspection indicated that the control subjects significantly improved RT performance over time. An inspection of intra-individual variability over block indicated a significant decrease in variability from early to late trial blocks for normal controls only.

Interestingly, Van Zomeren et al. (1984), showed certain head trauma patients to be more alert than controls on the second half of vigilance tasks. This was explained in terms of the coping hypothesis (head injured patients try to compensate for processing deficits by expending more effort on tasks). Such a mechanism has been evoked to explain the etiology of the postconcussional syndrome.

In their 1973 experiment, Johnson, Parsons, Holloway, and Bruhn measured RT latency as well as behavioral measures including errors of omissions, commission, and impulsivity (defined as an early response to a foil stimulus, or a false start) on a more complex CRT. This task was essentially identical to their 1971 experiment except for including a reversal shift manipulation. Significantly more errors of omission, commissions, and longer RT's for correct responses were noted for brain damaged patients over normal control subjects and alcoholics. A significant correlation between impulsivity and errors of commission were seen for brain damaged patients only.

Errors of commission or false alarms are considered indicative of an inability to inhibit responses to distractor foils or impulsivity (Sostek, Buchsbaum, & Rapoport, 1980). It has been suggested that the same internal factors which lead to distractibility also lead to performance inconsistency over time as the two are highly correlated (Schulman, Kasper, & Throne, 1965). On CRT tests, freedom from distraction requires the ability to maintain attention on a desired set of stimuli over time and counteract fatigue.

Bruhn and Parsons (1977) replicated their 1971 study using the standard CRT with BD and epileptic patients using randomized 2-6 sec inter-stimulus intervals (ISI's) on a longer 6 minute task. Analysis using the difference between RT extremes (.90th - .10th percentile) as a measure of intra-subject variability allowed the best overall group discrimination, correctly identifying 84% of BD and 94% of control subjects. These results support the use of CRT

as a screening measure, and the use of intra-individual variability as a sensitive dependent variable.

Varying ISI and time uncertainty on a CRT has been shown to provide an estimate of the ability of the subject to execute and initiate a response (Parsons & Bruhn, 1973). Van Zomeren and Deelman (1976), proposed a delay in the execution of the response (a deficit in the "go-mechanism") as a potential cause of slowing on both simple as well as choice RT and the lack of a complexity effect in MHI. By varying foreperiod or ISI, the investigator can selectively investigate the differential readiness of the subject to initiate a response (Costa, 1962). In normal individuals, shorter forperiod durations have been seen to facilitate response initiation using discrete trial paradigms. Using the CRT methodology, it has been shown that ISI's are positively related to RT with the effect of varying ISI's greater on BD patients (McDonald, 1964; Parsons & Bruhn, 1973). In the latter study, a significant interaction occurred between ISI value 2.5 and 4, and trial blocks indicating a failure in response initiation for the longer ISI as fatigue set in. Moreover, the inherent nature of a variable RT task as opposed to a constant one has been seen to be more sensitive to deficits in maintaining a constant level of responsiveness (Blackburn & Benton, 1957; Rodnick & Shakow, 1940; Zahn, Rosenthal, & Shakow, 1961).

DEPENDENT VARIABLES IN REACTION TIME STUDIES

While both mean/ median and SD are usually computed in post head injury RT studies, ordinarily, the only measure of group response has been the single measure of average speed. Traditionally, the

increase in RT latency has been considered the primary deficit indicative of a generalized slowing of mental processing. Median RT latency has frequently been reported as the measure of central tendency after head injury since the RT distribution is often skewed. The rationale for use of median RT is to arrive at a stable measure when extreme scores or outliers are considered atypical or invalid indicators of performance. However, when specifically exploring variability and the impact of extreme scores on a brain injured patient's performance, the mean is the best and most robust measure of central tendency (P. Ramsey, personal communication, 1991). Nevertheless, limiting the characterization of response to the mean (the common approach in reports of RT results with moderate to severe head injured patients) may overlook important information concerning the underlying central nervous system disturbance. A measure of SD averaged across patients provides a measure of mean intra-individual variability. Evidence of high variability can be related to subtle fluctuations in neural processing or momentary attentional lapses (Bruhn & Parsons, 1977). The relationship between SD and subject variables can then be investigated independent of the mean.

SUMMARY

Most of the RT literature after HI describes results based on the extensive use of the discrete trial RT task. This test has been successful in demonstrating deficits in response speed after moderate to severe head injury. The discrete trial RT, regardless of level of complexity, has not consistently shown itself to be a

sensitive technique for measuring the often subtle attentional deficits common after minor head injury. This methodology does not lend itself to the study of intra-subject variability, performance declines as a function of fatigue, and lapses of attention which can have a profound impact on performance clinically. The technique of rapid paced, continuous RT recording, not allowing the subject to rest between trials, is hypothesized to be a more likely situation in which to demonstrate these effects. Under such testing conditions, blocks of trials can be compared rather than the single measure of central tendency.

To date, no study has demonstrated differential aspects of performance stability over time on a task after MHI, either using vigilance (Van Zomeran, 1981) or CRT tasks (Greber & Perret, 1985). Lapses of attention have never been studied after MHI, and up to now, are referred to as a clinical concept operationally defined as response omissions or extremely long RT's.

It would be an important contribution to the understanding of functional deficits after minor head injury to be able to systematically evaluate breakdowns in CRT performance and relate these to differences in functional status post injury. Attentional lapses, and time on task decrements over trial blocks have never been explored as independent phenomena to validate clinical observations after MHI. The continuous experimenter paced RT task shares similarities with the continuous performance task (CPT) designed by Rosvold, Mirsky, Sarason, Bransome, and Beck (1956). It allows error analysis on a task requiring a high level of continuous or sustained attention over prolonged intervals of time. Results

can also be compared to those obtained in vigilance studies (Frankmann & Adams, 1962; Kupietz & Richardson, 1978) where the attentiveness of the subject and his ability to detect changes in stimulus events are measured over periods of sustained observation. While the CRT does not involve signal detection, it does meet the other criteria.

EVIDENCE FOR SUBGROUPING MHI PATIENTS

Recent studies with MHI patients have indicated great inter-individual variability which is often masked using group statistics (studies conducted with Kay, T., Ezrachi, O., and Cavallo, M., 1985-1987). A lack of consideration of these individual differences can lead to misinterpretation of results. In one study, serial testing of neuropsychological change after one year post injury using group statistical analysis revealed little improvement. Further inspection of individuals' performance revealed a significant degree of clinically significant change which was masked using large group analysis. Looking at subgroups of individuals, a considerable amount of variability was noted, both in terms of direction of change, and performance on specific tests within a functional domain. Two major relevant conclusions can be drawn from studies such as this one. One is that large group designs often mask performance of clinically significant subgroups (either causing overgeneralization of results based on a clinically impaired subgroup, or obscuring effects, due to the cancelling out of differences). Two, by looking at subgroups of MHI patients based on

relevant functional differences, more meaningful conclusions can be drawn about MHI patients' performance on cognitive tests.

Attempts to minimize between subject variability by equating subjects on neurological severity (duration of loss of consciousness [LOC], post traumatic amnesia [PTA], CT findings) have failed to eliminate the high inter-individual RT variability post CHI. In studies where measurable neurological differences were observed between subjects within a group, the impact of this factor on RT was statistically negligible. There were no significant differences in RT between patients with PTA longer than 15 minutes and the rest of the sample in MacFlynn et al.'s (1984) study with MHI patients reported earlier.

It is believed that a sound methodological approach is the identification of subgroups of MHI patients based on functional status in order to investigate the correlates of RT profiles specifically between those subgroups as compared to normal individuals. Subgroups can be identified based the persistence of postconcussional symptoms, the degree of impairment in functioning as a result of the head injury, and the patients' ability to return to premorbid levels of functioning.

Recent incidence studies of postconcussional symptoms indicate that for the majority of patients (approximately 60%), postconcussional symptoms subside over a three month period post injury (McLean, Dickmen, Tempkin, Wyler, & Gale, 1984; Rutherford, Merrett, & McDonald, 1977, Wrightson & Gronwall, 1981). While a percentage of MHI individuals continue to report symptoms after three months post injury (between 20 and 50% reported by Rutherford

et al, 1977, 1979; Wrightson & Gronwall, 1981), few studies have established the base rate of postconcussional symptoms in a non-head injured population (McLean et al., 1984). Rutherford et al. (1977, 1979) found that 8% of mild traumatic brain injured (MTBI) patients continued to report attentional problems specifically. In approximately 1/3 of MHI patients, subjective complaints persist long after this time frame and lead to functional disability (Rimel, Giordani, Barth, Boll, & Jane, 1981). Subgroups which differ based on the persistence of clusters of postconcussional symptoms i.e., cognitive vs. somatic complaints vs. no complaints (see Levin et al., 1987 review) may also differ on objective measures of attention. While MacFlynn et al. (1984) considered the possibility of differences between subgroups of MHI patients, his subgrouping methodology (patients with symptoms labeled as "organic" vs. "psychological") failed to reveal differences in RT performance.

Two subgroups of patients, labeled Functional and Dysfunction have been clinically identified based on research at the N.Y.U. Research and Training Center (1987 to present). Differences between the groups focus on their functional status post injury, the ability to return to premorbid vocational levels (work, school, homemaking), and the persistance of symptomatology resulting in impairment.

DEVELOPMENT OF RESEARCH TECHNIQUES

An experimenter paced continuous reaction time test (the HIVE) was developed to measure response speed and variability, fatigue effects, and attentional wandering over time using a simple test well within the grasp of minor head injured subjects. A goal in the

development of the HIVE was to minimize those cognitive functions (memory, complex visual perceptual discrimination, problem solving) which often confound RT tests due to the fact that they may also be impaired in individuals who have suffered from MHI. The HIVE includes an "ignore" paradigm to measure susceptibility to interference in a GO/ NO-GO situation, and varying inter-stimulus delays.

A discrete trial reaction time test: the reaction time test from the New York University Medical Center Orientation Remedial Module (ORM), was selected in order to compare performance between the two methodological approaches: the CRT and a more traditional type discrete trial RT paradigm. The ORM reaction time test was chosen based on its wide use in previous research studies conducted at N.Y.U. Medical Center with head injured patients and normal subjects over the past 10 years.

STUDY

In this study, subgroups of minor head injured individuals differing in degree of symptomatology and functional status will be compared to normal individuals on the CRT and discrete trial RT test. Differences between the subgroups will be assessed using comprehensive interviews and checklists to measure emotional status (the Beck Depression Interview and the Multiple Affect Adjective Checklist, MAACL-R), degree of symptomatology, severity of postconcussional symptoms, return to work status, and the presence and impact of attentional symptoms on daily functioning.

The two RT methodologies will be compared to determine their sensitivity in demonstrating deficits in speed and RT variability. Use of the two methodologies will address the question of whether MHI patients are in fact capable of responding within normal limits under certain testing conditions (discrete trial RT) months after their injury, while being unable to sustain or consistently maintain an optimal level of functioning, demonstrated under other conditions (the CRT). Use of the CRT will also allow for a more thorough evaluation of intra-individual variability after MHI, and its pattern over time.

HYPOTHESES

1. Effects of subgrouping MHI patients for RT comparisions with control subjects: It is hypothesized that MHI patients (the combined group) will be significantly more impaired on RT variables than normal control subjects. These differences however, may prove to be an overstatement of impairment given the differences in functional status of the two MHI groups. While differences are expected between dysfunctional patients and control subjects, the functional patients may or may not differ significantly from control subjects when the three groups are compared. A comparison between results obtained using the combined MHI sample versus the two subgroups in analysis with controls subjects will address the validity of subgrouping MHI patients based on functional status.

2. Relationship between RT and other performance variables between MHI subgroups: It is hypothesized that differences between the two clinically identified head injured subgroups will be demonstrated on the CRT, and that these differences will be consistent with between group differences in degree of symptomatology, affective status and work status as measured by interview. Gross CRT measures will be studied for their ability to discriminate between the two patients groups. MHI subjects clinically labeled as dysfunctional are expected to be slower and more variable in their CRT performance, and to exhibit a greater level of symptomatology and degree of emotional distress as measured by self report. The relationship between relevant RT and non-RT variables will be explored through selected correlational analysis. If between group differences fail to emerge, MHI subgroups will be collapsed for later analysis.

3. Sensitivity of RT methods for predicting group membership:

a. It is hypothesized that the CRT will be more accurate in its ability to correctly classify group membership than the discrete trial RT test. It is expected that a greater number of dysfunctional MHI patients will be correctly classified as "impaired" (true positives), and a greater number of normal controls will be correctly classified as "normal" (true negatives) on the CRT as compared to the ORM RT using optimal cutting scores as impairment criteria based on means and SD for that particular test.

b. It is hypothesized that more subjects will be misclassified using the discrete trial ORM task. It is expected that a greater percentage of normal control subjects will be misclassified as

"impaired" (false positives), and that a greater number of dysfunctional patients will be incorrectly classified as "normal" (false negatives) on the ORM. Both Mean and SD (the measure of intra-subject variability) will be compared for their sensitivity in correctly classifying group membership between tests.

Characteristics of CRT performance:

1. Effects of varying inter-stimulus interval (ISI): It is hypothesized that a deterioration in performance (consistency and speed) will occur as a function of ISI delay, and that longer delays will result in wandering of attention and longer RT`s specifically for the head trauma groups.

2. Effects of trial block: It is hypothesized that speed, variability and inattention will change as a function of time on task (fatigue) to a greater degree for patients than normal controls, indicating an inability to maintain a consistent level of focused attention over trial block (an interaction between group and block).

3. Error analysis- False Alarms: It is hypothesized that minor head injured patients will be less able to inhibit response to interference and maintain inhibitory regulation over time. In the present experiment, stimuli (both targets and foils) are presented with equal probability of occurrence so that any increase in RT speed elicited by foils should be a sensitive indicator of impulsivity (Hyman, 1953). According to Hicks (1952), when stimuli probability is held constant, RT should hold constant across

stimuli. Based on this model, both the number of false alarm errors and their mean RT value over the parameters of this CRT should be a valid measurement of impulsivity across groups.

4. Error analysis- Response Omissions: It is hypothesized that response omissions will occur to a greater degree in MHI patients than control subjects and to a greater degree in the later trial blocks. The presence of response omissions are considered indicative of lapses of attention.

5. Comparison of fastest RT's: It is hypothesized that the fastest RT's for both MHI groups will not differ from the fastest RT's of normal controls. This hypothesis will investigate whether MHI patients are capable of normal response latencies (a finding which is masked by high intra-individual variability) or whether there is a generalized slowing across the entire distribution. A comparison of optimal response speeds will be compared between groups.

METHODS

SUBJECTS

The head injured subjects in this study were adults between the ages of 17 and 55 who had sustained a minor traumatic head injury. MHI was defined as a blow to the head or whiplash injury resulting in no or brief loss of consciousness (less than 60 minutes), no neurosurgical intervention, and discharge directly home from the Emergency Room or acute care hospital within 48 hours post injury. All patients in this study were at least three months post injury so

as to ensure that a plateau of neurological recovery had been reached.

The following demographic variables were documented: age, sex, ethnicity, handedness, education, last grade completed, primary language, previous school curriculum, previous performance in school and RT hand used. The following neurological variables were documented: etiology and location of head trauma, nature of injury, presence and duration of loss of consciousness, admission Glasgow Coma Scaled score (GCS), time post injury, history of previous head injury or other central nervous system dysfunction, evidence of CT scan, MRI and EEG documented abnormalities, history of psychiatric disturbance, history of learning disability, history of drug and alcohol abuse, intoxication at time of injury, and involvement in litigation.

Subjects were excluded from this study if they had a history of chronic drug or alcohol abuse, psychosis, or prior CNS dysfunction. The majority of subjects in the dysfunctional group were self referred, a common finding in MHI patients who continue to experience difficulties months after a neurologically "normal" injury, which has resulted in functional disability.

Control subjects consisted of non-head injured adults matched for age, sex, and education. Subjects were screened for a history of head injury and other neurological or CNS dysfunction, drug and alcohol abuse, prior psychiatric history or hospitalization, and learning disability. The same demographic items described for MHI subjects were evaluated in control subjects.

Patients were classified as "functional" or "dysfunctional", a clinical categorization made at the time of the intake interview when the patient was referred to the N.Y.U Research and Training Center. The categorization was necessary in order to triage patients into one of three ongoing clinical research projects. The identification of a patient as dysfunctional was based on the following profile: impairment in one or more areas of functioning as a result of the head injury, inability to return to premorbid levels of vocational functioning (work, school or homemaking), report of symptoms which had impaired functioning and had led the patient to seek help, and complaints of emotional distress. The identification of a patient as functional was based on the following profile: no impairment in functioning, return to premorbid levels of functioning, report of symptoms which were subtle (if present at all), and which did not interfere with the patients' ability to function. To ensure an adequate number of patients in the "functional" group, head trauma subjects invited into the Medical Center for a routine one year post injury follow-up were screened for inclusion in this study. These subjects were followed as part of a larger study of discharge home from the affiliated Bellevue Emergency Room. They were evaluated as part of the research design regardless of functional status, or the presence of persisting symptoms.

DEMOGRAPHIC AND NEUROLOGICAL DATA

MHI SUBJECTS

Tables 1 and 2 present the demographic and neurological data for the Dysfunctional and Functional MHI subjects respectively. Seventeen Dysfunctional (HT1) and eighteen Functional (HT2) patients were assessed in this study. The three groups did not differ significantly in age (HT1 mean = 37.3, HT2 mean = 36.0, Control mean = 31.8, $F(2,48) = .88$, $p = .4$) or education (HT1 grades completed = 14.6 years, HT2 grades completed = 13.9 years, Control grades completed = 16.0 years, $F(2,48) = .08$, $p = .09$). Similarities were noted for handedness: 16 (94%) and 14 (78%) right handed, primary language spoken: English in 15 (88%) and 15 (83%) and Degree attained in school: College degree or above for 8 (47%) and 7 (40%) respectively between HT1 and HT2. The difference in handedness between the two groups was due to a greater number of ambidextrous subjects in HT2 (3 subjects) as compared to 1 subject in HT1. 94% of subjects in both groups used their right hand for RT testing (all ambidextrous subjects in HT2 were primarily right hand dominant). All subjects were fluent in English. An intriguing finding was the notable difference in groups based on sex as indicated in Table 1. Dysfunctional patients were composed of primarily women: 12 (71%) female, 5 (29%) male, while functional patients showed the reverse trend: 12 (67%) male, 6 (33%) female. An analysis of sex differences between all three groups showed a significant difference between only functional and control subjects in male to female ratio.

Table 1

Dysfunctional Minor Head Injured (HT1)

Demographic and Neurological Variables (N=17)

Age	N	17
	Mean	37.3
	SD	10.4
	Median	36.0
	Range	20-56

	Frequency	Percent
Sex		
Male	5	29
Female	12	71
Ethnicity		
Caucasian	13	76
Black	2	12
Hispanic	2	12
Handedness		
Right	16	94
Left	0	0
Ambidextrous	1	6
Education		
Master's Degree	2	12
Bachelor's Degree	5	29
Associates Degree	1	6
Some College	3	18
High School Diploma	5	29
Some K-12 Education	1	6
Last Grade Completed		
12	6	35
14	3	18
15	1	6
16	5	29
18	1	6
22	1	6
English Language		
Primary	15	88
Secondary	2	12
Nature of Injury		
Closed Head, no Fracture	14	82
Linear Fracture	2	12
Whiplash, no blow to head	1	6

Table 1 (Continued)

	Frequency	Percent
Glasgow Coma Scaled Score		
14	1	10
15	9	90
Etiology of Trauma		
Fall	4	23
MVA, passenger in car	8	47
MVA, pedestrian	2	12
Blow to head, assault	2	12
Blow to head, non assault	1	6
Location of Head Trauma		
Frontal	10	71
Temporal	6	50
Parietal	6	46
Occipital	5	42
Duration of LOC		
No LOC	5	29
Questionable	1	6
< 10 minutes	9	53
> 20 minutes < 60 minutes	2	12
Number of Prior Head Injuries		
0	16	94
1	1	6
2+	0	0
Intoxication at Time of Injury		
Alcohol Absent	15	88
Alcohol Present	2	12
Drugs Absent	17	100
Time Post Injury		
< 1 Year	2	12
1-2 Years	9	53
2-3 Years	2	12
> 3 Years	4	24
Prior CT Scan Performed	13	77
CT Scan Abnormal	2	15
Prior MRI Performed	11	65
MRI Abnormal	3	27

Table 1 (Continued)

	Frequency	Percent
Prior EEG Performed	6	35
EEG Abnormal	2	33
Lawsuit - Involved or Expect To Be	10	59
Psychiatric History		
No History	16	94
Single episode	1	6
Neurological History		
No History	16	94
History Minor Head Injury	1	6
Previous School Curriculum		
Advanced	4	23
Regular	13	77
Previous Performance		
Mostly A's	5	29
Mostly B's	7	41
Mostly C's	4	24
Mostly D's	1	6
Hand Used (Reaction Time)		
Right	16	94
Left	1	6

Table 2

Functional Minor Head Injured Subjects (MH2)

Demographic and Neurological Variables (N=18)

Age	N	18
	Mean	36.0
	SD	13.0
	Median	32.5
	Range	18-58

	Frequency	Percent
Sex		
Male	12	67
Female	6	33
Ethnicity		
Caucasian	8	44
Black	3	16
Hispanic	5	28
Oriental	1	6
Other	1	6
Handedness		
Right	14	78
Left	1	5
Ambidextrous	3	17
Education		
Master's Degree	1	6
Bachelor's Degree	5	28
Associates Degree	1	6
Some College	6	33
High School Diploma	3	16
Some K-12 Education	2	11
Last Grade Completed		
9	1	6
12	4	22
13	4	22
14	2	11
15	1	6
16	5	27
18	1	6
English Language		
Primary	15	83
Secondary	3	17

Table 2 (Continued)

	Frequency	Percent
Nature of Injury		
Closed Head, no Fracture	17	94
Whiplash	1	6
Glasgow Coma Scaled Score		
15	17	100
Etiology of Trauma		
Fall	4	22
MVA, passenger in car	8	44
MVA, pedestrian	1	6
Blow to head, assault	1	6
Blow to head, non assault	4	22
Location of Head Trauma		
Frontal	11	69
Temporal	2	12
Parietal	0	0
Occipital	5	30
Duration of LOC		
No LOC	11	61
Questionable	2	11
< 10 minutes	3	17
> 20 minutes < 60 minutes	2	11
Number of Prior Minor Head Injuries		
0	15	83
1	3	6
2+	2	11
Intoxication at Time of Injury		
Alcohol Absent	15	83
Alcohol Present	3	17
Drugs Absent	18	100
Time Post Injury		
< 1 Year	0	0
1-2 Years	16	94
2-3 Years	0	0
> 3 Years	2	6
Prior CT Scan Performed	2	11
CT Scan Abnormal	0	0

Table 2 (Continued)

	Frequency	Percent
Prior MRI Performed	0	0
MRI Abnormal	0	0
Prior EEG Performed	0	0
EEG Abnormal	0	0
Lawsuit - Involved or Expect To Be	6	33
Psychiatric History		
No History	17	94
Single Episode	1	6
Neurological History		
No History	15	83
History Minor Head Injury	3	17
Previous School Curriculum		
Advanced	4	22
Regular	13	72
Some Special Education	1	6
Previous Performance		
Mostly A's	8	44
Mostly B's	7	39
Mostly C's	2	11
Inconsistent, cannot characterize	1	6
Hand Used (Reaction Time)		
Right	17	94
Left	1	6

Both groups were essentially similar in the nature of their injury. For HT1, 14 (82%) had sustained a closed head injury, 2 (12 %) had sustained a linear skull fracture and 1 (6%) had sustained a whiplash injury only. For HT2, 17 (94%) sustained a closed head injury, and the remaining subject sustained a whiplash injury. GCS score on admission for all patients in both groups was between 13 and 15 (the definition of MHI). Being a passenger in a motor vehicle accident (MVA) was the most common etiology of trauma for both groups: 8 (47%) HT1, 8 (44%) HT2. The second most common etiology was a fall: 4 (23%) HT1, 4 (22%) HT2 and blow to the head, non assault for HT2: 4 (22%). In keeping with the definition of MHI, no subject had evidence of mass lesions or had required neurosurgical intervention. Location of head trauma (area struck in non-whiplash injuries) was most commonly the frontal pole: 10 (71%) HT1, 11 (69%) HT2. Duration of loss of consciousness (LOC) for all subjects was less than 60 minutes. For HT1, 5 (29%) suffered no LOC, 9 (53%) were unconscious for 10 minutes or less, and 2 (12%) were unconscious for greater than 20 minutes. For HT2, 11 (61%) suffered no LOC, 3 (17%) were unconscious for 10 minutes or less, and 2 (11%) were unconscious for greater than 20 minutes. It was the first MHI: 16 (94%) HT1, 15 (83%) HT2 for the majority of patients in both groups.

Based on the nature of the follow-up study which was used to recruit HT2 patients, 16 (94%) were one to two years post injury. Subjects in HT1 were seen at various time points beyond 6 months post injury with the majority seen between one to two years post: 9 (53%). Most of the patients in both groups who under went CT and/

or MRI testing had normal scans: 2 (15%) and 3 (27%) of CT's and MRI's for HT1 were abnormal respectively. The nature of the abnormality, when present, was almost always mild and atrophic in nature. No subject in HT2 demonstrated abnormality.

CONTROL SUBJECTS

Table 3 presents the demographic data for the sixteen control subjects assessed in this study. Ages ranged from 17 to 58 (M = 31.8 years), with 12 (75%) females and 4 (25%) males. 14 (88%) of the group were right handed and 15 (94%) spoke English as their primary language. 10 (63%) of the group had obtained a college degree or higher, with a mean of 16.1 years in school. None of the control subjects had a history of neurological illness, 6 (38%) were working full-time at the time of testing, 2 (12%) were working part-time, 6 (38%) were full-time students, and 2 (12%) were retired. 15 (94%) of the control subjects used their right hand for reaction time testing.

INTERVIEWS

The following measures were used to further characterize the number and severity of specific postconcussional symptoms and degree of emotional distress in the two head injured subgroups:

1. Sections of the New York University Medical Center Head Injury Family Interview (HI-FI) (Kay, Cavallo, & Ezrachi, 1988). This interview was used to gather information about: a) the presence of problems experienced in different areas of functioning (physical, cognitive, behavioral, social) and their severity since the head

Table 3

Control Group

Demographic Information (N=16)

Age	N	16	
	Mean	31.8	
	SD	13.6	
	Median	27.0	
	Range	17-58	
		Frequency	Percent
Sex			
	Male	4	25
	Female	12	75
Ethnicity			
	Caucasian	13	81
	Black	2	13
	Other	1	6
Handedness			
	Right	14	88
	Left	1	6
	Ambidextrous	1	6
Grade in School			
	11	2	12
	12	1	6
	14	2	12
	15	1	6
	16	6	40
	19	1	6
	21	1	6
	22	2	12
Primary Language			
	English	15	94
	Other	1	6
Education			
	Doctoral Degree	3	19
	Some Grad School	1	6
	Bachelor's Degree	6	38
	Some College	1	6

Table 3 (Continued)

	Frequency	Percent
Education (cont.d)		
High School Diploma	3	19
Some K-12 Education	2	12
Curriculum in School		
Advanced Classes	5	31
Regular Classes	11	69
Performance in School		
Mostly A's	9	56
Mostly B's	2	13
Mostly C's	15	31
Psychiatric History		
No History	15	94
Single Episode	1	6
Neurological History		
No History	16	100
Employment Status		
Working, Full-Time	6	38
Working, Part-Time	2	12
Student, Full-Time	6	38
Retired	2	12
Hand Used (Reaction Time)		
Right	15	94
Left	1	6

injury, and b) current work, educational or homemaking status, level of responsibility (comparable vs. compromised), and presence and type of problems experienced in the above categories (cognitive, physical, behavioral, social and emotional). A Problem Check-List (PCL) was administered requiring the subject to rate him or herself in a number of problem areas common to TBI. Patients were required to indicated whether they experienced (yes or no) any one of 34 postconcussive type symptoms, and if so, the degree to which the endorsed symptom presented a problem in their daily functioning (self-report rating made on a 7 point severity scale). A total weighted severity score was summed across all endorsed items for each subject from this checklist. Sections of the HI-FI are included in Appendix A.

2. The degree of emotional distress and the impact of this variable on RT performance was measured by the Multiple Affect Adjective Checklist (MAACL-R) (Zuckerman & Lubin, 1985). This is a self-administered adjective checklist inventory reflecting subjects' affective status in five domains: Anxiety, Hostility, Depression, Positive Affect and Sensation-seeking. This test is scored in terms of the total number of adjectives checked for items associated with each mood state. Presence and degree of pathological mood states were determined on the basis of published norms. The MAACL-R was also given to all normal controls who participated in this study. The following instructions are given for the MAACL-R:

> On this sheet you will find words which describe different kinds of moods and feelings. Blacken in the circles beside the words which describe how you generally feel. Some words may sound alike, but we want you to check off all the words that describe your feelings. Work rapidly.

3. The Beck Depression Interview (BDI) is a standardized 21 item interview which measures the severity of depression based on the endorsements of statements tapping vegetative and non-vegetative aspects of depression (Beck, 1972; Beck & Beamesderfer, 1974; Beck, Steer, & Garbin, 1978; Beck, Ward, Mendelson, Mock, & Erbaugh, 1961). Areas covered include sadness, pessimism, sense of failure, dissatisfaction, guilt, self dislike, self harm, social withdrawal, indecisiveness, self image changes, work difficulty, fatigue, and anorexia. The depression score is the sum of the weighted responses to all items. The following instructions are given for the BDI:

> On this questionnaire are groups of statements. Please read each group of statements carefully. then pick out the one statement in each group which best describes the way you have been feeling over the PAST WEEK, INCLUDING TODAY! Circle the number beside the statement you picked. If several statements in the group seem to apply equally well, circle each one. **Be sure to read all the statements in the group before making your choice.**

APPARATUS

The CRT was programmed in Quick Basic for use on IBM compatible monochrome monitors. A timing routine was designed to self calibrate and adjust before each trial run to allow for use across different computers. For this study, all subjects were evaluated on a Toshiba Laptop computer with a gas plasma screen, model T3100e.

PROCEDURE

Experimental subjects were administered the two RT tests (the HIVE and ORM), those interviews described above, and the Cognitive ADL Checklist (described below) as part of a larger battery of neuropsychological tests administered at New York University Medical

Center, Research and Training Center. All Subjects signed informed consent before participation in the particular research study. The consent forms used for experimental and control subjects appear in Appendix B. Control subjects were tested on both computerized reaction time tests, the MAACL-R, and the Cognitive ADL Checklist. This research had IRB approval.

HIVE CONTINUOUS REACTION TIME

Subjects were seated directly in front of the computer, and the following standard set of instructions were presented on the screen before the task: "In a little while the session will begin and you will hear three beeps to warn you that we are beginning. The figure below (red cross presented) will appear in the center of the screen. When you see this figure, you must press the space bar (the long key) as quickly as possible. One other figure will appear at different times. Do not respond to this."

Subjects were seated in front of the center of the screen. The subject was instructed to place his/her index finger lightly on the space bar. Instructions were read out loud to all subjects and the location of the space bar was indicated. Eight practice trials were presented at the onset of the task to ensure the subjects' understanding of the instructions. There was an option to repeat practice trials if necessary. The two symbols (cross and square dough-nut) were randomly presented in the center of the screen with a stimulus duration of 500 msec. Stimuli were separated by five inter-stimulus intervals of 1.5, 2.0, 2.5, 3.0, and 3.5 seconds. The same randomized sequence of stimuli and timing intervals were

presented to all subjects. There were a total of three hundred trial presentations, 50 % of which were targets, and 50 % foils, over a 12 minute testing session. The target was a cross approximately one inch in height and width, the foil was a square dough-nut of equivalent dimensions. The stimuli were red against a black background screen on the laptop computer. Contrast was automatically set for maximal visibility and resolution. Subjects were tested under constant lighting conditions.

ORM RT TASK

The discrete trial RT was part of a software package known as the ORM (Orientation Remedial Module) designed by E. Piasetsky and J. Rattok (1983) for use at the N.Y.U Medical Center Head Trauma Program. The variable RT test records the speed of response to the onset of a light stimulus. The following instructions were presented on the screen before the task: "This program tests your basic reactions. Each trial starts with a tone. This warns you to be alert and watch the target circle on the screen. As soon as the target turns red, press the space bar. After each trial, [examiner will] press enter to reset and start a new trial. You will receive three warm-ups before the test begins." (If more warm-ups are necessary, examiner presses the right arrow to redo). "Reminder, each trial begins the sound of a warning tone, when the target turns red, press the spacer as fast as you can" (press spacer to begin).

Initially the target circle was the same color as the rest of the screen (black). There were 3 warm-up trials and 12 test trials. Subject's average RT was based on the 12 recorded trials. RT

latency was displayed at the top of the screen. Impulsive responses (those which preceded the target stimulus) were not scored and were eliminated from data analysis. Trials on which impulsive (unscorable responses) occured ware repeated so that all subjects had 12 scorable RT latencies. In this condition, the interval between the warning tone and light stimulus onset was varied randomly between 2 to 5 seconds with 1 second intervals between.

COGNITIVE ADL CHECKLIST

The Cognitive ADL checklist was developed as an ancillary measure of self reported attentional difficulties and their impact on daily living. Designed for both patient and control subjects, the checklist is a 15 item scale requiring the subject to answer true or false to statements describing common attentional based symptoms and the extent (0 = none, 6 = severe) to which each endorsed statement interferes with the subjects daily life functioning. Two scores are derived from this scale: total number of statements endorsed, and mean interference score. This checklist was presented to both normal and head injured subjects. A copy of the Cognitive ADL checklist is presented in Appendix C.

RESULTS

DEMOGRAPHIC AND NEUROLOGICAL DIFFERENCES

The apparent differences between HT1 and HT2 in CT/MRI results, and length of LOC between groups, raised the question of whether neurological variables indicative of severity of injury could

contribute to between group differences on RT testing. To address these concerns, a Mann-Whitney U test was performed on total Mean HIVE RT latency between subjects for LOC extremes (no LOC vs. greater than 20 minutes), and CT/ MRI normality vs. abnormality. Due to the small within group sample size for these variables, analysis was performed between individual subject groupings on these variables irrespective of larger group membership. There were no significant differences in RT performance based on LOC extremes $\underline{u}$ = 30 < 52, $p>.05$. or CT/MRI normality and abnormality $\underline{u}$ = 23 < 31, $p>.05$.

While the groups did not differ with regard to age, reaction time studies have often been criticized for not taking into consideration the possibility of age related increases confounding results. For this reason, a Mann-Whitney U test was also performed on total Mean HIVE RT between individuals who fell in the extremes for age (25 years or younger vs. 55 years or older). There were no significant differences in Mean RT latencies between age groups $\underline{u}$ = 20 < 33, $p>.05$.

Current involvement or expectation of involvement in litigation versus no litigation involvement was also compared for its potential impact on RT latency. Several MHI studies have suggested that subjects who expect a lucrative legal settlement for their injuries may either consciously or unconsciously perform more poorly on neuropsychological tests (Binder, 1986; McKinlay, Brooks, & Bond, 1983; Rutherford, 1989). Since a greater number of HT1 subjects (59%) were involved in litigation as compared to HT2 subjects (33%), this variable could have contributed to the slower

performance of the HT1 patients on RT tests. Based on this concern, a Mann-Whitney U test was performed between groups of individuals irrespective of larger group membership who were versus were not involved in litigation. Results were not significantly different based on litigation motivation $U = 141 < 211$, $p > .05$.

AFFECTIVE STATUS

As expected based on group selection criteria, the two MHI groups were significantly different based on the total BDI score indicating a greater degree of depression for the HT1 subjects ($M = 20.3$) versus HT2 group ($M = 8.1$), $F(1, 33) = 9.9$, $p < .01$. Within the HT1 group, 13 patients (76%) obtained a BDI score greater than 10. Within the HT2 group, 14 patients (78%) obtained a BDI score below 10. Based on the normative data available for the BDI (Beck, 1978), HT1 subjects as a group could be categorized as moderately to severely depressed, while HT2 subjects as a group could be described as normal.

As indicated in Table 4, between group trends were similarly revealed on the scales of the MAACL-R. The mean T scores obtained for the three groups, HT1, HT2 and Controls, on the major scales of the MAACL-R were: Anxiety: $M = 73.4$, $M = 57.3$, $M = 56.1$, Depression: $M = 77.3$, $M = 57.5$, $M = 56.4$, and Hostility: $M = 73.7$, $M = 53.2$, $M = 54.3$, respectively. Dysfunctional MHI patients as a group were significantly more anxious $F(2,45) = 6.0$, $p < .01$, depressed $F(2,45) = 4.8$, $p < .01$, and hostile $F(2,45) = 11.8$, $p < .01$, than both Controls and Functional MHI patients based on the MAACL-R.

Table 4

Affective Variables

Functional MHI Group

	N	Mean	SD	Median	Range
MAACL-R					
Anxiety (T-Score)	17	57.3	18.8	49.0	42-112
Depression (T-Score)	17	57.5	17.8	46.0	42-102
Hostility (T-Score)	17	53.2	12.3	51.0	41-81
Positive Affect (T-Score)	17	46.7	9.2	50.0	23-58
Sensation Seeking (T-Score)	17	48.0	9.9	45.0	31-67
Dysphoria (T-Score)	17	57.7	17.9	49.0	42-102
Positive Affect/Sensation Seeking (T-Score)	17	47.4	8.6	48.0	28-61
Beck Depression Inventory					
Total	18	8.1	10.7	5.0	0-45

Dysfunctional MHI Group

	N	Mean	SD	Median	Range
MAACL-R					
Anxiety (T-Score)	17	73.4	14.0	63.0	48-95
Depression (T-Score)	17	77.3	26.2	75.0	45-115
Hostility (T-Score)	17	73.7	14.9	73.0	52-98
Positive Affect (T-Score)	17	27.7	14.3	30.0	7-50
Sensation Seeking (T-Score)	17	41.5	10.8	45.0	19-54
Dysphoria (T-Score)	17	79.1	17.7	76.0	50-110
Positive Affect/Sensation Seeking (T-Score)	17	28.3	13.7	27.0	2-48
Beck Depression Inventory					
Total	17	20.3	12.2	20.0	4.0-44

Table 4 (Continued)

Affective Variables

Control Group

	N	Mean	SD	Median	Range
MAACL-R					
Anxiety (T-Score)	16	56.1	12.8	53.0	42-85
Depression (T-Score)	16	56.4	18.8	45.0	44-102
Hostility (T-Score)	16	54.3	12.4	50.0	44-89
Positive Affect (T-Score)	16	44.2	11.6	45.0	15-60
Sensation Seeking (T-Score)	16	51.4	11.1	49.0	26-74
Dysphoria (T-Score)	16	56.8	14.8	49.5	45-98
Positive Affect/ Sensation Seeking (T-Score)	16	45.5	11.3	45.0	23-62

INTERVIEWS

Table 5 presents the results obtained for the individual items and total scores of the Cognitive ADL Checklist for the HT1, HT2 and Control groups respectively. Table 6 presents the summary data for total number of items endorsed as true and the average severity rating across the same three groups. The total number of statements endorsed as true differed significantly on the Cognitive ADL checklist between groups indicating a greater number of attentional problems present for the dysfunctional patients as a group: HT1 M = 12.4, HT2 M = 3.6, Control M = 4.0, $F(2,48) = 41.9$, $p<.01$. One-way analysis between groups on the individual items of the Cognitive ADL checklist indicated significance between the HT1 vs Control or HT1 versus HT2 on thirteen of the fifteen items. Those individual items endorsed with no greater frequency for the head trauma patients versus controls subjects were the following items: "I have difficulty maintaining attention for extended periods of time", and, "In conversation, I often lose my train of thought".

An analysis of variance for mean average severity of endorsed items was significantly different among the three groups. Attentional symptoms (regardless of their number) were perceived to interfere with daily functioning to a moderate to severe degree (HT1 M = 3.9), on average, as compared to a mild to moderate degree for HT2 M = 2.0, and Control M = 2.0, respectively, $F(2,46) = 11.7$, $p<.01$. The finding that dysfunctional patients report a significantly greater number of attentional symptoms than either functional or control subjects is not surprising, nor is the fact that the impact these reported symptoms have on every day life

Table 5

Dysfunctional MBI Group (BT1)

Cognitive ADL Checklist

	Endorse "True"			Degree of Interference	
	Total N	N	%	M	SD
1. I get distracted easily.	17	15	88	4.1	1.4
2. I need to take frequent breaks while working on a task.	17	16	94	3.5	1.2
3. I have difficulty maintaining attention for extended periods of time.	17	12	71	4.6	1.5
4. I get tired easily.	17	16	94	.9	.3
5. My mind often wanders off a task.	17	15	88	4.6	.9
6. When people speak to me quickly, I have trouble following what they are saying.	17	16	94	4.1	1.4
7. When a lot goes on around me, I often "tune out".	17	13	77	3.9	1.6
8. When I read, I find that my mind often wanders, and I have to go back and reread what I missed.	17	16	94	4.2	1.3
9. I never know how well I'll do on a task because my performance is very inconsistent.	17	13	77	3.8	1.6
10. No matter how hard I try, I sometimes only understand bits and pieces of information.	17	15	88	4.1	1.8
11. Often, I am unable to do a job well because I am tired.	17	13	77	3.0	1.3
12. In conversation, I often lose my train of thought.	17	10	62	4.6	1.5
13. I get bored easily.	17	13	77	3.8	1.0
14. I get tired when I am forced to concentrate.	17	15	88	3.9	1.3
15. I often need to ask people to repeat what they've said because my attention has drifted.	17	14	82	3.7	1.6

Table 5 (Continued)

Functional MHI Group (HI2)

Cognitive ADL Checklist

	Total N	Endorse "True" N	Endorse "True" %	Degree of Interference M	Degree of Interference SD
1. I get distracted easily.	18	5	28	3.6	.9
2. I need to take frequent breaks while working on a task.	18	1	6	1.0	0
3. I have difficulty maintaining attention for extended periods of time.	18	7	39	2.7	1.4
4. I get tired easily.	18	5	28	2.0	1.9
5. My mind often wanders off a task.	18	5	28	2.8	1.5
6. When people speak to me quickly, I have trouble following what they are saying.	18	4	22	1.5	.6
7. When a lot goes on around me, I often "tune out".	18	5	28	2.2	1.9
8. When I read, I find that my mind often wanders, and I have to go back and reread what I missed.	18	10	56	1.9	1.4
9. I never know how well I'll do on a task because my performance is very inconsistent.	18	2	11	3.0	1.4
10. No matter how hard I try, I sometimes only understand bits and pieces of information.	18	1	6	3.0	0
11. Often, I am unable to do a job well because I am tired.	18	1	6	1.0	0
12. In conversation, I often lose my train of thought.	18	5	28	2.8	1.3
13. I get bored easily.	18	6	33	3.2	1.7
14. I get tired when I am forced to concentrate.	18	4	22	1.5	1.3
15. I often need to ask people to repeat what they've said because my attention has drifted.	18	4	22	3.5	1.3

Table 5 (Continued)

Control Group

Cognitive ADL Checklist	Total N	Endorse "True" N	Endorse "True" %	Degree of Interference M	Degree of Interference SD
1. I get distracted easily.	16	10	62	2.2	1.8
2. I need to take frequent breaks while working on a task.	16	2	12	2.5	2.1
3. I have difficulty maintaining attention for extended periods of time.	16	5	31	2.4	2.1
4. I get tired easily.	16	5	31	2.4	1.5
5. My mind often wanders off a task.	16	3	19	2.7	1.2
6. When people speak to me quickly, I have trouble following what they are saying.	16	13	19	2.7	2.1
7. When a lot goes on around me, I often "tune out".	16	5	31	1.8	2.0
8. When I read, I find that my mind often wanders, and I have to go back and reread what I missed.	16	6	37	2.8	1.8
9. I never know how well I'll do on a task because my performance is very inconsistent.	16	3	19	1.3	.6
10. No matter how hard I try, I sometimes only understand bits and pieces of information.	16	1	6	3.0	0
11. Often, I am unable to do a job well because I am tired.	16	2	12	1.5	.7
12. In conversation, I often lose my train of thought.	16	5	31	2.0	1.2
13. I get bored easily.	16	5	31	2.2	2.0
14. I get tired when I am forced to concentrate.	16	4	25	2.0	2.2
15. I often need to ask people to repeat what they've said because my attention has drifted.	16	5	31	1.8	1.9

Table 6

Cognitive ADL Checklist Summary Scores

Dysfunctional Group

	N	Mean	SD	Median	Range
Cog ADL Total - Sum True	17	12.4	3.1	14.0	5.0-15.0
Cog ADL Total - Average Severity	17	3.9	1.0	3.9	2.3-5.5

Functional Group

	N	Mean	SD	Median	Range
Cog ADL Total - Sum True	18	3.6	3.3	2.5	0-11.0
Cog ADL Total - Average Severity	18	2.0	1.4	2.0	.0-5.0

Control Group

	N	Mean	SD	Median	Range
Cog ADL Total - Sum True	16	4.0	3.1	3.0	0-10
Cog ADL Total - Average Severity	16	2.0	1.5	2.0	0-6.0

functioning is perceived to be significantly more disabling. It is of interest, however, that despite the control subjects' endorsement of fewer attentional symptoms, when symptoms do occur they are rated as having a mild to moderate impact on functioning, even in the absence of a head injury. In addition, the presence of a head injury alone, as indicated for the functional patients, did not necessarily increase the likelihood of suffering from more attentional problems.

Total severity of endorsed problems on the PCL of the HI-FI was also significantly different between HT1 and HT2 patients, M = 121.8, and M = 16.5, $F(1,33) = 70.9$, $p<.01$, respectively. Within the HT1 group, 15 patients (88%) attained a total severity score greater than 55 on the PCL. Within the HT2 group, 17 patients (94%) attained a total score below 55 on the PCL. Dysfunctional patients, as a group, were highly symptomatic, consistent with their spontaneous complaints during intake interview.

WORK STATUS

Table 7 presents work status measured at the time of testing for the two groups of MHI patients. Consistent with initial subgrouping criteria, the two groups were markedly different in the degree to which their head injury had prevented their return to employment, the level of responsibility they had returned to post injury, and the frequency of problems reported in their current position. 10/17 (59%) of HT1 subjects were unemployed due to head injury related problems as compared to 1/18 (6%) of HT2 subjects. For those unemployed HT1 subjects, the most common causes of

Table 7

Dysfunctional MHI Group (HT1)

WORK STATUS

	Frequency	Percent
Working Currently		
No, Not Due to Head Injury	2	12
No, Due to Cognitive Problems	5	29
No, Due to Physical Problems	2	12
No, Due to Soc/Emotional Problems	1	6
No, Due to All of the Above	2	12
Yes, Compromised Position	4	23
Yes, Comparable Position	1	6
Working - Comparable Position (N=1) Problems?		
Yes, Cognitive Problems	1	6
Working - Compromised Position (N=4) Problems?		
Yes, Cognitive Problems	2	12
Yes, Physical Problems	1	6
Yes, All of the Above	1	6
School Currently		
No, Not Due to Head Injury	14	82
No, Due to Cognitive Problems	3	18
Home-maker Currently		
No, Not Due to head Injury	14	82
Yes, Compromised Position	2	12
Yes, Comparable Position	1	6
Home-maker Comparable Position (N=1) Problems?		
Yes, Physical Problems	1	100
Home-maker Compromised Position (N=2) Problems?		
Yes, Cognitive Problems	1	50
Yes, All of the Above	1	50
WORK STATUS CODE		
1 = Unemployed	10	59
2 = Compromised	5	29
3 = Comparable With Problems	2	12
4 = Comparable Without Problems	0	0

Table 7 (Continued)

Functional MRI Group (HI2)

WORK STATUS

	Frequency	Percent
Working Currently		
No, Not Due to Head Injury	1	6
No, Due to Behavioral Problems	1	6
Yes, Compromised Position	1	6
Yes, Comparable Position	15	82
Working - Comparable Position (N=15) Problems?		
No Problems	13	88
Yes, Physical Problems	1	6
Yes, Behavioral Problems	1	6
Working - Compromised Position (N=1) Problems?		
Yes, Problems due to all the above	1	100
School Currently		
No, Not Due to Head Injury	17	94
No, Due to Cognitive Problems	1	6
Home-maker Currently		
No, Not Due to head Injury	17	94
Yes, Comparable Position	1	6
Home-maker Comparable Position (N=1) Problems?		
No Problems	1	100
WORK STATUS CODE		
1 = Unemployed	1	6
2 = Compromised	1	6
3 = Comparable With Problems	2	11
4 = Comparable Without Problems	14	77

inability to return to work were cognitive problems: 5 (29%), and physical problems: 2 (12%). Of employed subjects in HT2, only 1 (6%) reported functioning in a compromised position as compared to 4 (23%) of the employed HT1 subjects. At the time of initial referral, only 1 (6%) of HT1 subjects were functioning in comparable positions (relative to premorbid levels) as compared to 15 (82%) of HT2 subjects. These differences strengthen the argument for subgrouping MHI patients based on functional status in spite of their equivalent severity and neurological history.

REACTION TIME DATA COLLECTION

HIVE RT latency for correct responses were generated as a function of three trial blocks consisting of 50 target responses each. RT latency was also scored for each of the five randomized ISI values consisting of 30 target responses each. Reaction times were measured with msec accuracy. Reaction times less than 100 msec were deleted from the computation of means and SD's, but recorded for review. Reaction time accuracy (number of correct responses, errors of omission, errors of commission) were presented as a function of trial block and ISI. An error of omission was scored for each target missed, while a commission error (false alarm) was scored when a response was made to a non-target stimuli. Omissions were defined as the absence of a response within the amount of time provided between two successive stimuli. All errors of omission by definition exceed 1500 msec, which is the value of the smallest ISI. Total accuracy and latency scores (mean and SD) were calculated for correct responses per subject. Latency was scored for false alarm

errors as a function of block and ISI. For the ORM, RT mean and SD was calculated for the twelve response trials for each subject.

REACTION TIME RESULTS

Subgrouping Analysis - HIVE and ORM Summary scores

The first series of analyses with RT data explored the validity of subgrouping MHI subjects based on functional status and the potentially misleading effects of combining the subgroups in between group analysis. Comparisons were performed with summary RT measures between the combined MHI group and controls, and between the three groups to determine a) if differences were apparent, b) if differences were consistent in direction with the above mentioned affective and functional variables, and c) the extent to which the combined analysis accurately represented the standing of each group. To answer these questions, analysis of variance and follow-up comparisons (Scheffe) were performed for the total summary latency and error scores for the HIVE and the ORM RT. Initial comparison between the combined MHI group and controls on the HIVE revealed that MHI patients were significantly slower (HT M = 422.4 msec, Control M = 332.2 msec, $F(1,49) = 6.2$ $p<.05$) and more variable (HT SD = 115.6 msec, Control SD = 55.6 msec, $F(1,49) = 5.4, p<.05$) in reaction time than control subjects. Consistent with the subgrouping hypothesis, further analysis between the three groups revealed that HT1 subjects were slower and more variable than both HT2 subjects and controls, with no significant differences obtained between HT2 subjects and controls: (HT1 M = 482.6 msec, HT2 M = 365.6 msec, Control M = 332.2), $F(2,48) = 8.5$, $p<.01$; HT1 SD =

157.9, HT2 SD = 75.6 Control SD = 55.6, $F(2,48) = 7.9$ $p<.01$ on the HIVE Continuous RT test. The HIVE results suggest that combining HT1 and HT2 subjects in analysis falsely represents the HT2 group as impaired, due primarily to the performance of the dysfunctional subgroup. In the case of the ORM RT test, significant differences on the ORM SD were masked when comparing the combined MHI and control subjects $F(1,48) = 3.6$, $p>.05$. Yet subgrouping analysis revealed that HT1 subjects were both slower (HT1 M = 343.4, Control M = 200.9), $F(2,47) = 5.8$, $p<.01$; and more variable than both HT2 and controls subjects (HT1 SD = 81.0, HT2 SD =43.1, Control SD = 37.4), $F(2,47) = 6.3$, $p<.01$ on the ORM Variable RT test.

Overall, the lack of significant difference between functional and control subjects on RT variables suggests that the combined analysis is misleading. Dysfunctional MHI patients are significantly more impaired in their RT speed and their ability to maintain a consistent level of RT speed than both functional MHI patients and control subjects. Subsequent analyses were based on the three separate groups.

Error Analyses

There was a significant difference between HT1 and control subjects on total number of correct responses, M = 141.5 versus M = 149.9 respectively, $F(2,48) = 4.3$, $p<.02$. This is indicative of a greater number of omission errors in HT1. There was no significant difference between HT2 subjects and control subjects in number of correct response. Although total number of false alarms on the HIVE were greater for HT1 subjects (M = 10.8) as compared to HT2 (M =

7.6) and Control subjects (M = 7.1), these differences were not significant $F(2,48) = 1.2$, $p = .3$.

Correlational Analyses between RT and non-RT variables

The relationship between summary HIVE variables and degree of dysfunction within the combined MHI group was explored using correlational analyses (Spearman) between RT Mean, SD and PCL, Cognitive ADL Checklist, and level of compromise in work status. As anticipated, there was a significant relationship between Mean RT and severity of postconcussional symptoms (PCL): $r = .43$, $p<.01$ and between mean RT and work status: $r = .48$, $p<.01$. Patients with slower RT scores were more symptomatic and in a more compromised work position as compared to premorbid levels. There was no significant relationship between Mean RT and number of symptoms reported, or severity on the Cognitive ADL Checklist: $r = .22$, $p>.05$, $r = .20$, $p>.05$ respectively. SD RT was positively correlated with PCL: $r = .34$, $p<.05$ as well as number of attentional symptoms reported on the Cognitive ADL Checklist: $r = .31$, $p<.05$. Individuals who were more variable in RT latency complained of a greater number of attentional symptoms and more severe postconcussional complaints. There was no relationship between SD RT and work status, or severity on the Cognitive ADL Checklist: $r = .29$, $p>.05$, $r = .27$, $p>.05$ respectively.

In order to determine whether depressed HT patients were slower than non-depressed patients, a Mann-Whitney U test was performed on Mean HIVE RT latency between subjects diagnosed as depressed vs. non-depressed regardless of subgroup membership. Using a T score

greater than 60 on the MAACL-R Depression scale, 60% of HT1 and 35 % of HT2 subjects met the criteria for depression. The differences in RT latency for depressed patients as compared to non-depressed patients were not significant $U = 125 < 179$, $p>.05$. These results indicate that depression per se is not responsible for an increase in RT latency. The performance of depressed MHI patients was not more impaired than the performance of non-depressed MHI patients.

The relationship between severity of depression and RT was next explored through correlational analyses between RT mean and SD and BDI total score. There was a significant relationship between HIVE SD and BDI, $r = .42$, $p<.01$ within the combined MHI group. The correlation between HIVE Mean and BDI was not significant, $r = .32$, $p=.06$. Patients who were more severely depressed tended to more variable in RT latency.

Sensitivity Hypothesis: A comparison between HIVE and ORM

The second level of RT exploration concerned the sensitivity of the HIVE versus the ORM RT in correctly classifying group membership. Optimal cutting scores were chosen to maximally separate the three groups. An impairment criterion of 1.5 SD above the Control group's mean corresponded to the optimal cutting score for both HIVE and ORM, Mean and SD. Table 8 presents the percent correctly classified in each group for the HIVE Mean and HIVE SD as a function of normal control group RT scores. Table 9 presents the percent correctly classified using ORM VRT Mean and SD.

As indicated in tables 8 and 9, a comparison between ORM and HIVE Mean revealed a greater number of HT1 patients correctly

Table 8

Identification of HT1, HT2 and Controls Using Optimal Cutting Scores on HIVE

Groups	Mean (msec)			SD (msec)		
	< 332	332-374	> 375	<55	56-73	>74
HT1 (N=17)	0%	29%	71%	6%	35%	65%
HT2 (N=18)	17%	61%	22%	22%	39%	28%
Controls (N=16)	44%	56%	0%	50%	44%	6%

Table 9

Identification of HT1, HT2 and Controls Using Optimal Cutting Scores on ORM

Groups	Mean (msec)			SD (msec)		
	< 200	201-237	> 237	<37	38-64	>65
HT1 (N=17)	0%	38%	62%	31%	12%	56%
HT2 (N=18)	17%	39%	44%	56%	33%	11%
Controls (N=16)	50%	44%	6%	63%	31%	6%

classified as impaired (true positives) using the HIVE Mean (71%) as compared to the ORM Mean (62%). None of the control subjects as compared to 6% were incorrectly classified as impaired (false positives) using the HIVE versus ORM Mean respectively. Based on the group RT value for total mean on both of these tests, the HT2 group performed in the intermediate range between the other two groups. Using the same optimal cutting scores, a greater number of HT2 patients were classified as performing within 1.5 SD above the mean on the HIVE (61%) vs the ORM (39%).

For SD RT, a greater number of HT1 patients were correctly classified as impaired using the HIVE SD (65%) versus ORM SD (56%). While both tests were equally good (6%) at minimizing the incidence of false positives among control subjects using the measure of variability, a greater number of HT1 subjects were incorrectly classified as "normal" (false negatives) on the ORM SD (31%) as compared to only (6%) on the HIVE SD. These results indicate that the CRT is better able to separate the groups and predict group membership than the discrete trial ORM test. Within each test, the mean is a better predictor of group membership than the SD.

HIVE ANALYSIS

BLOCK AND ISI EFFECTS

A three factorial double repeated measures Multivariate Analysis of Variance (MANOVA) was performed using the two HIVE RT dependent variables: (mean and SD) to investigate the Block by Group by ISI effect. The use of such a statistic is warranted when two dependent variables (DV) are believed to be correlated. The MANOVA

considers both DV's simultaneously. It allows for the detection of main effects and interactions amongst the three factors, while controlling type one error rate. Table 10 presents the results of this analysis. Using MANOVA, all main effects were significant as well as a significant block by ISI interaction. To further explore the basis for these results, separate three way univariate factorial ANOVA's were performed for each dependent variable separately. These results are presented in tables 11 and 12.

The significant group effect (collapsed across ISI and BLOCK) occurred for both mean $F(2,47) = 8.0$, $p<.001$, and SD, $F(2,47) = 9.0$, $p< .001$. Post - hoc multiple comparisons were performed using the Tukey - HSD procedure. HT1 was significantly different ($p<.05$) from both HT2 and controls on both mean and SD. Dysfunctional patients had significantly slower and more variable RT's than both functional patients and control subjects. There were no significant differences between the functional and control subjects for mean or SD RT.

The significant block effect (collapsed across group and ISI) occurred for mean RT only, $F(2,94) = 10.4$, $p<.001$. Post - hoc comparisons using Tukey - HSD revealed significant differences between all three blocks. As indicated in figure 1, all subjects were fastest on Block 1, became progressively slower on block 2, and were slowest on block 3. While mean RT increased over blocks, there was no significant increase in variability (Figure 2). While there was a trend towards a block by group interaction (the HT1 patients showed the greatest decrement across blocks), this analysis failed to reach significance $F(4,94) = 2.1$, $p = .08$. Based on these

Table 10

Multivariate ANOVA Summary Table

Source	Value	Hypoth. df	Error df	F	p
Group	.39578	4	90	4.452	.002
Group x Block	.12593	8	184	1.448	.179
Block	.30948	4	184	7.118	.000
Block x ISI	.10352	16	748	2.420	.001
ISI	.21321	8	372	4.957	.000
Group x ISI	.0712	16	372	.827	.654
Group x Block x ISI	.0710	32	748	.830	.736

Table 11

Univariate ANOVA Summary Table - Mean RT

Source	SS	df	MS	F	p
Group within cells	9303805.66	47	197953.31		
Group	3155346.65	2	1577673.3	7.97	.001
Block within cells	438993.73	94	4670.15		
Block	96951.75	2	48475.87	10.38	.000
Group x Block	39766.10	4	9941.52	2.13	.083
ISI within cells	291086.01	188	1548.33		
ISI	41743.56	4	10435.89	6.74	.000
Group x ISI	8450.13	8	1056.27	.68	.707
Block x ISI within cells	1107384.73	376	2945.17		
Block x ISI	33422.13	8	4177.77	1.42	.187
Group x Block x ISI	30623.61	16	1913.98	.65	.842

Table 12

Univariate ANOVA Summary Table - SD RT

Source	SS	df	MS	F	p
Group within cells	2712194.16	47	57706.26		
Group	1034414.55	2	517207.28	8.96	.001
Block within cells	295463.81	94	3143.23		
Block	1354.03	2	677.02	.22	.807
Group x Block	9027.30	4	2256.83	.72	.582
ISI within cells	488659.31	188	2599.25		
ISI	9396.33	4	2349.08	.90	.463
Group x ISI	31223.01	8	3902.88	1.50	.159
Block x ISI within cells	2016482.40	376	5362.99		
Block x ISI	56433.67	8	7054.21	1.32	.234
Group x Block x ISI	41755.90	16	1913.98	.49	.953

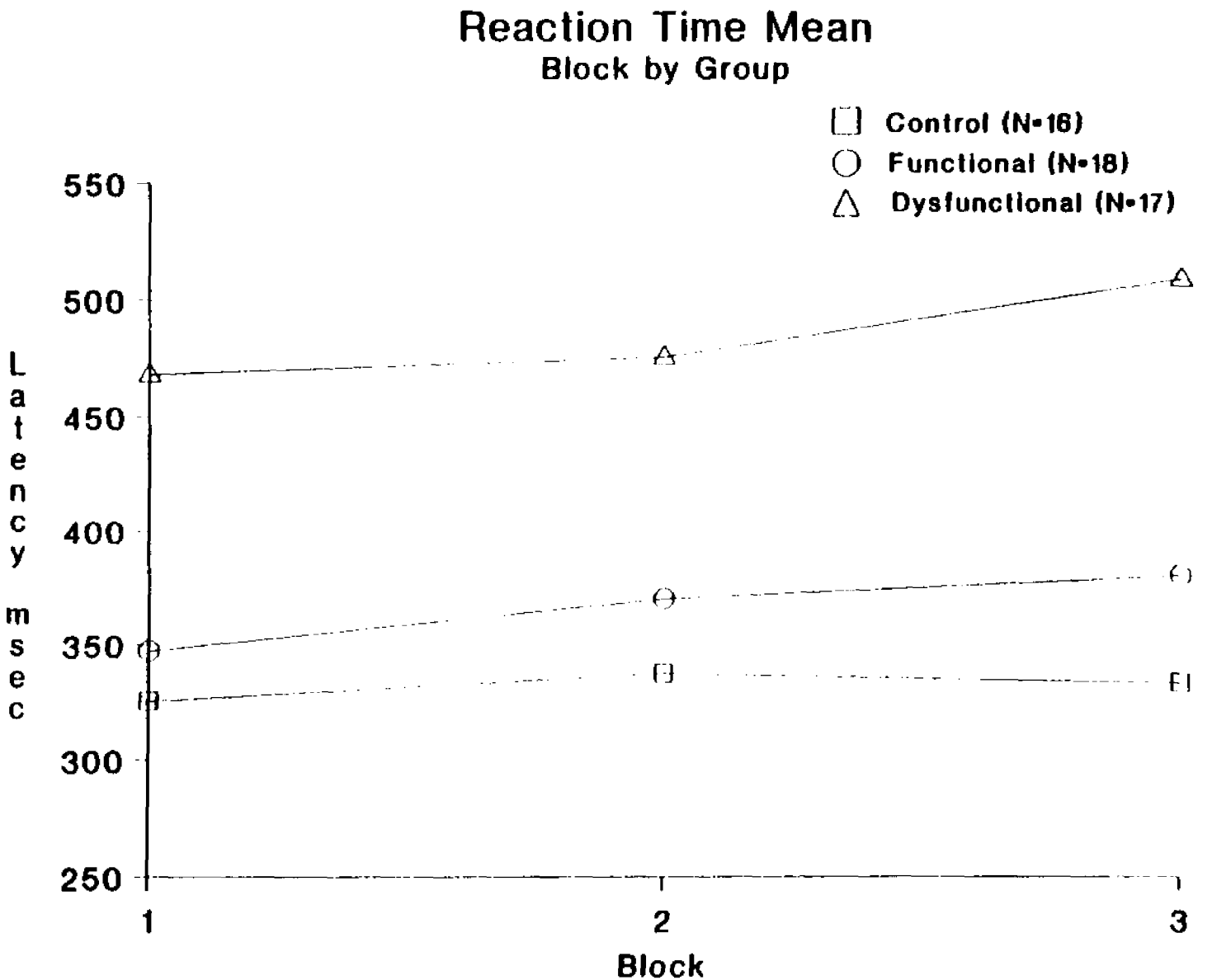
Reaction Time Mean
Block by Group
Control (N=16)
Functional (N=18)
Dysfunctional (N=17)
550
500
450
400
350
300
250
Latency msec
1
2
3
Block

Figure 1.

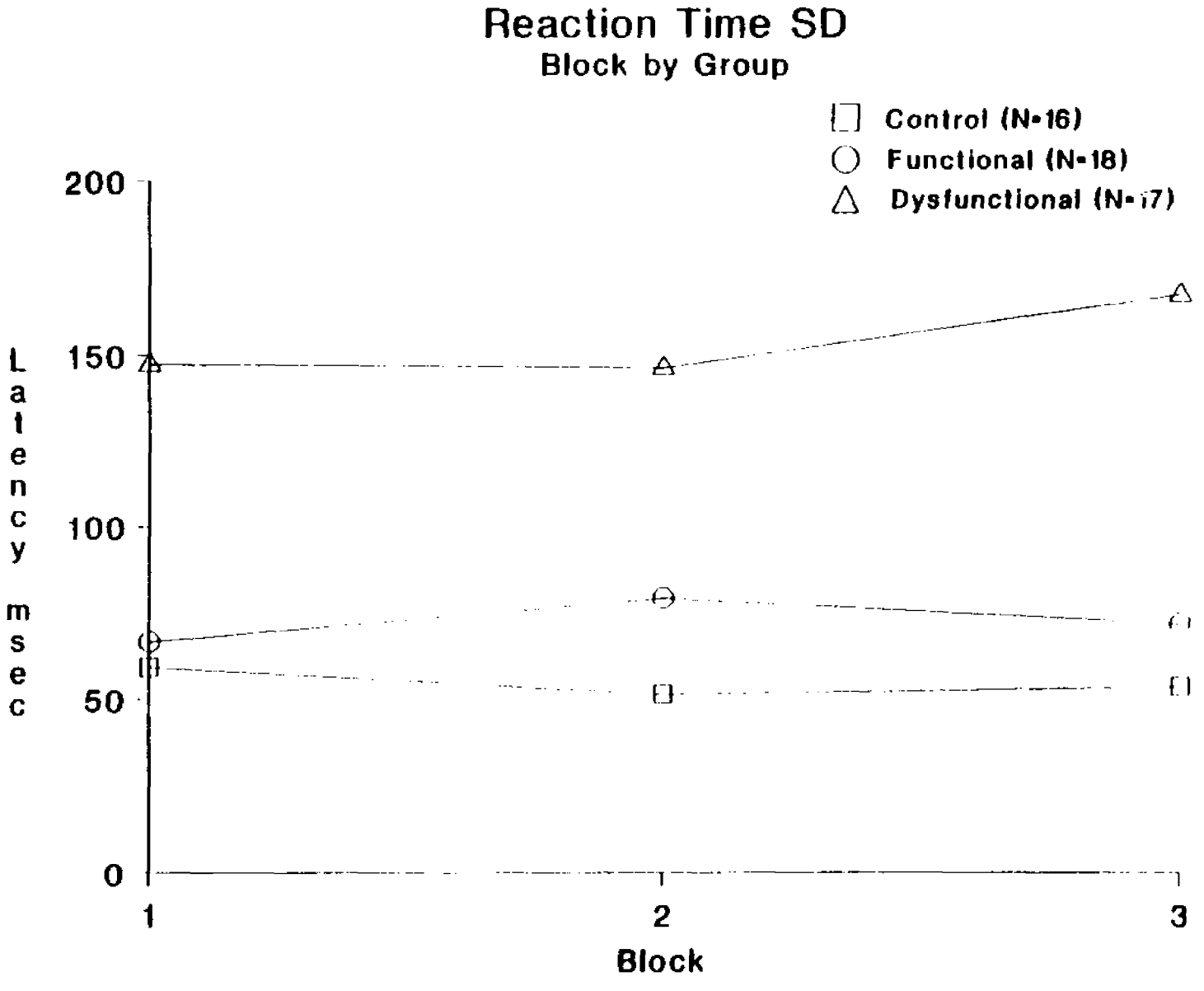
Reaction Time SD
Block by Group
Control (N=16)
Functional (N=18)
Dysfunctional (N=17)
200
150
100
50
0
Latency msec
1
2
3
Block

Figure 2.

univariate results, the HT1 patients could be categorized as consistently inconsistent over time.

Univariate factorial follow-up analysis on the significant main effect for ISI, revealed a significant effect for mean RT only, $F(4,188) = 6.7$, $p<.001$. Post - hoc comparisons using Tukey - HSD revealed significant differences between ISI 1 and 3, 1 and 4, and 1 and 5; 2 and 3, 2 and 4, and 2 and 5. Irrespective of group membership, all subjects' mean RT's were slowest on the shortest ISI values (1.5 and 2 sec), and fastest on the longest ISI values. Results for mean RT latency for ISI by group is presented in Figure 3. The interaction was not significant. There was also no significant ISI effect for SD displayed in Figure 4.

While MANOVA revealed a significant block by ISI interaction, this effect was neither seen for RT Mean nor RT SD alone, as indicated in the univariate follow-up ANOVA's presented in tables 11 and 12. These results suggest that the interaction is only detected when the two dependent variables are entered into analyses simultaneously, due to their high correlation. The lack of differences on follow-up analysis negate the further exploration of this finding.

ERROR ANALYSIS: FALSE ALARMS MEAN

Initial analysis with total number of false alarm errors between the MHI subgroups and control subjects revealed no significant difference in error rate between groups. Additional analysis was performed for false alarm mean latency for block (figure 5) and ISI (figure 6) between groups. As indicated in

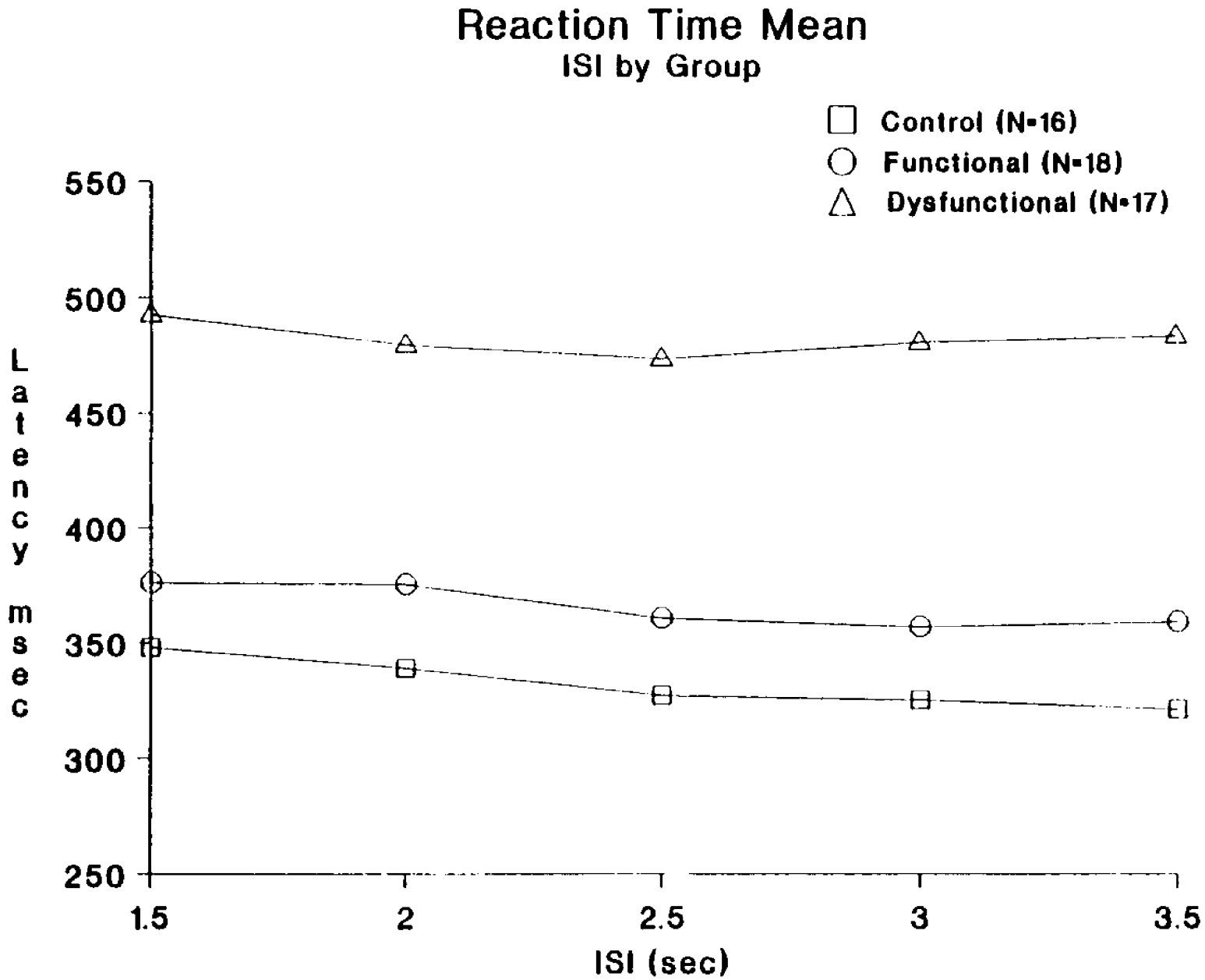
Reaction Time Mean
ISI by Group
Control (N=16)
Functional (N=18)
Dysfunctional (N=17)
550
500
450
400
350
300
250
Latency msec
1.5
2
2.5
3
3.5
ISI (sec)

Figure 3.

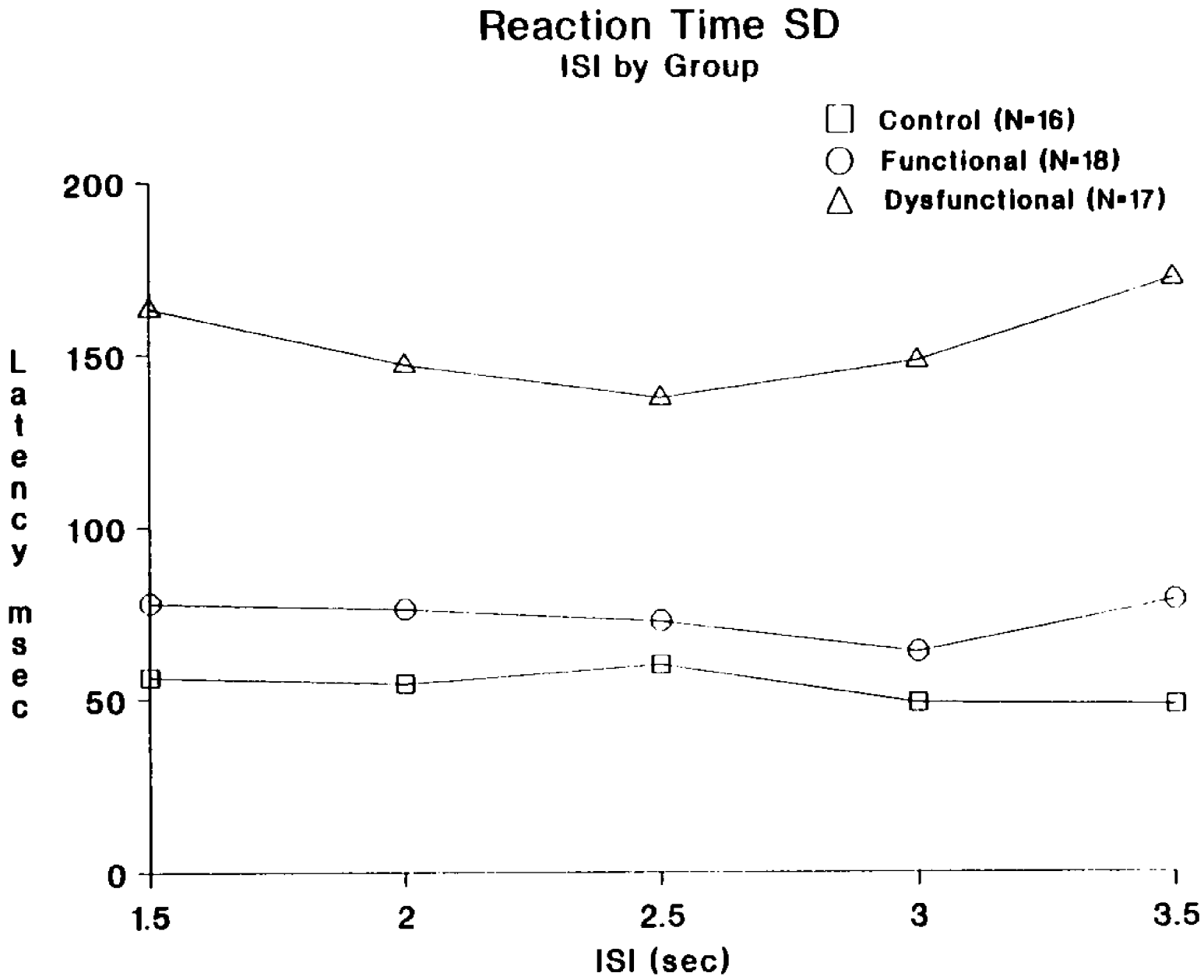
Reaction Time SD
ISI by Group
Control (N=16)
Functional (N=18)
Dysfunctional (N=17)
Latency msec
200
150
100
50
0
1.5
2
2.5
3
3.5
ISI (sec)

Figure 4.

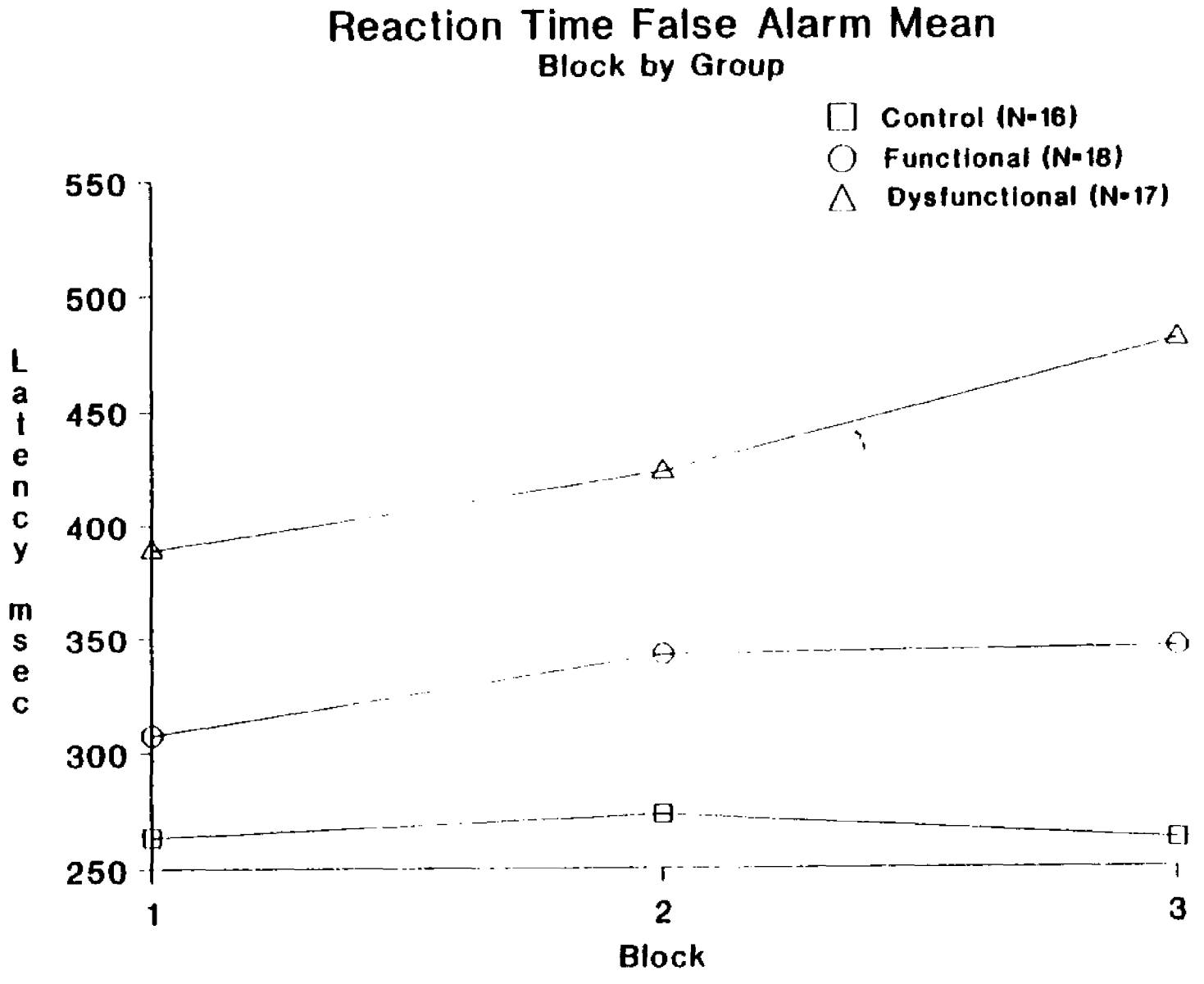
Reaction Time False Alarm Mean
Block by Group
Control (N=16)
Functional (N=18)
Dysfunctional (N=17)
550
500
450
400
350
300
250
Latency msec
1
2
3
Block

Figure 5.

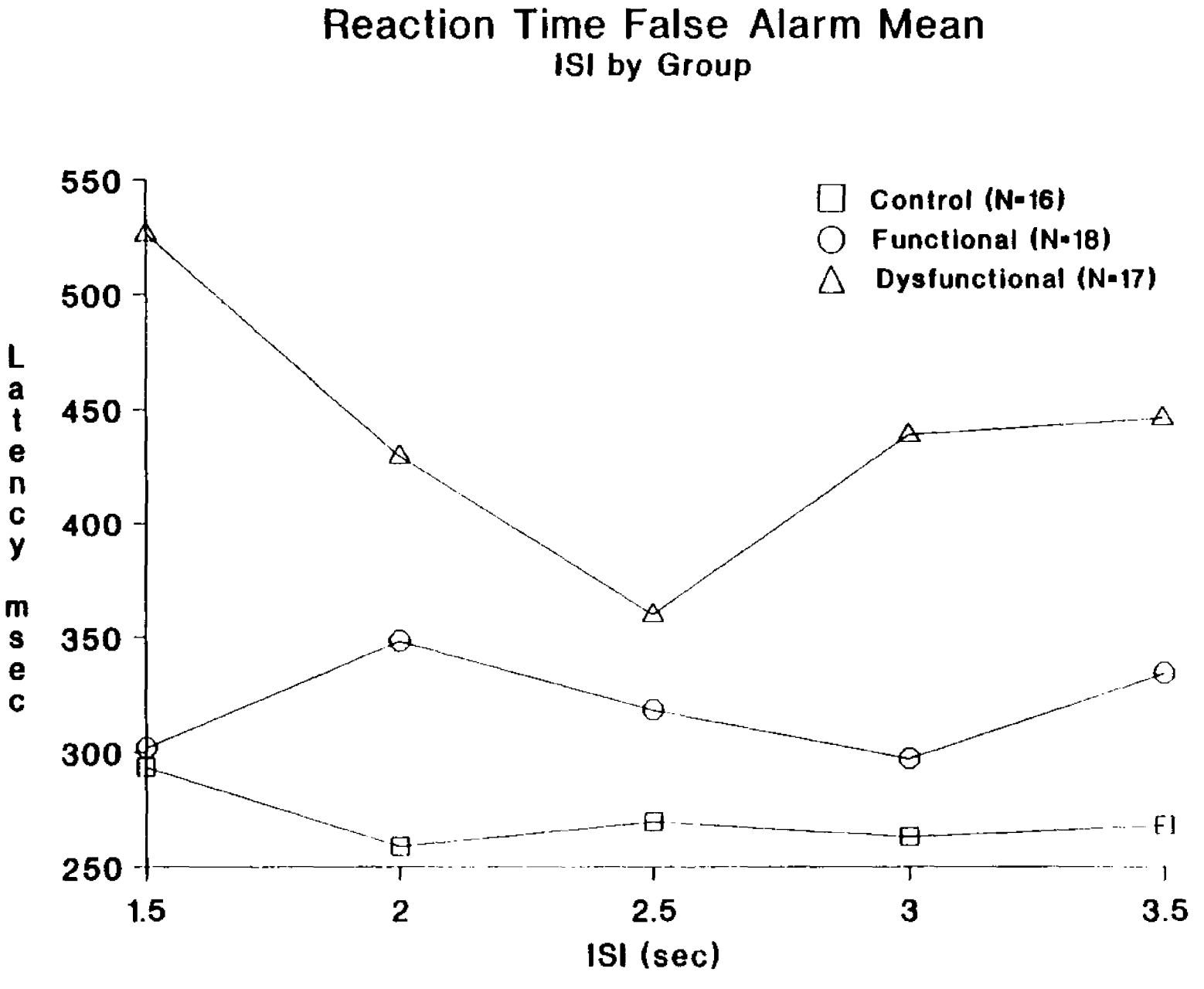
Reaction Time False Alarm Mean
ISI by Group
Control (N=16)
Functional (N=18)
Dysfunctional (N=17)
Latency msec
550
500
450
400
350
300
250
1.5
2
2.5
3
3.5
ISI (sec)
FI

Figure 6.

Tables 13 and 14, the two way ANOVA for block by group, and ISI by group failed to reach significance. There were no differences between groups in false alarm speed.

Follow-up correlational analysis revealed no significant relationship within the HT1 group or combined MHI groups between number of false alarms and response omissions: r = .03, p>.9; r = .20, p>.2 respectively.

ERROR ANALYSIS: OMISSIONS

Initial analysis revealed a significant difference between groups for total number of correct responses indicating a greater tendency towards lapses of attention in the dysfunctional group. In order to determine whether attentional lapses were susceptible to time on task increases or fatigue, a two - way analysis of variance for groups by block was performed. As indicated in figure 7, there was a significant group by block interaction, $F(4,96) = 2.7$, $p< .05$. Inspection of error rate within the dysfunctional group (figure 9) revealed a progressive increase in omission errors across blocks: number of correct response M = 48.2, M = 47.3, M = 45.9, respectively for block one, two and three. Of the four patients who demonstrated errors of omission within block one, all had an equal or greater number of omissions in block three. Of the 13 patients who did not show errors of omission in block one, 6 did show omission errors by block three. For block three, mean number of correct responses was significantly different between HT1 and both other groups: HT1 M =45.9, HT2 M = 49.6, Control M = 49.9, $F(2,48)$ = 4.0, p =.02. This finding demonstrates that dysfunctional patients

Table 13

False Alarm ANOVA Summary Table
Block x Group

Source	SS	df	MS	F	p
Group within cells	3163855.41	27	117179.83		
Group	409302.98	2	204651.49	1.75	.194
Block within cells	269209.17	54	4985.36		
Block	12684.61	2	6342.30	1.27	.288
Group x Block	12196.04	4	3059.01	.61	.656

Table 14

False Alarm ANOVA Summary Table
ISI x Group

Source	SS	df	MS	F	p
Group within cells	4569772.76	13	351520.98		
Group	973918.17	2	486959.08	1.39	.285
ISI within cells	714435.33	52	13739.14		
ISI	25123.56	4	6280.89	.46	.767
Group x ISI	62826.94	8	8856.60	.64	.737

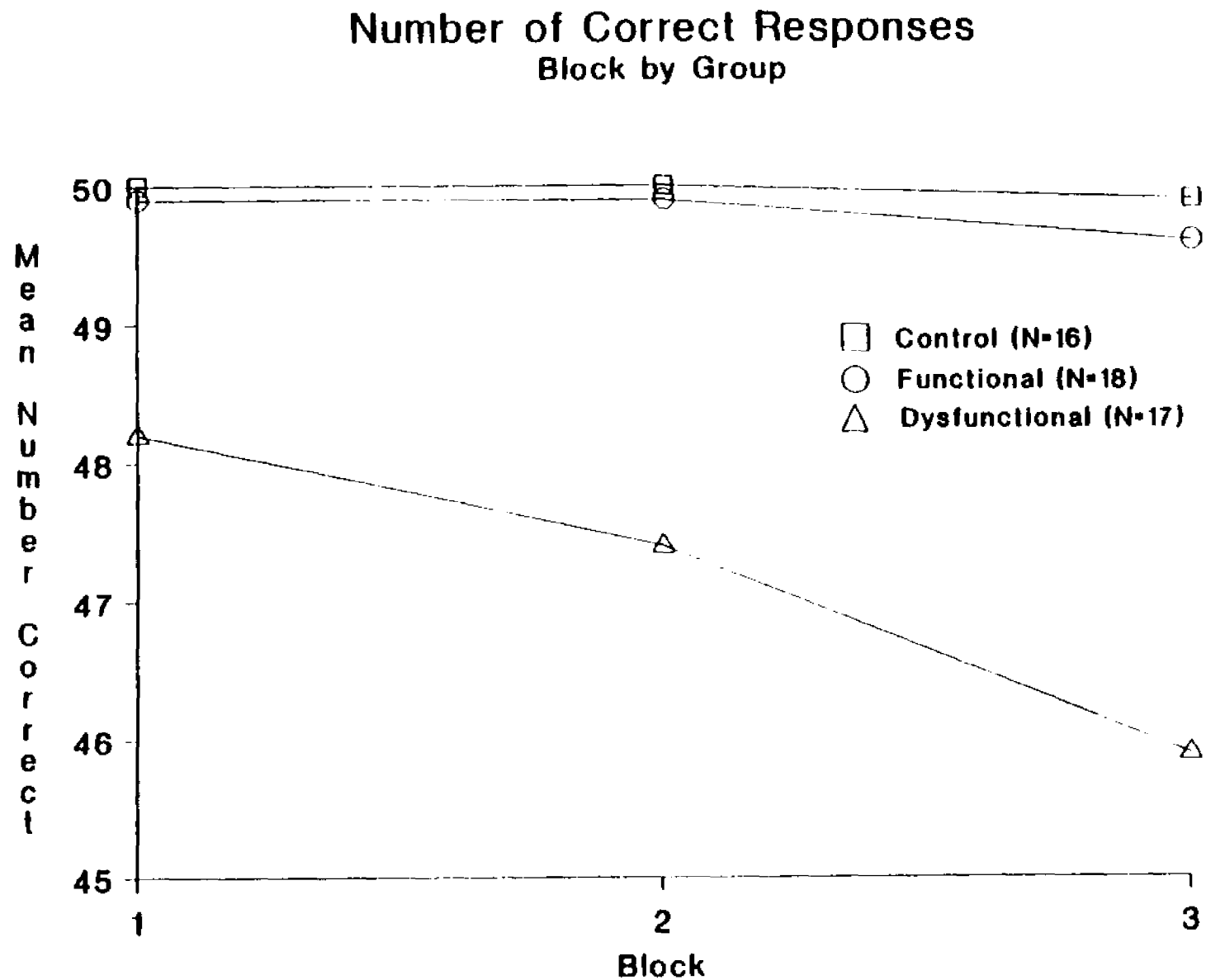
Number of Correct Responses
Block by Group
Mean Number Correct
50
49
48
47
46
45
1
2
3
Block
Control (N=16)
Functional (N=18)
Dysfunctional (N=17)

Figure 7.

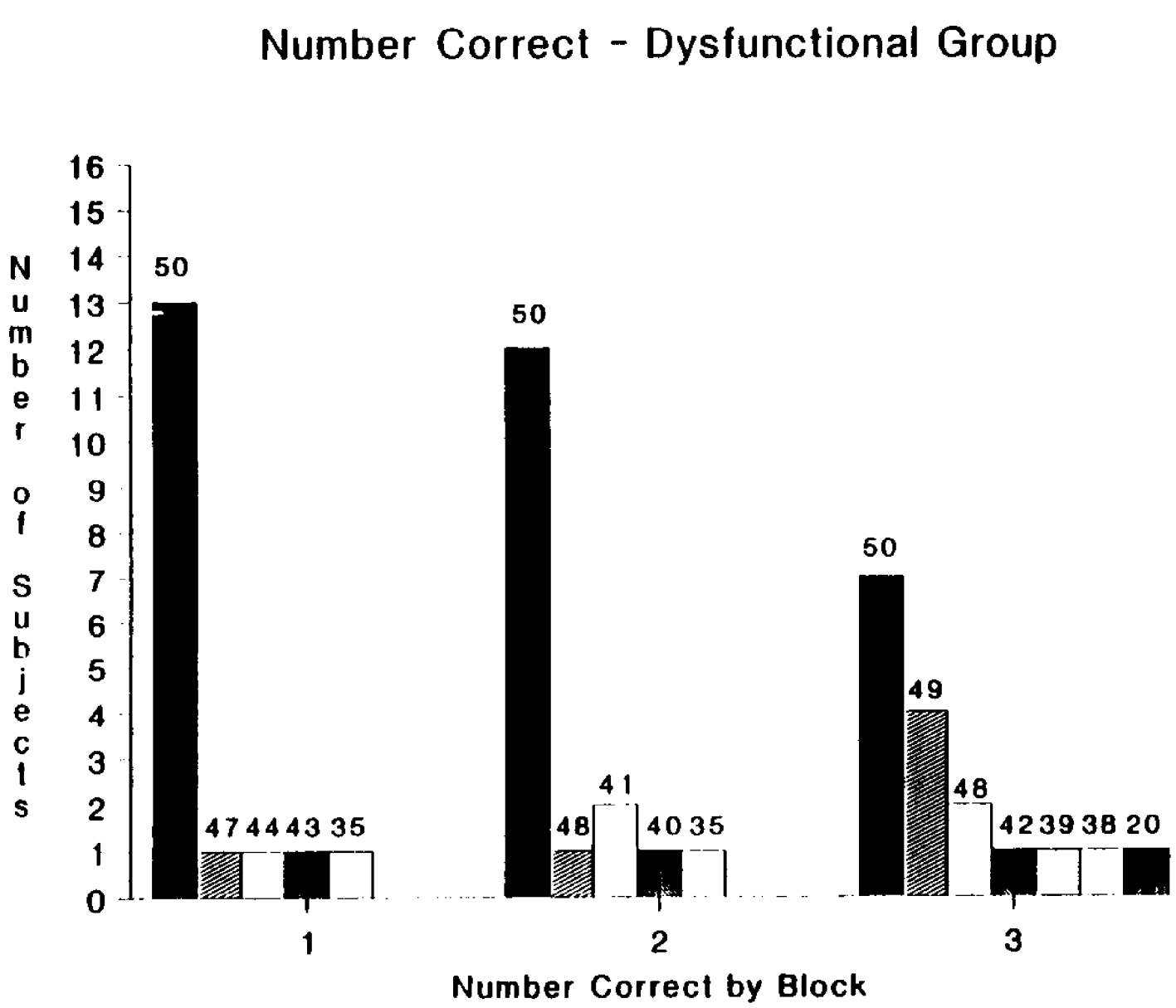
Number Correct - Dysfunctional Group
Number of Subjects
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
50
47 44 43 35
50
48
41
40 35
50
49
48
42 39 38 20
1
2
3
Number Correct by Block

Figure 9.

are sensitive to fatigue effects, which are manifested as errors of omission.

Susceptibility to variations in inter-stimulus interval was analyzed to determine if differences in error rate between groups were evenly distributed between the shortest and longest ISI values. A group by ISI ANOVA revealed only a group main effect as discussed earlier. As indicated in figure 8, the lack of increase in lapses of attention across ISI, and absence of an interaction, suggests that wandering of attention is not related to deficits in response initiation.

The relationship between errors of omission and additional performance variables was examined in a series of correlational analysis. The number of errors of omission within the HT1 group were significantly positively related to RT latency and variability: $r = .65$, $p<.001$ with Mean; $r = .80$, $p<.001$ with SD. The greater the number of errors of omission, the slower and more variable the latency of correct responses. For the combined MHI group, lapses of attention were significantly correlated with severity of postconcussional symptoms as measured by the PCL: $r = .31$, $p<.05$.

There was no relationship between the number of errors of omission and degree of depression (BDI), age, duration of LOC, total number of HIVE false alarms or complaints on the Cognitive ADL Checklist within the HT1 group or the combined MHI group.

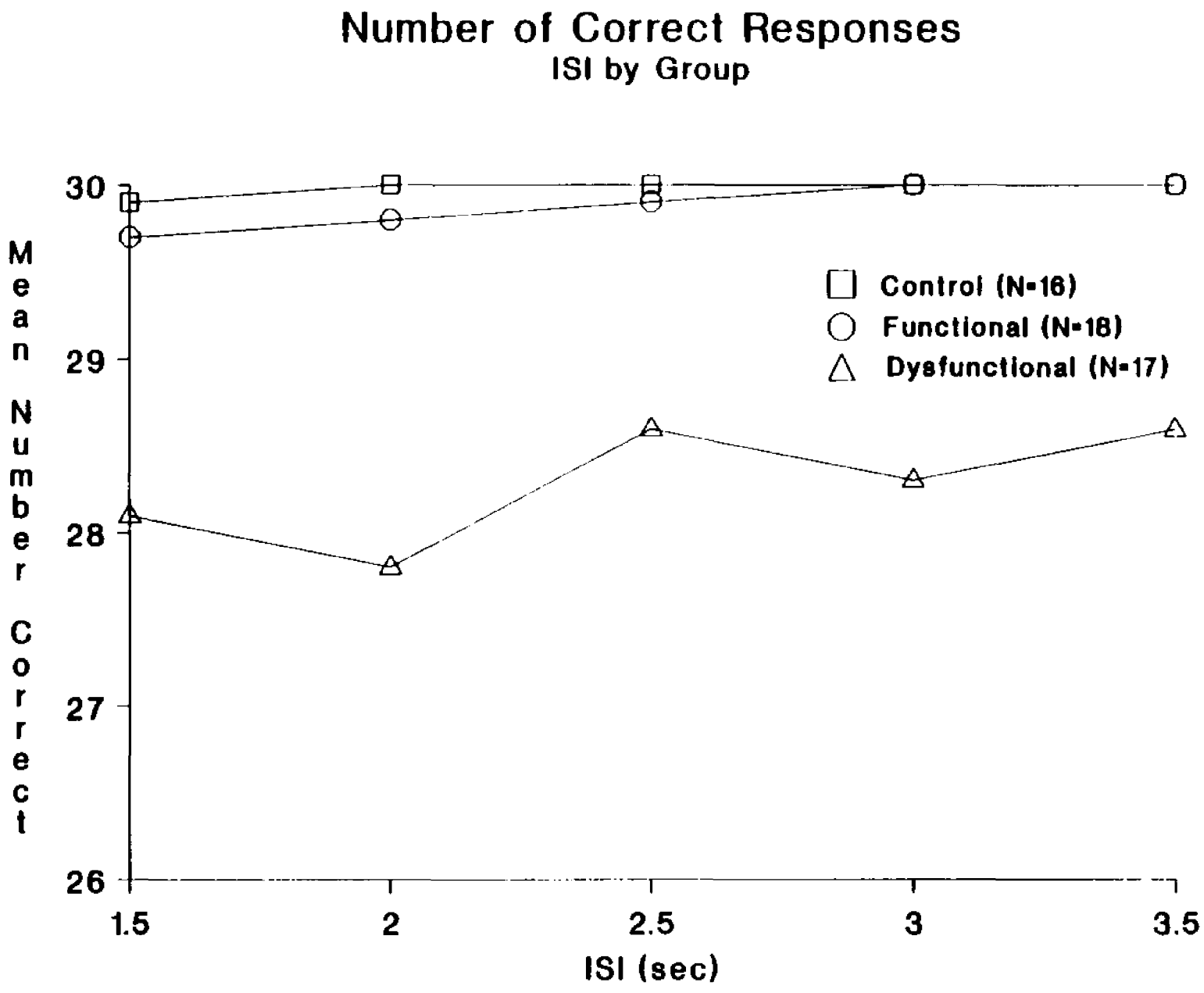
Number of Correct Responses
ISI by Group
Mean Number Correct
30
29
28
27
26
1.5
2
2.5
3
3.5
ISI (sec)
Control (N=16)
Functional (N=16)
Dysfunctional (N=17)

Figure 8.

EXTREME RT DIFFERENCES

An analysis of the fastest RT's was performed to answer the question of whether MHI patients were capable of responding with "normal" RT latencies. In order to compare the fastest RT's from among correct responses (rather than impulsive responses), the RT value corresponding to the 10th percentile was chosen for each subject. The 10th percentile RT value is unlikely to be due to impulsive responses (based on the observed false alarm error rate of 5 - 7 percent for the control and HT1 group respectively). Group mean 10th percentile values were compared in an analysis of variance. The results of this analysis indicated that the fastest reaction time latencies produced by HT1 patients were significantly slower than that of control subjects HT1 M = 323.4, HT2 M = 285.2, Control M = 266.0, $F(2,47) = 6.5$, $p<.01$. There were no significant differences between the fastest RT's of HT1 and HT2 subjects, or between HT2 and controls. These findings are consistent with those results obtained by Bruhn and Parsons (1971) after brain damage, indicating a failure to demonstrate a capacity for normal information processing. While dysfunctional patients are indeed more variable than control subjects, their demonstrated slowing in speed of reaction time cannot be solely accounted for by increases in response variability.

Final Exploratory HIVE analysis: HT2 versus Controls

While actual RT Mean and SD RT appeared consistently greater for the HT2 subjects as compared to controls, this impression could not be validated using the conventional between group analyses.

There was a possibility that a difference between the functional and control groups was masked by the greater error variance of the HT1 group. In order to determine if a small but significant difference in HIVE latency could be detected between HT2 and control subjects, a follow-up ANOVA was performed between these two groups without the HT1 group. Results of ANOVA was significant for HIVE total Mean (HT2 M = 365.6, Control M = 332.2 $F(1,32) = 6.1$, $p<.05$ and HIVE total SD (HT2 M = 75.6, Control M = 332.2 $F(1,32) = 4.9$, $p<.05$. This final analysis revealed that as a group, functional patients exhibit a small magnitude of impairment which is detectable in a direct comparison with normal control subjects.

DISCUSSION

Effects of Subgrouping

Objective links were established in this study between the subjective complaints by post MHI patients of persisting symptoms associated with functional disability, and RT variables. MHI patients identified as dysfunctional based on clinical interview were significantly slower, more variable, and more susceptible to attentional lapses on a CRT than patients identified as functional. These differences were consistent in direction with the severity of persisting postconcussional complaints, failure to return to pre-injury vocational levels, attentional complaints in every day life, and degree of emotional distress. Experimental and subjective differences between these subgroups were demonstrated long after neurological recovery had presumably plateaued (average time post injury was 2.5 years for combined MHI group). Moreover, these subgroups did not differ on any neurological indices of severity or relevant demographic variables. These findings are underscored given the prevalence of complaints of attentional deficits in this population, and the lack of sensitivity of many conventional assessment techniques in validating such deficits.

The fact that RT testing discriminated between patients differing in the frequency and severity of persisting postconcussional symptoms, and ability to return to premorbid vocational levels argues in favor of subgrouping MHI patients based on these complaints. Failure to consider the relationship between functional status and objective test performance may explain some of the conflicting reports in the literature on the persistance of

cognitive deficits in this population. A number of studies have failed to reveal differences between MHI patients and control subject using large group designs which obscure performance of a clinically impaired subgroup. Categorizing subjects based on functional status in this study served as a valid methodological approach for understanding RT functioning after MHI. In the case of the CRT, combined analyses between all MHI subjects and control subjects falsely overstated impairment for the functional group on the HIVE mean and SD due to the performance of the impaired dysfunctional subgroup. Separate analysis between the dysfunctional, functional and control groups did not reveal a difference in performance between the functional and control subjects. Using the discrete trial RT test, combined analysis served to cancel out between group differences on the ORM SD. The more subtle difference between functional and control subjects on HIVE latency was only revealed in a separate exploratory analysis.

The precise nature of the complex inter-relationship between persisting symptomatology, reduced work status, and test performance is difficult to untangle. In this study, increases in RT latency were significantly related to severity of postconcussional symptoms and reductions in work status. Deficits in the ability to maintain a consistent level of speed (intra- individual variability) were related to severity of symptoms, depression, and the number of attentional symptoms reported on the Cognitive ADL checklist. Gronwall and Wrightson, 1974, proposed that deficits in speed of information processing as measured by the Paced Auditory Serial Addition Test (PASAT), were an important factor in the genesis of

the postconcussional syndrome. A reduced rate of information processing could put patients at risk for associated symptomatology (e.g., fatigue and headache when attempting to concentrate) which in turn result in stress and frustration when patients attempt to return to premorbid levels of functioning. It is clinically well established that the persistence of undiagnosed neuropsychological problems long after MHI can lead to failure, frustration, depression and reduced self esteem. Indeed, all of the patients in the dysfunctional group appeared to exhibit this pattern when finally evaluated long after their injury. In this study patients with significant postconcussional symptoms were moderately to severely depressed based on self report interview.

It is well established clinically, that the presence of depression in MHI patients can exacerbate the appearance of neuropsychological deficits. This is particularly true on tests involving speed of information processing, and attention. It is not uncommon to find improvement in selective tests involving these functions when depression resolves. At the same time, some depressed patients perform within normal limits on neuropsychological tests regardless of their depression. In this study, the presence or absence of depression was not a factor in RT performance. Depressed patients were not more impaired in RT than non-depressed patients. On the other hand, severity of depression was significantly related to RT variability. These findings suggest that the higher incidence of depression among dysfuctional patients is not directly responsible for their poor RT performance. Within this group, however, impaired RT performance coexists with a profile

of greater functional impairment, more severe postconcussive complaints, and more severe depression.

Other critical psychological, personality and environmental variables, often interact to determine how a given individual will respond to the persistance of symptoms and to alterations in ability to function. While the impact of these variables were beyond the scope of this investigation, factors such as involvement in litigation (a frequently suspected motivating factor in the continuation or magnification of functional complaints), length of loss of consciousness, CT or MRI documented abnormalities, and age had no significant effect on RT speed.

It is interesting to note that the two head injured groups differed in male to female ratio. The majority of dysfunctional subjects were women (71%) while the majority of functional subjects were men (67%). It is possible that these differences may be explained by differences in subject selection for this study. Subjects in the dysfunctional group were largely self referred while those in the functional group were invited in for evaluation. Women may be more likely to seek outside help for their dysfunction than men post MHI.

Effect of Trial Block and ISI

Both time on task, which determined fatigue level, and length of ISI had a significant effect on performance speed. However, these effects were equivalent across groups. On the CRT, all subjects showed a similar increase in RT latency over time due to fatigue. While there was a trend toward a group by block

interaction (a greater increase in response latency over time for HT1 subjects), this was not significant. Under these testing conditions, the dysfunctional group was not especially more vulnerable to fatigue effects. The lack of a main effect for SD failed to support the hypotheses predicting an increase in intra-individual variability as a function of time on task or increases in ISI length. Subjects' RT latencies, regardless of group membership, did not become progressively more variable over time, nor did subjects demonstrate greater attentional wandering with longer ISI delays. These findings demonstrate that MHI patients are consistently more variable on a CRT test. The overall increase in intra-individual variability for dysfunctional patients reflects a generalized failure to maintain a consistent level of RT speed.

The hypothesis that increases in ISI would reveal deficits in response initiation (slowing) in MHI patients was not demonstrated. In contrast, all subjects became faster with increases in ISI value. On the HIVE, it appeared that readiness to respond peaked on delays greater than 2 secs. for all subjects regardless of group membership. This finding varies from reports in the literature suggesting a positive relationship between ISI and RT in brain injury (McDonald, 1964; Parsons & Bruhn, 1973). The fact that response initiation or execution was facilitated with increases in ISI on this task may be a function of differences in experimental tasks, subject selection and population differences (use of heterogenous brain damage patients vs. MHI patients) in the other studies.

For example, Costa (1962) used a constant RT task and presented three preparatory intervals (interval between warning tone and light stimulus) in consecutive counterbalanced trials. In Parsons and Bruhn's (1973) experiment in which a block by ISI interaction was seen for brain damaged patients, ISI values were not randomized, and the two levels of ISI (2.5 and 4 sec) were presented in counterbalanced order in a constant paradigm across the two blocks. Czuder and Rourke (1970) found RT latency to be directly related to length of preparatory interval (PI) only on a constant discrete trial paradigm in normals but not brain damaged adults, however, time on task and fatigue effects were a major confound on the constant RT (longer PI delays were presented later in the session). Using a variable RT test, the same authors showed that both groups performed significantly more slowly on the 2 sec vs 4, 6 and 8 sec PI. Some studies have suggested that a bimodal distribution may emerge with increases in RT using PI's beyond 4 secs. (Rodnick & Shakow, 1940). While it is possible that increasing the range of ISI interval beyond the 3.5 sec highest value of the current task would have increased RT latencies specifically for the MHI group (an interaction), such a trend was not evident during pilot studies with values of 5 and 6 sec. In this study, varying ISI value failed to reveal a selective deficit in response initiation after MHI.

Evidence for Slowing and Intra-individual Variability

Results of the present study provide evidence for a general slowing of RT latency as the primary deficit for dysfunctional MHI patients. Based on results from the MANOVA, dysfunctional MHI

subjects were slower in speed of processing than both functional and non-head injured subjects across all trial blocks and ISI's. While these patients' RT latencies were more variable, intra-individual variability was likely a secondary characteristic of performance since unlike mean, it was insensitive to fatigue effects or varying ISI delays. Within the HIVE, mean RT was more accurate than intra-individual SD in its ability to correctly classify group membership (decreasing false negatives among HT1 patients and false positives among control subjects). The hypothesis that MHI patients can respond as quickly as normal controls, a finding which is masked by their high RT variability, was not supported. This conclusion is based on the fact that the fastest RT scores of the normal control subjects were significantly faster than those of the dysfunctional patients using the optimal response calculation on the CRT. While dysfunctional patients were indeed more variable than functional and non-head injured adults, the above result suggests that variability was not solely responsible for the slower RT. Rather, there appears to be a shift in the range of RT's for dysfunctional patients suggestive of a generalized slowing for the entire RT distribution. It is possible that the significant difference between the fastest RT scores between groups could have been due to the conservative criteria selected to define the fastest RT from the distribution (10th percentile value). The value was chosen based on the false alarm error rate for the three groups. While the presence of false alarms are believed to be reflective of impulsivity (Sostek, Buchsbaum, & Rapoport, 1980), the rationale for the optimal response calculation as proposed by Bruhn (1970), Bruhn and Parson, (1971),

and Berkson and Baumeister (1967,1972) is that of the fastest true speed of RT after impulsive responses (false starts) are eliminated. For this purpose, it is believed that the 10th percentile value is a valid indicator of the fastest "true" RT's of each group.

While both mean and SD RT were highly correlated in this study, there were interesting differences in how each of these variables correlated with non-RT measures. As indicated earlier, only variability was related to depression and number of symptoms experienced on the Cognitive ADL Checklist. The relationship between variability (not speed) with subjective reports of depression may have some bearing on the clinical manifestation of these problems. Inconsistent performance may have a more distressing effect than a consistent slowing across all tasks or activities. Depression may be intensified by a lack of predictability or control over ones ability to perform at an optimal level. The relationship between variability and the attentional checklist specifically is consistent with the initial objective of this interview. The checklist was developed as an assessment tool designed to reflect the subjects' perception of the functional impact of their performance variability on activities of daily living. The relationship between mean RT (but not variability) and ultimate work status post injury suggests that slowing has a more objective consequence than variability. Indeed, in many pressured work settings, inability to finish tasks quickly and in a timely manner would be expected to have a more obvious and disruptive effect on efficiency and productivity than variability, which appears to have a more subjective consequence.

Sensitivity Hypothesis

A comparison between the two RT methodologies used in this study supports the designation of the CRT as a more powerful screening tool than the discrete trial methodology among MHI patients. The HIVE provided a higher degree of accuracy in discriminating between patients with and without functional complaints and normal controls. The diagnostic sensitivity of the CRT was greater when a single cutting score was used: the percentage of individuals in each group correctly classified was 71 %, 78 %, 100 %, for the HT1, HT2 and Control subjects respectively using the HIVE Mean.

In support of the hypotheses: the HIVE Mean correctly classified a greater number of dysfunctional patients as impaired (true positives) and fewer normal controls as impaired (false positives) than the ORM Mean. A comparison of mean and SD within test revealed that the HIVE Mean was superior to the HIVE SD in both of these elements: there was a greater rate of false positives among normal controls, and fewer true positives among dysfunctional patients using HIVE SD. Overall, there were more misclassifications using the ORM as compared to the HIVE, and more misclassifications using SD as compared to Mean.

It should be noted that even the more sensitive test in this study failed to achieve greater than a 71% accuracy rate in classifying dysfunctional patients using the optimal impairment cutting score set for the respective test. There was a considerable degree of overlap between the RT means of subjects in the functional group and those in the dysfunctional group. Furthermore, overlap

(albeit small) was evident between the RT mean of the fastest dysfunctional patients, and the RT mean of the slowest normal control subjects.

Despite the limitations noted in classifying subjects based on RT mean, this study has demonstrated that the CRT can serve as a clinical diagnostic and assessment tool for patients post MHI. Especially for patients who have become functionally disabled long after a neurologically trivial head injury, it provides the long overdue validation of complaints of problems with sustained attention, rapid information processing, and "maintaining a focus". The value of the CRT probably does not lie in its ability to demonstrate slowing of RT per se, since numerous tests of varying levels of complexity (including the discrete trial RT in this study) have been able to do this. Rather, it is the ability of the CRT to assess the neglected concepts of intra-individual variability, lapses of attention, and fatigue effects, variables with clinical relevance and functional impact, that make it a valuable instrument. Further research during the early states of recovery will determine whether this test can identify those at risk for later dysfunction.

Lapses of Attention

One highly significant finding was the presence of response omissions seen on the CRT for the dysfunctional group which became progressively greater in number as a function of fatigue. Response omissions were extremely rare among control subjects suggesting its presence to be pathognomonic to MHI. The increased frequency of response omissions supports the hypothesis that dysfunctional

patients possess a greater tendency towards lapses of attention than control subjects.

Lapses of attention, as measured in the present study, may be similar to the phenomenon described on vigilance tasks (Buchtell, 1987) where there is a tendency to drift away from the task at hand as the subject experiences drowsiness, or begins thinking of more interesting activities. It can be hypothesized that after MHI, an inability to actively suppress the tendency to drift may result in missing the relevant stimuli as well as slowing of RT. Eventually, fatigue sets in at which point the patient loses the ability to regulate focused attention and inhibit distracting stimuli or thoughts. In normal individuals, the tendency to drift is suppressed to a greater degree. If wandering does occur, it does not occur to the degree necessary to create the missing of relevant information. On the HIVE, at least 1500 msecs would have to pass without a response for a stimulus to be counted as an omission (the shortest ISI value). Apparently, for normal subjects, any wandering that does occur is quickly redirected back to the task within that time limit. Therefore a second problem may be occurring for HT1 patients. That is the inability to redirect attention or refocus attention before such lapses become dysfunctional. This hypothesis may explain the lack of group by block interaction for RT latency and variability, and the significant interaction for response omissions, in spite of their high intercorrelation. Intra-individual variability (reflective of attentional wandering) did not vary as a function of fatigue for any subject. What was different

was the inability of HT1 patients to refocus such attentional wandering once their threshold was exceeded.

The point at which discontrol occurs appears to differ between subjects as well. It is proposed that all individuals have a threshold for suppressing the tendency to drift. This threshold is reduced in HT1 patients, and within this group, there is considerable variability of this threshold. As indicated by the results of this study, those patients who experienced attentional lapses early on (within the first four minutes of the CRT) continued to experience them in greater numbers for the duration of the test. The patients who did not experience attentional lapses early in the task managed to control their occurrence until the last trial block, at which point they too experienced lapses. It is hypothesized that subjects with a higher threshold for fatigue are able to maintain RT efficiency over a longer period of time until their threshold is exceeded. At that time, they too lose the ability to sustain or regulate attention.

Evidence from EEG and EP research may provide a second explanation for this phenomenon. EEG studies in normal sleep deprived adults have linked behavioral evidence of missed signals on vigilance or signal detection tasks to increases in theta and decreases in alpha activity (Groll, 1966; O'Hanlon & Beatty, 1977; Schacter, 1977; Williams, Granada, Jones, Lubin, & Armington, 1962). Van Zomeren, Brouwer, and Deelman (1984) reported a relationship between drowsiness on EEG and omissions on an auditory vigilance task in normals but <u>not</u> severely head injured subjects. While signal detection was reduced in the severely head injured patients,

EEG was relatively stable and alert throughout the vigilance task. Van Zomeren and Brouwer (1985) found that short episodes of lowered alertness using EEG and vigilance testing were no more common in concussed than in control subjects. Some research has accumulated to suggest that desynchronization of EEG as well as the contingent negative variation (CNV) waveform, (a negative shift in EEG following a warning stimulus and preparation to respond) may be quantified during ongoing RT, or information processing tasks in head injured (Curry, 1981) and normal subjects (Loring & Sheer, 1984). Abberations in CNV parameters (amplitude and latency) may be related to degree of impairment in alertness, attention and response readiness (Papanicolaou, 1987) however the CNV is limited to situations where a warning stimulus precedes the target. Additionally, enhancement and attenuation of N1 amplitude has been observed depending on whether a stimulus is attended to or ignored (Naatanen, 1982; Papanicolaou, 1987). While lapses of attention have been linked to EEG abnormalities, these studies have primarily used epileptic patients with evidence of EEG spikes, slow waves and generalized paroxysms of high amplitude (Bruhn, 1970; Hicks & Birren, 1970; Kooi & Hovey, 1957). It would be desirable to simultaneously record CRT and EEG in the future in order to provide objective evidence for phenomena such as lapses of attention and intra-individual variability after MHI.

Fatigue effects on RT performance

In this study, MHI patients were not more vulnerable to fatigue effects than normal control subjects in terms of the degree of

increase in RT latency over time between groups. This lack of an interaction for block by group in terms of RT speed, and the occurrence of a block by group interaction for response omissions is difficult to explain. A deficit in sustained attention would be expected to effect both speed and accuracy equally. In this study, response omissions, speed and variability were highly correlated in MHI patients. The few studies which have specifically investigated sustained attention in HI adults (Brouwer & Van Wolffelaar, 1985; Dencker & Lofving, 1958; Ewing, McCarthy, Gronwall, & Wrightson, 1980) have shown that while patients on the average make more errors and are slower than controls, they do not differ from controls in the amount of deterioration over time in either variable. In all cases, however, severity of injury was considerably greater than in the present study. Furthermore, results obtained using signal detection experiments and the CPT (Brouwer & Van Wolffelaar, 1985; Greber & Perret, 1985; Rosvold et al., 1956) may not yield comparable results. These tasks can be considerably more difficult than that used in the current experiment, in terms of length of time (30 mins. in the Brouwer & Van Wolfelaar study) or level of cognitive processing required (the CPT). Interestingly, using the signal detection task, Brouwer and Van Wolfelaar (1985) found individuals who did display the expected time on task decline with fatigue, again indicating the danger in forming conclusions based on group statistics. The trend towards a block by group interaction for speed suggests that individuals within the HT1 group may be showing the hypothesized fatigue effect.

Error Analysis: False Alarms

There was a non significant trend in the dysfunctional group towards a greater number of false alarms. The frequency and number of false alarms did not differ significantly between groups. The tendency to respond to non-target stimuli on a CRT of this length would appear to be a normal occurrence, non-specific to MHI. The fact that the effects of distraction or response interference was equivalent between groups suggests that MHI patients and controls are equally able to inhibit response to distractor foils. Number of false alarms was not related to either the number of attentional lapses, nor to intra-individual variability either for the combined or dysfunctional groups. This result fails to support the contention that both distractibility and variability are due to the same internal factors (Schulman et al., 1965).

Hyman (1953) had suggested that the increase in RT speed elicited by foils was indicative of impulsivity. In this study, false alarm latencies appear consistently faster than correct response latencies across block and ISI within each group. The decrease in RT latency for false alarm errors over correct responses suggests that they are impulsive errors. Previous research had indicated that the ability to inhibit impulsive responses to non relevant stimuli was impaired after moderate to severe head injury (Sostek, Buchsbaum, & Rapoport, 1980). Impulsivity and distractibility are noted to be particularly common in traumatic brain injured patients with frontal dysfunction. In this study, group differences in impulsivity (speed of fast responses to non targets) were not significant. The impulsive responses of MHI

patients were as fast as that of controls subjects. This also would suggest that under certain conditions, MHI patients are capable of "fast" responses which do not differ from the average RT latency of normal adults. The results from the current study suggest that distractibility and impulsivity are no more common after MHI than in a normal population.

Qualitative findings

An interesting clinical issue is the consideration of subjects' perception of the test and their opinion of their performance. Upon completing the CRT, all subjects, when asked how they thought they did, commented on the number of "mistakes" they made, referring to how many times they responded accidentally to the wrong symbol. Never did a subject report on aspects of speed or missing the cross (the target symbol). In the dysfunctional group, where errors of omission were more common, the failure to report such errors, even when probed, suggested that they were unaware of the occurrence of lapses of attention. Data from the attentional checklist provides further evidence to support this hypothesis. While all dysfunctional subjects endorsed a wide array of statements about the impact of attentional problems on their daily functioning on the Cognitive ADL Checklist, the only two items which were <u>not</u> significantly different in terms of frequency of interference in ADL between groups were: " I have difficulty maintaining attention for extended periods of time, and, "In conversation, I often lose my train of thought". Compared to the frequency of the other endorsed items by the dysfunctional group (ranging from 71 to 94%), the

latter item was endorsed somewhat less frequently (62%) by dysfunctional subjects and more frequently (31%) by control subjects. Together, these findings raise a number of interesting speculations. Given the occurrence of attentional lapses, and their increase as a function of time on the task, lack of awareness of such a deficit, if true, could potentially make attentional lapses that much more debilitating.

Intuitively, lack of awareness of what is not attended to appears plausible. It suggests that while valuable bits of moment to moment information may be lost to the subject, he/she is not aware of the loss specifically. Based on subjective complaints and symptom reports, the subject appears to only be aware of the consequences of lost information. The consequences of attentional lapses would be predicted to interfere significantly with return-to-work success especially at higher job levels, social interaction and higher level cognitive functioning. Lack of knowledge about the underlying deficit could lead to confusion, frustration and ultimately avoidance of situations likely to elicit it. If this scenario were true, it would serve to exacerbate, if not directly contribute to, the degree of dysfunction experienced by this subgroup. Indeed, lapses of attention were significantly correlated with degree and severity of postconcussional complaints among MHI patients.

Speculations on Neuropathology

Evidence in this study of two head injured subgroups differing in both functional profiles and RT parameters raises interesting

questions concerning possible differences in the extent to which there is an underlying organic basis to these behavioral deficits. The term Mild Traumatic Brain Injury (MTBI) has recently been proposed to label those chronically impaired MHI patients with persisting complaints, impairment in functioning, and functional disability. Since this group may have sustained actual damage to the brain (hence the words brain injury), the term MTBI better characterizes their disorder. It is impossible to verify the precise nature of this damage since conventional neuroradiological techniques (MRI, CT) are limited in their diagnostic sensitivity. Nevertheless, the presence of attentional lapses and increased RT speed in the HT1 group strongly suggest the likelihood of an organic basis for their functional disability. It is clear, however, that some individuals within the Functional group were depressed (35%), compromised in work status (6%), or experiencing problems in their post-morbid work status (11%). Within the HT2 group, 22% were classified as impaired on the HIVE, as compared to 0% of controls. While it is highly likely that all HT1 patients warrant the label MTBI, it is also possible that a number of HT2 subjects have sustained similar damage. This possibility is strengthened given the overlap in RT distributions between the two head injured groups in mean RT, and the fact that separate analysis between control and functional patients indicated a small magnitude of impairment. Within the latter group, this may be explained by the performance of a few functional patients who appear similar to dysfunctional patients in RT performance. Further research into the neuropathological basis for deficits in attention after MHI may

prove RT testing to be a sensitive indicator of underlying brain dysfunction.

Attempts have been made to relate reductions in speed and impairments in attention after moderate to severe head injury to specific pathophysiological mechanisms. Several of these mechanisms can also be hypothesized to explain similar deficits after MHI. Impairments in the ability to focus, sustain, or direct attention can result from damage anywhere along a tripartite neuroanatomical division formed by cortical and subcortical structures comprising the frontal-diencephalic/ limbic and reticular system (Stuss & Benson, 1984). While the precise site of pathology responsible for disrupted attention is rarely known after head injury, the contribution of each of these neuroanatomical divisions to attentional breakdowns has been specified in other populations (Benson & Geschwind, 1975; Stuss & Benson, 1984). The vulnerability of this system to damage based on the shear-strain model has been well described for severe head trauma where damage is diffuse and widespread (Adams, Mitchell, Graham, & Doyle, 1977; Jane et al., 1982; Strich, 1961, 1969, 1970, 1976), and where deficits in arousal/ alertness persist long after emergence from coma.

Unfortunately, the neuropathological mechanism/s of minor head injury are less clearly understood. This is primarily due to the fact that such patients do not ordinarily die from a minor head injury and are not examined histologically. Nevertheless, there is some evidence (see Jane et al., 1982; Nevin, 1967; Oppenheimer, 1968) that the same acceleration/deceleration forces which result in shear strain and associated microscopic tearing and stretching in

various ascending and descending white matter tracts may be involved in minor head injuries. Histological evidence of myelin destruction, microglial clusters, and axonal retraction balls has been described after trivial injuries (minimal loss of consciousness and excellent neurological recovery) in patients who died of other causes (Oppenheimer, 1968), and in animals (Jane et al., 1982; Parsons & Guthrie, 1981). The extent of these changes are less severe and less extensive than those seen after moderate and severe head injuries (Gennarelli et al., 1982).

The contention that a primary mechanism of minor head injury may be the acceleration model is supported by the fact that approximately 80% of minor head injuries result from MVA's, sports injuries, or falls making the above model of rotational forces especially relevant (Boll & Barth, 1983). In the two groups in this study, 59% versus 50% of HT1 and HT2 patients respectively were involved in MVA's. Histologically, the greatest damage occurs within the brain stem and frontal- reticular system (Nevin, 1967; Povlishock et al., 1979). This could account for the subtle alterations in level of consciousness, and attentional dysfunction seen after minor head injury (Jane et al., 1982).

A second line of evidence regarding primary site of neuropathology following minor head injury supports the contention that areas of maximum vulnerability for contusions and microscopic hemorrhagic changes are the frontal and temporal lobes. This is likely due to the location of bony protrusions (the orbital bone and sphenoid wing) by these areas, increasing the likelihood of injury following either coup or contrecoup forces. 71% of HT1 and 69% of

MI2 patients received a blow to the frontal area while 50% and 12% of each group received a blow to the temporal area. Damage can occur even when the blow is of insufficient severity to cause contusions or skull fracture (Voris, 1974). Recent MRI studies (Levin et al., 1987) have revealed lesions concentrated in the frontal and temporal areas involving both gray and white matter on T2 weighted images in MHI subjects with normal CT scan.

Given the shear strain model, the notion of long term attentional deficits and their relationship to underlying pathology after MHI is likely. Hebb (1949) spoke of how attentional processes could be disrupted by interference of the sequential firing of cell assemblies. Given the vulnerability of frontal structures and systems to head injury, and its role in regulating attentional functioning, there is further evidence for a core deficit in attention after MHI (Stuss & Benson, 1986). Perhaps all MHI subjects sustain varying degrees of pathology. Ultimately, better measurement of both the neuropathological consequences of MHI, as well as non-injury specific risk factors, will provide a fuller understanding of the resulting differences in functional status and cognitive sequelae.

Future Directions

Future research involving the use of the CRT in a predictive study may serve to identify patients early after MHI who are at risk for later dysfunction and poor outcome. The results of this study suggest that this technique, and the measures it provides, may serve as a more sensitive measure of functioning than traditional RT

measures early post injury. A closer investigation of the relationship between RT and non-RT variables could allow for a more complete understanding of why some individuals are more at risk than others for developing dysfunction. Such a study could include organic and non-organic (e.g., psychological, personality and environmental) determinants of impairment.

Based on the highly significant finding of lapses of attention, a thorough exploration is warranted into the correlates of this phenomenon, its impact in everyday life functioning and on higher cognitive functioning. Links between attentional lapses and EEG/EP anomalies should be assessed simultaneously during CRT performance. Such a study would allow for an understanding of the physiological, functional and neuropsychological correlates of this phenomenon.

Hypothesis Outcome Summary

Hypothesis	Outcome
1. Effects of subgrouping MHI patients for RT comparisons with control subjects:	
- Results from combined analysis (HT1 and HT2) hypothesized to be misleading given differences in funtional status between subgroups.	confirmed
- HT1 group hypothesized to be slower and more variable than HT2 and controls.	confirmed
2. Relationship between RT and other performance variables between HT1 and HT2:	
- HT1 group hypothesized to be slower, more variable, more symptomatic, more compromised in work status, and more depressed.	confirmed
3. Sensitivity of RT method for predicting group membership:	
- CRT hypothesized to be better at correctly classifying groups than discrete trial RT.	confirmed
Characteristics of CRT	
1. Effects of varying ISI:	
- Positive relationship hypothesized between ISI delay and RT latency for MHI patients as compared to controls	
Group Effect	confirmed
ISI Effect - mean RT only	negative relationship
Interaction	not confirmed
2. Effects of trial Block:	
- Positive relationship hypothesized between trial block and RT latency (fatigue effect) for MHI patients as compared to controls.	
Group Effect	confirmed
Block Effect - mean RT only	confirmed
Interaction	not confirmed
3. Error analysis: False alarms:	
- MHI patients hypothesized to exhibit more false alarms.	not confirmed
4. Error analysis: Response omissions:	
- MHI patients hypothesized to exhibit more response omissions.	
Group Effect	confirmed
Group by Block Interaction	confirmed

(continued)

Hypothesis Outcome Summary

5. Comparison of fastest RT's between groups:	
- No difference hypothesized between fastest RT's of MHI patients vs. controls.	not confirmed

APPENDIX A

HIFI SVI Version 1.2

SURVIVOR INTERVIEW
Version 1.2

SECTION 1

PROBLEMS AND CHANGES

(1) I'd like to ask you some questions about how you're doing now. After a head injury, there can be changes that are mild or severe. Thinking of the way you're feeling right now, what changes do you notice about yourself that may be different from the way you were before your injury? What are the biggest differences?

(2) Do you have any significant physical problems?

(3) How about your behavior? Do you think you act in ways that are different from the way you were before your injury?

(4) Do you notice anything different about your thinking? Are any mental activities more difficult than before your injury?

(5) How about socially? Do you notice any changes in the way you relate to other people? Is anything different from before the injury?

(6) Of the problems you have just mentioned, which do you find most troublesome? Which cause you the greatest difficulty?

(7) How do you handle these problems when they come up?

(8) On a scale of 1 to 10, how well do you feel you understand the changes that have happened, and can make sense of these problems and differences? One (1) would be not understanding the changes at all and 10 would be understanding the changes quite well.

(9) On a scale of 1 to 10, how well do you feel you are able to cope with what has happened to you, and the changes you notice about yourself? One (1) would be totally unable to cope and 10 would be coping extremely well.

Additional Comments:

HIFI SVI Version 1.2

SECTION 3

EMPLOYMENT STATUS

Were you working before the accident? _____ Yes _____ No

If yes, were you working full-time or part-time?

___ Full-time ___ Part-time

What were your responsibilities?

_____

_____

_____

Please check the statement below which best applies to your current situation.

_____ Have not worked at all since the last interview (since discharge).
GO TO SECTION 3A, PAGE 8

_____ Have worked since the last interview (since discharge), but am not working now. GO TO SECTION 3B, PAGE 9

_____ Am working now. GO TO SECTION 3C, PAGE 13

SECTION 3A. FOR THOSE WHO HAVE NOT WORKED AT ALL SINCE THE LAST INTERVIEW (SINCE DISCHARGE).

(1) Have you tried to find a job? _____ Yes _____ No

(2) If yes, what happened when you tried? _____

_____

_____

(3) If no, why did you decide not to look for a job? _____

_____

_____

(4) Do you feel that problems resulting from your head injury are preventing you from going back to work?

_____ Yes _____ No IF NO, GO TO QUESTION (6)

(5) If yes, what problems? _____

_____

_____

(6) Does it bother you that you are not working?

___ Not at all ___ Bothers me a little ___ Bothers me a lot

(7) How are you supporting yourself? _____

_____

_____

(8) Since you have not been working, how are you spending your time?

_____

_____

GO TO SECTION 4, PAGE 18

Additional Comments:

SECTION 3B. FOR THOSE WHO HAVE WORKED SINCE THE LAST INTERVIEW (SINCE DISCHARGE), BUT ARE NOT WORKING NOW.

(1) For each job you've had, indicate the kind of job it was (i.e., what position you held).

Job 1 _____

Job 2 _____

Job 3 _____

(2) For each job you've had, how many hours a week you worked, and how long you held the job.

Job 1: Hours per week: _____ How long held: _____

Job 2: Hours per week: _____ How long held: _____

Job 3: Hours per week: _____ How long held: _____

(3) Were any of these jobs the same job that you had before your injury?

_____ Yes _____ No IF NO, GO TO QUESTION (5)

(4) If yes, which one(s)? _____

(5) For each job, what were your responsibilities on the job?

Job 1 _____

_____

Job 2 _____

_____

Job 3 _____

_____

(6) For each job, how did the responsibilities compare to the job you had before injury? (Are they different in any way?)

Job 1 _____

_____

Job 2 _____

_____

Job 3 _____

_____

(7) What kind of difficulties, if any, did you encounter on the job(s)?

Job 1 _____

_____

Job 2 _____

_____

Job 3 _____

_____

(8) Did you experience any of the following on your job(s)?

Getting tired quicker:	___ Yes	___ Somewhat	___ No
Being treated differently by employer:	___ Yes	___ Somewhat	___ No
Being treated differently by co-workers:	___ Yes	___ Somewhat	___ No
Not being able to do your job as well:	___ Yes	___ Somewhat	___ No
Difficulty keeping organized:	___ Yes	___ Somewhat	___ No
Difficulty remembering things:	___ Yes	___ Somewhat	___ No
Difficulty concentrating:	___ Yes	___ Somewhat	___ No
Working slower:	___ Yes	___ Somewhat	___ No
Harder to learn new things:	___ Yes	___ Somewhat	___ No
Other _____:	___ Yes	___ Somewhat	___ No

(9) For each job, indicate why you left.

Job 1 _____

Job 2 _____

Job 3 _____

(10) How are you supporting yourself? _____

_____

(11) Are you currently seeking employment?

_____ Yes _____ No IF YES, GO TO QUESTION (13)

(12) If not, for what reason? _____

_____

GO TO QUESTION (17)

(13) If yes, what kind of job are you looking for? _____

_____

(14) What difficulties, if any, are you having in finding a job?

_____

_____

(15) Is anyone helping you look for a job?

_____ Yes _____ No IF NO, GO TO QUESTION (17)

(16) If yes, who? _____

(17) Has your head injury caused you any difficulties in resuming work?

_____ Yes _____ No IF NO, GO TO SECTION 4, PAGE 18

(18) If yes, what kind of difficulties? _____

_____

_____

(19) How do you deal with these difficulties? _____

_____

_____

(20) Since you have not been working, how have you been spending your time?

_____

_____

GO TO SECTION 4, PAGE 18

Additional Comments:

SECTION 3C. FOR THOSE WHO ARE WORKING NOW

(1) What is your job? _____

(2) How long have you been at this job? _____

(3) Are you working full-time or part-time? If part-time, how many hours a week?

_____

(4) Is this the same job you held before your injury?

_____ Yes _____ No

(5) What are your responsibilities on the job? _____

_____

(6) Do these responsibilities differ from those you had before your injury?

_____ Yes _____ No IF NO, GO TO QUESTION (8)

(7) If yes, how are they different? _____

_____

(8) Is your salary comparable to what it was before your injury?

_____ Yes _____ No

(9) Are you earning: _____ More _____ Less _____ Same

(10) Is this a problem for you?

_____ Yes _____ No IF NO, GO TO QUESTION (12)

(11) If yes, in what way? _____

_____

(12) Did you have any difficulties finding employment?

_____ Yes _____ No IF NO, GO TO QUESTION (16)

(13) If yes, what were the problems you had? _____

_____

_____

(14) Was anyone helping you with these problems?

_____ Yes _____ No IF NO, GO TO QUESTION (16)

(15) If yes, who? _____

(16) What kind of difficulties, if any, are you encountering on your current job?

_____

_____

_____

(17) Did you experience any of the following on your job?

Getting tired quicker:	___ Yes	___ Somewhat	___ No
Being treated differently by employer:	___ Yes	___ Somewhat	___ No
Being treated differently by co-workers:	___ Yes	___ Somewhat	___ No
Not being able to do your job as well:	___ Yes	___ Somewhat	___ No
Difficulty keeping organized:	___ Yes	___ Somewhat	___ No
Difficulty remembering things:	___ Yes	___ Somewhat	___ No
Difficulty concentrating:	___ Yes	___ Somewhat	___ No
Working slower:	___ Yes	___ Somewhat	___ No
Harder to learn new things:	___ Yes	___ Somewhat	___ No
Other _____:	___ Yes	___ Somewhat	___ No

(18) Did your employer make special arrangements for your return to work (e.g., gradually increasing hours; reducing workload)?

_____ Yes _____ No IF NO, GO TO QUESTION (20)

(19) If yes, what arrangements? _____

_____

_____

(20) Has your head injury caused you any difficulties in resuming work?

_____ Yes _____ No IF NO, GO TO QUESTION (23)

(21) If yes, what kind of difficulties? _____

_____

_____

(22) How do you deal with these difficulties? _____

_____

_____

(23) How satisfied are you with your current job?

_____ Very Satisfied
_____ Moderately Satisfied
_____ Moderately Dissatisfied
_____ Very Dissatisfied

(24) If you're not very satisfied, why? _____

_____

_____

(25) Have you had any other jobs since the last interview (since discharge)?

_____ Yes _____ No IF NO, GO TO SECTION 4, PAGE 14

(26) If yes, for each job you've had indicate the kind of job it was (i.e., what position you held).

Job 1 _____

Job 2 _____

Job 3 _____

(27) For each job, indicate how many hours per week you worked, and how long you held the job.

Job 1: Hours per week: _____ How long held: _____

Job 2: Hours per week: _____ How long held: _____

Job 3: Hours per week: _____ How long held: _____

(28) Were any of these jobs the same job that you had before your injury?

_____ Yes _____ No IF NO, GO TO QUESTION (30)

(29) If yes, which one(s)? _____

(30) For each job, what were your responsibilities on the job?

Job 1 _____

_____

Job 2 _____

_____

Job 3 _____

_____

(31) For each job, how did the responsibilities compare to the job you had before injury? (Are they different in any way?)

Job 1 _____

_____

Job 2 _____

_____

Job 3 _____

_____

(32) What kind of difficulties, if any, did you encounter on the job(s)?

Job 1 _____

_____

Job 2 _____

_____

Job 3 _____

_____

(33) For each job, indicate why you left.

Job 1 _____

Job 2 _____

Job 3 _____

GO TO SECTION 4, PAGE 18

Additional Comments:

SECTION 4

HOMEMAKER STATUS

(1) Before the accident, was "homemaking" your primary responsibility?

_____ Yes _____ No IF NO, GO TO SECTION 5, PAGE 20

(2) Since the accident, have you made any attempt to resume any of your homemaking responsibilities?

_____ Yes _____ No IF YES, GO TO QUESTION (5)

(3) If no, why not? _____

_____

_____

(4) Who has taken over these responsibilities? _____

_____

GO TO SECTION 5, PAGE 20

(5) How much difficulty have you had resuming your homemaker responsibilities?

_____ A great deal _____ Some _____ None

(6) Which homemaking activities have you found the easiest to resume?

_____

_____

(7) Which homemaking activities have you found the most difficult to resume?

_____

_____

(8) How successful have you been in resuming the following activities? Use the codes below to rate each of the activities.

1 = Resumed with no difficulties
2 = Resumed with minor difficulties
3 = Resumed with major difficulties
4 = Unable to resume at all
0 = Does not apply, never engaged in

_____ Housecleaning (e.g., laundry, vacuuming, washing dishes)
_____ Meal planning and preparation
_____ Household business (e.g., errands, paying bills, shopping)
_____ Child care: Physical care (e.g., feeding, dressing)
_____ Child care: Home supervision (e.g., discipline, playing)
_____ Child care: Coordinating activities (e.g., school, socialization)

(9) What has made it difficult for you to resume these activities?

_____

_____

_____

(10) Is anyone helping you with these responsibilities? ___ Yes ___ No

If yes, who? _____

GO TO SECTION 5, PAGE 20

Additional Comments:

SECTION 5

EDUCATIONAL STATUS

Pre-Accident Academic Attainment:

___ Doctoral Degree
___ Master's Degree
___ Some Graduate School
___ Bachelor's Degree
___ Associate of Arts Degree
___ Some College
___ Technical Certificate
___ High School Diploma
___ Some K-12 education
___ No academic education

Were you in school at the time of the accident? ___ Yes ___ No

If yes, full-time or part-time? ___ Full-Time ___ Part-Time

What type of program? _____

(1) Since the last interview (discharge) have you attended school?

_____ Yes _____ No IF NO, GO TO QUESTION (15)

(2) If yes, full-time or part-time? _____

(3) Describe what courses you have been taking (what program you have been in).

_____

_____

(4) If you were in school before your injury, was the coursework/ program the same?

_____ Yes _____ No IF YES, GO TO QUESTION (6)

(5) If not, what are the differences? _____

_____

(6) What kind of difficulties, if any have you encountered in school since your injury?

_____

_____

_____

(7) Have you encountered any of the following in school since your injury?

Difficulty learning new things	__ Yes	__ Somewhat	__ No
Difficulty understanding new concepts or ideas	__ Yes	__ Somewhat	__ No
Difficulty remembering what you've heard in class	__ Yes	__ Somewhat	__ No
Difficulty keeping organized	__ Yes	__ Somewhat	__ No
Difficulty organizing your thoughts	__ Yes	__ Somewhat	__ No
Difficulty remembering what you've read	__ Yes	__ Somewhat	__ No
Difficulty concentrating	__ Yes	__ Somewhat	__ No
Difficulty reading for long periods	__ Yes	__ Somewhat	__ No
Getting tired quicker	__ Yes	__ Somewhat	__ No
Being treated differently by teachers	__ Yes	__ Somewhat	__ No
Being treated differently by other students	__ Yes	__ Somewhat	__ No
Working slower	__ Yes	__ Somewhat	__ No
Getting lower grades	__ Yes	__ Somewhat	__ No
Other _____	__ Yes	__ Somewhat	__ No

(8) Have any special arrangements been made for you in school (e.g., having more time for tests; bringing tape recorder to class)?

_____ Yes _____ No IF NO, GO TO QUESTION (10)

(9) If yes, what arrangements? _____

_____

_____

(10) Has your head injury caused you any difficulties in school?

_____ Yes _____ No IF NO, GO TO QUESTION (13)

(11) If yes, what kind of difficulties? _____

_____

_____

(12) How do you deal with these difficulties? _____

_____

_____

(13) Are you still taking courses?

_____ Yes _____ No IF YES, GO TO SECTION 6, PAGE 23

(14) If no, why did you stop? _____

_____

_____

GO TO SECTION 6, PAGE 23

(15) If no, (if you have not attended school since last interview), did you want to?

_____ Yes _____ No IF NO, GO TO QUESTION (17)

(16) If you wanted to attend school and didn't, why didn't you?

_____

_____

(17) Do you feel that your head injury would prevent you from attending school?

_____ Yes _____ No IF NO, GO TO SECTION 6, PAGE 23

(18) If yes, in what way? _____

_____

_____

Additional Comments:

SECTION 6

PROBLEM CHECKLIST

Instructions: This form is to be filled out by the head-injured person.

On the left you will find a list of symptoms often encountered by a person after a head injury. Next to each item, you are asked to indicate whether this is something you experience. If you answer yes, then you will be asked to indicate how much of a problem this presents in your daily functioning. Circle one of the numbers from 1 (no problem) to 7 (severe problem). The higher the number you circle, the more of a problem it is for you.

Please complete all items.

Symptom	Do you experience...? Yes	No	IF YES, How much of a problem does this present in your daily functioning? 1 No Problem	2	3 Moderate Problem	4	5	6	7 Severe Problem
1. Visual problems; difficulty seeing	Y	N	1	2	3	4	5	6	7
2. Poor balance	Y	N	1	2	3	4	5	6	7
3. Doing things slowly	Y	N	1	2	3	4	5	6	7
4. Headaches	Y	N	1	2	3	4	5	6	7
5. Fatiguing quickly; getting tired easily	Y	N	1	2	3	4	5	6	7
6. Difficulty remembering the right word (word-finding)	Y	N	1	2	3	4	5	6	7
7. Expressing self in a wordy, roundabout way	Y	N	1	2	3	4	5	6	7
8. Difficulty speaking smoothly, easily and clearly (dysarthria)	Y	N	1	2	3	4	5	6	7
9. Being easily distractible	Y	N	1	2	3	4	5	6	7
10. Poor concentration for extended periods of time	Y	N	1	2	3	4	5	6	7
11. Being forgetful; difficulty remembering things	Y	N	1	2	3	4	5	6	7

Symptom	Do you experience...? Yes	No	IF YES, How much of a problem does this present in your daily functioning? 1 No Problem	2	3 Moderate Problem	4	5	6	7 Severe Problem
12. Difficulty planning and organizing things	Y	N	1	2	3	4	5	6	7
13. Difficulty setting realistic goals	Y	N	1	2	3	4	5	6	7
14. Difficulty following through or finishing things	Y	N	1	2	3	4	5	6	7
15. Apathy, lack of interest in things	Y	N	1	2	3	4	5	6	7
16. Lack of initiative, don't start things up	Y	N	1	2	3	4	5	6	7
17. Irritability	Y	N	1	2	3	4	5	6	7
18. Impatience	Y	N	1	2	3	4	5	6	7
19. Restlessness	Y	N	1	2	3	4	5	6	7
20. Temper outbursts	Y	N	1	2	3	4	5	6	7
21. Mood swings, quick emotional shifts	Y	N	1	2	3	4	5	6	7
22. Difficulty bringing emotions under control once expressed	Y	N	1	2	3	4	5	6	7

Symptom	Do you experience...? Yes	No	IF YES, How much of a problem does this present in your daily functioning? 1 No Problem	2	3	4 Moderate Problem	5	6	7 Severe Problem
23. Getting into arguments with others	Y	N	1	2	3	4	5	6	7
24. Being physically violent	Y	N	1	2	3	4	5	6	7
25. Getting bored easily	Y	N	1	2	3	4	5	6	7
26. Complaining about things	Y	N	1	2	3	4	5	6	7
27. Dependency on others	Y	N	1	2	3	4	5	6	7
28. Needing supervision	Y	N	1	2	3	4	5	6	7
29. Anxiety/tension	Y	N	1	2	3	4	5	6	7
30. Depression	Y	N	1	2	3	4	5	6	7
31. Loneliness	Y	N	1	2	3	4	5	6	7
32. Low sexual drive	Y	N	1	2	3	4	5	6	7
33. High sexual drive	Y	N	1	2	3	4	5	6	7
34. Changed personality	Y	N	1	2	3	4	5	6	7

APPENDIX B

Normal Controls Dissertation

NEW YORK UNIVERSITY MEDICAL CENTER
A private university in the public service
550 FIRST AVENUE, NEW YORK, N.Y. 10016
CABLE ADDRESS: NYUMEDIC

INFORMED CONSENT TO PARTICIPATE IN RESEARCH

You are being asked to volunteer to be a subject in a research study. This form is designed to provide you with information about this study which you should know and to answer any of your questions.

PROJECT DIRECTOR: Leonard Diller, Ph.D. (for dissertation of Bonnie Newman, M.A.)

TITLE OF RESEARCH STUDY: THE EFFECTS OF INTRASUBJECT VARIABILITY ON CONTINUOUS REACTION TIME PERFORMANCE FOLLOWING MINOR HEAD INJURY

☐ This research study includes procedures that may change the treatment you would otherwise receive. We hope the knowledge gained will be of benefit to you.

☒ This research study includes procedures which may not give you immediate benefits. It is hoped the knowledge gained will be of benefit to others in the future.

☐ This research study is planned to select your treatment by chance. It is not known if the treatment you will receive will be of benefit to you.

THE PURPOSE OF THE RESEARCH IS:

To learn more about how normal adults perform on tests designed to measure cognitive functioning after minor head injury.

DONATION OF BLOOD: None cc. (equivalent to _____ ounces).
Frequency of withdrawal: _____. The potential risks of donating blood, none of which are likely to occur, may include pain, bruising, fainting or a small infection at the puncture site.

THE FOLLOWING PROCEDURES WILL BE INVOLVED: (IF LIMITED TO DONATION OF BLOOD, LEAVE BLANK.)

You will be given two computerized tests designed to measure attention, and how quickly you can respond to pictures on the screen. You will also be interviewed about whether or not you experience any cognitive problems in your daily life. The entire procedure will take less than an hour to complete and there is no risk or discomfort to you.

REV 8/82 # 3067

CONSENT TO PARTICIPATE IN RESEARCH (CONTINUED)

THE POTENTIAL RISKS OR DISCOMFORTS TO YOU ARE: (IF LIMITED TO DONATION OF BLOOD, LEAVE BLANK)

None

THE POTENTIAL BENEFITS TO YOU OR OTHERS ARE:

To improve diagnostic procedures developed for brain injured patients and to develop a normative base for such procedures.

GENERAL CONDITIONS: Should you consent to participate in this research, your identity will be kept confidential. You may change your mind at any time. Refusal to participate will not harm your relationship with the faculty and attending staff.

AGREEMENT TO PARTICIPATE

I have read the above description of the research study and general conditions (or it was read to me by: _____). Anything I did not understand was explained to me by: _____, and any questions I had were answered by: _____. I certify that I am / am not (circle one) participating in another research project at this time, and have discussed the implications of such activity with the project director(s). In consideration of this understanding, I voluntarily agree to participate in this research at: ☐ NYUMC ☐ Bellevue Hospital ☐ Goldwater Hospital ☐ Other _____

Name of Subject _____ Age (if under 18) _____

WHEN THE SUBJECT IS AN ADULT

Signature of Participant or Legal Representative	Date	Print Name of Legal Representative	
Signature of Investigator	Date	Signature of Witness	Date

WHEN THE SUBJECT IS A CHILD

☐ I have solicited the assent of the child. ☐ I have not solicited assent for the following reason(s): _____

_____

_____

_____
Signature of Investigator

☐ I agree with the manner in which assent was solicited and given by my child and I agree to have my child participate in the study.

☐ Although my child did not or could not give his/her assent I agree to have my child participate in the study.

Signature of Parent(s)	Date	Print Name of Legal Representative	
Signature of Child	Date	Signature of Witness	Date

For children between the ages of 12 and 17, their signature is generally required in addition to that of the parent or legal representative.

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NEW YORK UNIVERSITY MEDICAL CENTER
A private university in the public service
550 FIRST AVENUE, NEW YORK, N.Y. 10016
CABLE ADDRESS: NYUMEDIC

INFORMED CONSENT TO PARTICIPATE IN RESEARCH

You are being asked to volunteer to be a subject in a research study. This form is designed to provide you with information about this study which you should know and to answer any of your questions.

PROJECT DIRECTOR: Leonard Diller, Ph.D. DEPT. Rehab. Medicine TEL. # (212) 263-6161

TITLE OF RESEARCH STUDY: R15: Cognitive Breakdowns Under Conditions of Divided Attention After Minor Head Injury: Test Development and P300's

YOUR PARTICIPATION WILL INVOLVE THIS AMOUNT OF TIME: 4 hours

WE EXPECT TO ENLIST THIS NUMBER OF VOLUNTEERS: 30

☐ This research study includes procedures that may change the treatment you would otherwise receive. We hope the knowledge gained will be of benefit to you.

☒ This research study includes procedures which may not give you immediate benefits. It is hoped the knowledge gained will be of benefit to others in the future.

☐ This research study is planned to select your treatment by chance. It is not known if the treatment you will receive will be of benefit to you.

THE PURPOSE OF THE RESEARCH IS.

To better understand the problems that occur when attention is paid to two different things at the same time.

THE FOLLOWING PROCEDURES WILL BE INVOLVED:

Psychological tests (consisting of paper and pencil and computerized tests) of attention, memory, and quickness will be given. In addition, an Evoked Potential Measure will be obtained. "Evoked Potential" is a procedure that measures brain electrical activity by placing four small surface electrodes on your scalp while you are resting quietly.

REV 8/82 • 3066

CONSENT TO PARTICIPATE IN RESEARCH (CONTINUED)

THE POTENTIAL RISKS OR DISCOMFORTS TO YOU ARE:

There are no risks of discomfort involved during psychological testing or during the evoked potential procedure.

THE POTENTIAL BENEFITS TO YOU OR TO OTHERS ARE:

While there are probably no direct benefits to you, others will benefit from the results of this study as the findings are incorporated into rehabilitation programs.

IF YOU DO NOT PARTICIPATE IN THE RESEARCH, YOU MAY RECEIVE THE FOLLOWING ALTERNATIVE TREATMENT:

You may withdraw from the study at any time without losing any of the rehabilitation services you have been, or will be receiving.

CONSENT TO PARTICIPATE IN RESEARCH (CONTINUED)

GENERAL CONDITIONS

1. Should you consent to participate in this research, your identity will be kept confidential within these limits: If investigational drugs and/or devices subject to U.S. Food and Drug Administration regulations are involved, it may be necessary for this consent form and other medical records to be reviewed by representatives of the F.D.A. and the agency providing the test substance.
2. In the case of physical injury resulting from your participation in the study, only immediate, essential, short-term treatment as determined by the doctors will be made available without charge to you. There will be no monetary compensation or non-emergency care provided by New York University Medical Center or the Health and Hospitals Corporation, New York City.
   Information on the availability of treatment for any physical injury resulting from your participation in the research project may be obtained from Leonard Diller, Ph.D., project principal investigator, Telephone No. 263-6161, or from the NYU Medical Center Office of Grants Administration and Institutional Studies, Telephone No. (212) 340-6703.
3. You will be told of any new findings that may influence your willingness to continue your participation in the research.
4. If you would like to discuss your participation with an institutional representative who is not part of this study, please call (212) 340-6703.
5. Should you agree to participate in this research, you may change your mind at any time. Refusal to participate will not harm your relationship with the faculty and attending staff nor will it prejudice your further treatment.

AGREEMENT TO PARTICIPATE

I have read the above description of the research study and general conditions (or it was read to me by: _____). Anything I did not understand was explained to me by: _____, and any questions I had were answered by: _____. I certify that I am / am not (circle one) participating in another research project at this time, and have discussed the implications of such activity with the project director(s). In consideration of this understanding, I voluntarily agree to participate in the research at: ☐ NYUMC ☐ Bellevue Hospital ☐ Goldwater Hospital ☐ Other _____

Name of Subject _____ Age (if under 18) _____

WHEN THE SUBJECT IS AN ADULT

Signature of Participant or Legal Representative	Date	Print Name of Legal Representative	
Signature of Investigator	Date	Signature of Witness	Date

WHEN THE SUBJECT IS A CHILD

☐ I have solicited the assent of the child. ☐ I have not solicited assent for the following reason(s): _____

_____

_____

Signature of Investigator

☐ I agree with the manner in which assent was solicited and given by my child and I agree to have my child participate in the study.

☐ Although my child did not or could not give his/her assent I agree to have my child participate in the study.

Signature of Parent(s)	/ / Date	Print Name of Legal Representative	
Signature of Child	/ / Date	Signature of Witness	/ / Date

For children between the ages of 12 and 17, their signature is generally required in addition to that of the parent or legal representative.

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INFORMED CONSENT TO PARTICIPATE IN RESEARCH

You are being asked to volunteer to be a subject in a research study. This form is designed to provide you with information about this study which you should know and to answer any of your questions.

PROJECT DIRECTOR: Leonard Diller, Ph.D.

TITLE OF RESEARCH STUDY: Identification and Treatment of Non-hospitalized Patients with Minor Head Injury (Control Group)

☐ This research study includes procedures that may change the treatment you would otherwise receive. We hope the knowledge gained will be of benefit to you.

☒ This research study includes procedures which may not give you immediate benefits. It is hoped the knowledge gained will be of benefit to others in the future.

☐ This research study is planned to select your treatment by chance. It is not known if the treatment you will receive will be of benefit to you.

THE PURPOSE OF THE RESEARCH IS:

To determine the course of recovery, incidence of long term disability, early risk factors, and effectiveness of a system of early intervention, for patients suffering minor head injury (concussion), seen in the ER, but not admitted to the hospital.

DONATION OF BLOOD: _____ cc. (equivalent to _____ ounces).
Frequency of withdrawal: _____. The potential risks of donating blood, none of which are likely to occur, may include pain, bruising, fainting or a small infection at the puncture site.

THE FOLLOWING PROCEDURES WILL BE INVOLVED: (IF LIMITED TO DONATION OF BLOOD, LEAVE BLANK.)

You will be interviewed about how you are feeling, the extent to which you have resumed normal activities, and any problems that may remain since your injury. You will be given a battery of tests which measure attention, concentration, memory, and how quickly you can do things. The entire procedure will take about two hours, and there is no risk or discomfort for you.

CONSENT TO PARTICIPATE IN RESEARCH (CONTINUED)

THE POTENTIAL RISKS OR DISCOMFORTS TO YOU ARE: (IF LIMITED TO DONATION OF BLOOD, LEAVE BLANK)

NONE

THE POTENTIAL BENEFITS TO YOU OR OTHERS ARE:

What we learn from this study will help us identify who is at risk for long term problems after minor head injury, enabling us to provide them with the needed services as quickly as possible.

GENERAL CONDITIONS: Should you consent to participate in this research, your identity will be kept confidential. You may change your mind at any time. Refusal to participate will not harm your relationship with the faculty and attending staff.

AGREEMENT TO PARTICIPATE

I have read the above description of the research study and general conditions (or it was read to me by: _____). Anything I did not understand was explained to me by: _____ , and any questions I had were answered by: _____ . I certify that I am / am not (circle one) participating in another research project at this time, and have discussed the implications of such activity with the project director(s). In consideration of this understanding, I voluntarily agree to participate in this research at: ☐ NYUMC ☐ Bellevue Hospital ☐ Goldwater Hospital ☐ Other _____

Name of Subject _____ Age (if under 18) _____

WHEN THE SUBJECT IS AN ADULT

_____ / _____ _____

Signature of Participant or Legal Representative — Date — Print Name of Legal Representative

_____ / _____ _____ /

Signature of Investigator — Date — Signature of Witness — Date

WHEN THE SUBJECT IS A CHILD

☐ I have solicited the assent of the child. ☐ I have not solicited assent for the following reason(s): _____

_____

_____

_____

Signature of Investigator

☐ I agree with the manner in which assent was solicited and given by my child and I agree to have my child participate in the study.

☐ Although my child did not or could not give his/her assent I agree to have my child participate in the study.

_____ / _____ _____

Signature of Parent(s) — Date — Print Name of Legal Representative

_____ / _____ _____ /

Signature of Child — Date — Signature of Witness — Date

For children between the ages of 12 and 17, their signature is generally required in addition to that of the parent or legal representative.

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APPENDIX C

Name: _____ Date: _____

COGNITIVE ADL CHECKLIST

CIRCLE TRUE OR FALSE FOR EACH OF THE FOLLOWING STATEMENTS. IF TRUE, INDICATE THE DEGREE TO WHICH IT INTERFERES WITH YOUR DAILY LIFE.

			DEGREE OF INTERFERENCE: None		Moderate				Severe
1. I get distracted easily.	True	False	0	1	2	3	4	5	6
2. I need to take frequent breaks while working on a task.	True	False	0	1	2	3	4	5	6
3. I have difficulty maintaining attention for extended periods of time.	True	False	0	1	2	3	4	5	6
4. I get tired easily.	True	False	0	1	2	3	4	5	6
5. My mind often wanders off a task.	True	False	0	1	2	3	4	5	6
6. When people speak to me quickly, I have trouble following what they are saying.	True	False	0	1	2	3	4	5	6
7. When a lot goes on around me, I often "tune out".	True	False	0	1	2	3	4	5	6
8. When I read, I find that my mind often wanders, and I have to go back and reread what I missed.	True	False	0	1	2	3	4	5	6
9. I never know how well I'll do on a task because my performance is very inconsistent.	True	False	0	1	2	3	4	5	6
10. No matter how hard I try, I sometimes only understand bits and pieces of information.	True	False	0	1	2	3	4	5	6
11. Often, I am unable to do a job well because I am tired.	True	False	0	1	2	3	4	5	6
12. In conversation I often lose my train of thought.	True	False	0	1	2	3	4	5	6
13. I get bored easily.	True	False	0	1	2	3	4	5	6
14. I get tired when I am forced to concentrate.	True	False	0	1	2	3	4	5	6
15. I often need to ask people to repeat what they've said because my attention has drifted.	True	False	0	1	2	3	4	5	6

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