Memory and head injury severity

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SUMMARY One hundred and two consecutive head injured patients were studied at 1 and 12 months after injury. Their performances were compared with a group of uninjured friends. The results indicate that impairment in memory depends on the type of task used, time from injury to testing, and on the severity of head injury (that is, degree of impaired consciousness). Head injury severity indices are more closely related to behavioural outcome early as compared with later after injury. At 1 year, only those with deep or prolonged impaired consciousness (as represented by greater than 1 day of coma, Glasgow Coma Scale of 8 or less, and post traumatic amnesia of 2 weeks or greater) are performing significantly worse than comparison subjects.

Problems remembering new information following head injury are the most frequently reported difficulties by patients and those associated with them. Researchers have investigated memory problems more than any other neuropsychological deficit in the area of head injury. The focus of the investigative work has been to determine the nature and severity of the problems and to identify factors (for example, different indices of head injury severity or neurological complications) responsible for or associated with the problems observed.¹⁻³ The work done to date has made us aware that memory problems are frequent; yet, we are just beginning to understand their nature and are still far from fully understanding the aetiology of memory difficulties of head injured patients. In general more severe injuries are associated with greater cognitive impairments. However, there is less specific information and consistent empirical documentation of the relationships between various indices of head injury severity and cognitive outcome, how these relationships hold over time, and what level of head injury severity is associated with impaired cognitive performance. Part of the problem is the determination of the complex nature of the constructs of memory and how to go about measuring them. The other part of the problem is the multitude of factors that may influence memory and the deter-

mination of memory impairment following head injury.

In the present study we define memory as what the Wechsler Memory Scale⁴ and the Selective Reminding⁵ Procedure measure. We do not specifically deal with different memory systems and how they are affected by head injury (for example, short vs long term, semantic vs episodic etc.). Rather, we focus on the importance of different head injury severity indices and the impact of time from injury to evaluation on memory. In addition, considerable effort was expended to rule out or control for the effects on memory functioning of as many confounding variables as possible. To that end, consecutive cases were selected and every attempt was made to reduce attrition over the follow-up period in order to obtain as representative a sample of head injured patients as possible. Cases with pre-existing neurological or neuropsychiatric conditions were excluded to avoid confusing pre-injury memory problems from those resulting from the head injury. And finally, a group selected from friends of the head injured cases was used for comparison purposes. The general purpose of this study was to examine the effects of injury severity, time from injury to testing, and type of tasks on memory performance following head injury with specific emphasis on head injury severity.

Methods

SUBJECTS

Head injured The subjects were 102 consecutive, acute,

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adult head injured patients who were admitted to Harborview Medical Center in Seattle. The criteria for subject selection included all of the following: (1) any period of loss of consciousness or post-traumatic amnesia (PTA) > 1 hour or objective evidence of cerebral trauma; (2) head injury sufficiently serious to require hospitalisation; (3) no history of prior central nervous system insult or involvement or significant neuropsychiatric difficulties; (4) age range between 15 and 60 years; (5) residence allowing availability for 12 month follow-up; (6) English speaking; and (7) willingness to participate in the study.

All patients had sustained blunt head injuries. Moving vehicle accidents were responsible for the injury in 79 cases, falls in 10, fights/assaults in eight and five cases were the result of other causes. The group consisted of a broad spectrum of severity of head injury with mild and moderate cases constituting the majority of the group. Table 1 presents the distribution of time from injury to consistently following commands, Glasgow Coma Scale (GCS) scores within 24 hours of injury, and post traumatic amnesia (PTA) represented in the sample. Time to following commands (TFC) is operationally defined by the motor response of the Glasgow Coma Scale.

Non-injured comparison group The comparison group also consisted of 102 cases selected from friends of the head injured. Methods suggested by Pocock and Simon⁶ and Taves⁷ were used to match the non-injured group to the head injured on the variables of age, education, race and sex. A pool of pre-injury friends were used as potential controls based on the assumption that one usually chooses friends similar to oneself, and therefore, the friends and the head injured subjects will be roughly similar on potentially important cognitive and psychosocial characteristics. The non-injured subjects were recruited around the time of the 1 month examination of the head injury subjects, rather than during the course of the one-year follow-up. This was done to insure a sample as comparable as possible to the pre-trauma status of the head injury subjects.

The demographic features of the two groups are presented in table 2. In summary, men exceed women by a factor of two. The majority of the subjects are single, in their early to mid-twenties and have a high school education. The head injured subjects were examined at 1 and 12 months post injury. Thirteen cases were neurologically too impaired (for example, in coma) to be testable at 1 month. The non-injured subjects were also tested twice with the same test-retest interval. Ninety seven of the 102 head injured and 88 of the 102 non-injured subjects were seen for 1 year follow-up.

Table 2 Subject demographic characteristics at 1 month

Characteristics	Head Injured	Friends
Mean Age	26-33	24-52
Mean Education	12-05	12-39
Sex		
Male	69	65
Female	33	37
Race		
White	100	99
Non-White (Blacks & Asians)	2	3
Marital Status		
Single	61	73
Married	24	21
Divorced	10	6
Separated	6	2
Widowed	1	0

Measures

A. Head injury severity measures

- (1) *Glasgow Coma Scale (GCS)*, as assessed within 24 hours of the injury, was used as an index of depth of coma.⁸
- (2) *Time from injury to consistently following simple commands (TFC)* was used as an index of length of coma. The operational definition for following commands is the same as that specified in the motor response category of the GCS.
- (3) *Post traumatic amnesia (PTA)*, defined as the interval between the injury and regaining continuous day to day memory, was used as another index of length of impaired consciousness.⁹ The determination of PTA was done at 1 month after injury, at the same time as the first memory evaluation and was assessed retrospectively by careful questioning of the patients.

B. Memory measures

- (1) *Wechsler Memory Scale (WMS)*⁴ attempts to examine various aspects of memory and memory related abilities. Because of this, it continues to be one of the more widely used measures in spite of some of its reported weaknesses. It assesses knowledge of personal and current information, orientation, mental control (that is, counting backwards, reciting the alphabet, and counting by three's, all under time pressure), logical memory (that is, recalling the number of details from two short passages), attention span (that is, recalling digits forward and backward), visual reproduction (that is, reproducing from memory geometric designs), and associate learning (that is, learning easy and hard word pairs). In addition to the immediate recall, 30-minute delayed recall was tested for logical memory and visual reproduction. Two alternate forms of the test were counterbalanced and administered at the two evaluation pe-

Table 1 Indices of severity at one month

Post-traumatic amnesia		Glasgow Coma Scale		Time to following commands	
Category	Frequency	Category	Frequency	Category	Frequency
< 24 h	23	3-8	30	< 1 h	46
1-6 days	25	9-11	12	1-24 h	27
7-13 days	20	12+	60	25 hrs-6 days	11
≥ 14 days	33			≥ 7 days	18
Unknown	1				

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riods. A total of 11 scores representing different abilities were derived from this measure.

(2) *Selective Reminding Procedure (SRP)*⁵ is a multiple trial, free-recall memory and learning procedure which has gained considerable popularity in the area of head injury.¹⁰ It examines storage and subsequent retention and retrieval from long-term storage of new verbal information. For the present study, 10-item unrelated word lists were used and 10 trials were given. Four alternate forms of the Selective Reminding Procedure were counterbalanced and administered at the two evaluation periods. Eight scores were derived from this procedure.

Data analysis

The data were analysed to answer the following questions:

- (1) Are there memory difficulties at 1 and 12 months post injury and, if so, are they related to time to following commands? To address the question of memory difficulties at 1 and 12 months, the entire group of head injured patients was compared with the non-injured group at the two time periods on each score derived from the Wechsler Memory Scale and the Selective Reminding Procedure. Wilcoxon rank sum tests were used for this purpose. In order to examine the relationship between memory impairment and TFC, the performances of the head injury subgroups divided on the basis of TFC and the uninjured group were compared using Kruskal-Wallis distribution-free analysis of variance. Significant overall differences on a test were followed by post hoc comparisons among all of the pairs of groups using Tukey's method.¹¹ A significance level of 0.05 was used.
- (2) Is the relationship between degree of memory impairment and impaired consciousness similar across different indices of impaired consciousness? The head injury

group was divided into subgroups on the basis of TFC, PTA, and GCS. The performances of these subgroups were compared with those of the uninjured and among all pairs of groups as described above. These comparisons were restricted to only one measure derived from the Selective Reminding Procedure (that is, sum of consistent long-term retrieval).

Results

The results will address each of the two questions posed in the Data Analysis section.

(1) *Memory difficulties at 1 and 12 months after injury and as a function of time to following commands.* Memory impairments are clearly present at 1 and 12 months after injury as seen in table 3. At 1 month, the head injury group performed significantly worse than the uninjured group ($p < 0.001$) on each of the subscales extracted from the Wechsler Memory Scale and the Selective Reminding Procedure. Most subscales continue to show significant impairment for the head injury group as a whole at 1 year. The degree of impairment is influenced by time from injury to following simple commands (TFC). Table 4 summarises the results that are in support of this conclusion. Presented are the percentage of the 11 tests of the Wechsler Memory Scale and the eight scores of the Selective Reminding Procedure on which the head injured subgroups were significantly more impaired than the comparison subjects at 1 and 12 months post injury. The head injury group was divided into four

Table 3 Median performances on Memory Measure at 1 and 12 months after injury

Measures	Head Injured		Friends	
	1 month (102)	12 months (97)	1 month (102)	12 months (88)
<i>Wechsler Memory Scale</i>				
Personal, Current Info	5*	6†	6	6
Orientation	5*	5	5	5
Mental Control	7*	8‡	9	9
Logical Memory Immed.	9*	11*	12	13
Logical Memory Delayed	7*	9*	10	12
Digits Forward	6*	7	7	7
Digits Backward	4*	5‡	5	5
Vis. Reprod. Immed.	11*	12	13	13
Vis. Reprod. Delayed	10*	12‡	12	12
Assoc. Learn. Easy	16*	17†	18	17
Assoc. Learn. Hard	7*	8*	10	10
MQ	99*	106*	118	119
<i>Selective Reminding</i>				
Sum RCL	80*	86*	90	90
Sum LTS	76*	83*	90	89
Sum LTR	70*	80*	87	87
Sum CLTR	56*	72*	83	83
Delay RCL-30 min	7*	8†	9	9
Delay RCL-4 h	6*	8†	9	9
Delay Recog.-30 min	10*	10	10	10
Day Recog.-4 h	10*	10	10	10

Significance levels refer to comparisons between HI and friend controls at 1 month and at 12 months.

* $p < 0.001$.

† $p < 0.01$.

‡ $p < 0.05$.

( ) sample size.

Table 4 Percentages of subtests on which head injured and friend control subject differed significantly

		Time to Following Commands							
		1 month				1 Year			
		≥ 7 d	25 hr-6 d	1-24 hr	< 1 hr	≥ 7 d	25 hr-6 d	1-24 hr	< 1 hr
WMS	100	72	9	9	63	18	0	0	
SR	100	75	75	25	75	38	0	0	

WMS—Wechsler Memory Scale.

SR—Selective Reminding procedure.

subgroups on the basis of TFC: (1) 7 days or greater; (2) 1-6 days; (3) 1-24 hours; (4) none or less than 1 hour. The median subtest values and the results of the comparisons among the head injury subgroups are not presented in order to save space. This information is available from the authors upon request. At 1 month after injury, the subgroups with more severe head injury are significantly impaired on more subtests on both the WMS and SRP than the uninjured subjects. For instance, those with TFC equal to or greater than 7 days were significantly impaired on all subtests of both the WMS and the SRP ($p < 0.001$). In fact, 11 of the 18 cases that were in coma for 7 or more days were neurologically too impaired to be tested at 1 month post injury. Those with coma length of 1 to 6 days are not impaired on as many subtests as those with 7+ days of coma but are impaired on more subtests than the two milder groups. The same trend is to be noted at 1 year after injury as a function of length of coma. However, it should also be noted that the subgroups are impaired on fewer measures reflecting recovery of memory over time. These results also suggest the persistence to at least 1 year, of memory problems for those more severely injured, that is, in coma for greater than 1 day, and particularly for those in coma for more than 7 days. In contrast, the two milder groups appear comparable and are not significantly different from the group of uninjured subjects.

Finally, there also seems to be an effect due to the nature and difficulty level of the task. In general, the SRP appears to be a little more sensitive than the WMS to the severity level of head injury. Proportionally speaking, the head injury subgroups are significantly impaired on more of its components than on the components of the WMS (for example see the results for the 1-24 hours of coma group on the two measures at 1 month or for the 25 hour-6 day group at 12 months). With respect to the WMS, those components that are more robust or less affected are measures of orientation, concentration (i.e. mental control), and short term memory (i.e. digit span forward) while those more sensitive are those that are difficult and require storage into long-term memory (for example logical memory, delayed recall, hard

pairs of associate learning). With regard to the SRP, indices of short-term memory and recognition recall are the most robust while those requiring consistent retrieval from long-term memory are the more vulnerable.

(2) *The relationship between memory impairment and different indices of impaired consciousness.* Table 5 shows median performances on the sum of consistent long term retrieval of the SRP at 1 and 12 months after injury for the head injury group classified on the basis of TFC, PTA, and GCS obtained within 24 hours of injury. The results of these analyses suggest that impaired consciousness, irrespective of the index used, has an impact on memory. In terms of the specifics: (a) There is a systematic ordering of memory performance as a function of severity of impaired consciousness at 1 month. This relationship is much weaker at 1 year; (b) There is a substantial improvement in memory from 1 month to 1 year in all subgroups classified on the basis of the three indices of impaired consciousness. The greater the degree of impairment the greater is the room to improve and the greater is the magnitude of change; (c) By one

Table 5 Impaired consciousness sum of consistent longterm retrieval medians

Severity indices	1 month	1 year
<i>Time to Follow Commands</i>		
≥ 7 d	u*	39*
25 hr-6 d	25*	67‡
1-24 h	65‡	80
< 1 h	77	80
Controls	83	83
<i>Post-Traumatic Amnesia</i>		
≥ 14 d	0*	43*
7-13 d	71	83
1-6 d	66	74
< 24 h	76	80
Controls	83	83
<i>Glasgow Coma Scale</i>		
3-8	0*	45*
9-11	50‡	73
12+	66‡	79
Controls	83	83

Significance levels refer to comparisons between head injured and friend controls at 1 and 12 months.

* $p < 0.001$.‡ $p < 0.01$.‡ $p < 0.05$.

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year, with the exception of the most severe subgroup(s) within each of the classifications, the head injury subgroups are performing at or near the level of the comparison subjects. At 1 year roughly one third of the group within each of the classifications is significantly impaired in memory functioning.

Discussion

The results, consistent with reports in the literature and the common complaints of head injured patients, suggest that head injuries are associated with memory problems. However, the effect is not an all-or-none phenomenon. Many factors and their interactions influence the nature and severity of the problems observed. *Time* from injury to when the assessment is performed, the *nature* of the memory task, and the *severity* of the injury are all influential. Time reflects recovery. The longer the time since injury, the greater the amount of recovery and the less the magnitude of impairment. Head injured patients performed better at 1 year than they did at 1 month, the two time points selected for this study. The nature of the task, reflecting the demands placed on the individual, is also important in observing an impairment. Head injured patients were not equally impaired on various components of the measures used. Even though this was not the primary focus of the study, easy measures, and measures assessing certain processes, such as orientation, or short term memory, were less likely to identify a deficit than more complex measures and those involving storage of new information into long term memory. These observations are consistent with those previously reported in the literature.^{12 13} The influence of time or the nature of the task depend on the *severity* of the head injury.

Keeping *time* and the *tasks* constant, several severity indices were used to explore the degree to which they are associated with memory performance and whether or not they may provide reliable estimates of memory impairment. All three indices of impaired consciousness used, namely, time to following commands, PTA, and GCS within 24 hours of injury, are closely associated with memory outcome. The degree of this relationship, however, changes with time. The results in table 5 clearly show the increasing levels of memory impairment with increasing levels of impaired consciousness at 1 month after injury, irrespective of how impaired consciousness is defined. The relationship is a little more systematic for TFC and GCS than retrospectively assessed PTA. Even though the medians of all head injury subgroups classified on the basis of PTA were lower than for the comparison subjects, only the group with 14 or more days was reliably more impaired. With the other indices, each of the three subgroups with greater than 1

hour of coma and each subgroup based on GCS were performing reliably worse than the comparison group. This close association, however, disappears at 1 year so that only the subgroup(s) representing approximately one third of the total group and the most severely injured are reliably impaired. The ranges for this impairment are: TFC > 1 day, PTA ≥ 14 days, and GCS ≤ 8. For the rest of the subgroups, recovery and factors affecting recovery seem to take over. A familiar pattern, consistent with our earlier findings, is the magnitude of change as a function of head injury severity.¹⁴ The greater the degree of impairment, the greater the room for improvement, and the greater the amount of change. However, in spite of the magnitude of change, those who are initially most severely injured are also the ones who remain the most impaired. In other words, very severe cases improve a lot, but do not recover fully by 1 year.

A closer association between degree of impaired consciousness and behavioural outcome soon after injury as compared to later is an important observation which has also been previously reported by others. Klove and Cleeland¹⁵ reported a significant relationship between PTA and Halstead's Impairment Index within 3 months of injury but not later. Mandelberg¹⁶ found Wechsler Adult Intelligence IQ values to be related to PTA at 3 months and 6 months after injury but found no such relationship later. Disassociation of relationships seems to apply also to indices other than impaired consciousness. Levin *et al*² found focal lesions involving the left temporal lobe to be associated with verbal memory difficulties within 6 months after injury but not at 1 year. Such disassociation, unfortunately, does not seem to occur for the more severe diffuse injuries as reflected in the groups with deep or prolonged impaired consciousness, a finding consistent with those of Levin *et al*² and Van Zomeren and Van Den Burg.¹⁷

The results of the present study indicate that the time from injury to when the assessment is made, the nature of the task, the severity of the injury, and the interaction of these variables influence memory performance. Therefore, these variables need to be considered, controlled, or accounted for in studies of cognitive functioning, as well as, in the evaluation of the individual head injured case. Differences in the distribution of ranges of these variables in different studies need to be examined as potential causes for the inconsistencies in the literature regarding the relationship between severity and outcome or the relationship of time from injury to the testing of outcome.

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