CHAPTER 5. RESULTS AND DISCUSSION - INDIVIDUAL SUBJECTS

5.1. Preamble

As several researchers (Katz, 1992; Lezak & Gray, 1984; Ponsford, 1985; Wilson, 1987) point out, closed head injury is not a homogeneous diagnosis and this creates a problem in studying this population. Although all of the subjects included in the group data had had a very severe head injury, in that the length of PTA for each of them was greater than four weeks, the nature of their injuries was not identical. Some had sustained only diffuse damage while others had focal injuries in addition to the diffuse damage. Moreover, the focal injuries were not identical in each subject. Wilson (1987) argued that studying single subjects is often of value because individual differences can be masked in group studies. This was the case in this study where responses for a number of subjects deviated from the overall pattern. Therefore, it seemed important to look at individual subject results.

Data was also obtained for two subjects who were not included in the group results. The pattern of recovery from PTA was different for one of these subjects, in that amnesia and temporal orientation resolved simultaneously, thus she was tested on only three occasions instead of four. The second subject suffered a penetrating head injury, whereas all other subjects had sustained a closed head injury. Data for these

two subjects will be reported separately from those of the thirteen subjects who comprised the group.

5.2. RESULTS FOR INDIVIDUALS INCLUDED IN THE GROUP

Note 1: Although the median is considered to be a better index of central tendency, in the following results means were used on some occasions. This was due to the requirements of the statistical procedures used to analyse individual results.

Note 2: It is commonly believed that outcome after traumatic brain injury is affected by age. One of the subjects, M.R., was sixty three years old and his results were examined to determine whether his pattern of performance was different from that of the other subjects. His results and the pattern of his recovery were similar to several other subjects and where his results are shown individually in the following tables they have been marked thus (#) to allow the reader to identify them.

5.2.1. ATTENTION: PATTERNS ACROSS TEST OCCASIONS

5.2.1.1. Results

To examine the results of individual subjects the twenty one responses for each test occasion were converted to log 10. The conversions were necessary because the distribution was positively skewed and this transformation resulted in the distribution being more symmetrical to fit the requirements of analysis of variance tests. A Oneway ANOVA was performed to determine whether there were significant differences between test occasions and a post hoc Bonferroni was then applied. because of the multiple comparisons, to avoid making a Type I error.

There was a highly significant improvement between Test Occasions 1 and 2 for all subjects. However, four of the thirteen subjects did not improve significantly between Occasions 2 and 3. When Occasion 3 was compared with Occasion 4, the majority (9) showed no improvement, that is, attention plateaud once they came out of PTA. The group result, however, had indicated a statistically significant improvement between these two test occasions, albeit smaller than the improvements demonstrated between the first three occasions. Because the group comparison for Occasions 3 and 4 did not appear to be reflecting the individual differences in results it was decided to examine the data further.

It was not possible to submit the data of one subject to further analysis because of some missing data for Occasion 3 due to printer malfunction. (Scores for the first five responses as well as the mean and median of the twenty one responses were printed, which was sufficient information to include this subject's data in earlier analyses.) Thus, further analysis examining changes for individuals between Occasions 3 and 4 were carried out for twelve subjects.

Individual responses from Occasion 3 were paired with corresponding responses for Occasion 4 for each subject and a Wilcoxon Matched-Pairs Signed-Ranks test, which is suitable for use with repeated measures, was carried out. With this comparison six subjects (one of whom was the sixty three year old) showed a statistically significant change between the last two occasions of testing while six subjects did not. These results are shown in Table 5.1. on the following page.

Table 5.1. Changes in speed of reaction time between Test Occasions 3 and 4

Subjects showing significant change:

Subject	z score	p =
J.Z.	-4.0145	0.0001
M.R.#	-3.1919	0.0014
H.K.	-3.4083	0.0007
O.L.	-3.2672	0.0011
C.C.	-3.5279	0.0004
L.A.	-3.4931	0.0005

Table 5.1. Changes in speed of reaction time between Test Occasions 3 and 4 (cont.) Subjects showing non-significant change:

Subject	z score	p =
F.G.	-1.8109	0.0702
M.P.	-0.224	0.8228
K.C.	0.0000	1.0000
B.W.	-1.0826	0.2790
P.R.	-0.8928	0.3720
A.E.	-1.4483	0.1475

While the Wilcoxon Test showed significant changes between Occasions 3 and 4 for six subjects, Bonferroni tests demonstrated significant change for only four subjects. Therefore, further statistical procedures were carried out to validate results. T-tests were applied to the data, and randomisation tests were also used to establish significance levels. They confirmed a significant change for the six subjects. Reaction times and memory scores across the four test occasions have been plotted on graphs for each subject and are shown in Appendix 5.

5.2.1.2. DISCUSSION

The above discrepancy in results may have arisen because the Wilcoxon and the T-tests were based on **paired** individual responses for the two test occasions whereas the ANOVA and Bonferroni post-hoc tests were not.

When the results of the two subjects who showed significant change only on the Wilcoxon Test were plotted on a graph, the changes from Occasion 3 to 4 were miniscule in comparison with the changes over the first three occasions and were unlikely to be of clinical significance. (One of these subjects was the sixty three year old). As Wilson (1987) points out **statistical** significance does not necessarily indicate **clinical** significance nor does the reverse necessarily apply. Taking the

results of these two subjects and the seven subjects who showed no change from Occasion 3 to Occasion 4, one could argue that reaction time did not improve significantly in a clinical sense, for the majority of subjects, once they emerged from PTA.

The four subjects who showed a significant improvement between Occasions 3 and 4, on all of the statistical tests, were examined to determine whether there were any common features. All of them had a PTA duration of less than eight weeks. All but one of the subjects whose performance plateaud between the last two test occasions had a PTA duration of more than 8 weeks, ranging from 70 to 144 days.

As discussed in section 1.3. Bishara et al. (1992) have suggested that classification of head injury severity based on PTA should be redefined, placing those with a PTA duration of more than 8 weeks into a separate category. In their study patients in the latter category had a poorer outcome at 12 months post-trauma than those with a PTA of less than 8 weeks.

None of the subjects in this study, with a PTA duration of more than 8 weeks, improved significantly on the reaction time task once they emerged from PTA. However, some of them **did** continue to improve on the memory task when they were out of PTA.

As discussed earlier, some patients with very severe head injuries are unable to achieve a perfect PTA score due to chronic severe memory impairment, which makes it difficult for them to remember such details as the day of the week. Others have a language impairment which interferes, for example, with the ability to learn the name of the therapist and so prevents them from achieving a perfect score. Thus, in such cases the PTA scale is an imperfect tool and the measurement of speed of reaction time could prove a useful alternative given that the above results support the hypothesis that significant improvement in reaction time may provide a better indicator of the resolution of PTA than changes in memory.

5.2.2. Attention : Variability of Performance

5.2.2.1. Results

The question of whether or not variability is a function of speed has been raised (Stuss et al. 1994). The findings of a study of **mild** head-injured subjects were suggestive of a dissociation between speed and variability (MacFlynn et al. 1984) but as Stuss et al. point out this question has not been addressed in a severely head injured group. When the performances of individual subjects in this current study were examined results appear to support the hypothesis that variability is not a function of speed.

Subject F.G. had the slowest speed of the group on Occasion 1 with a median score almost twice that of the subject with the next slowest score but his standard deviation was the second smallest of all subjects. Moreover, although his speed improved significantly across the first three test occasions his standard deviation did not follow this pattern, particularly on Occasion 2 where his speed improved dramatically but his standard deviation **increased.** These scores are illustrated in Table 5.2 .

Table 5.2. Subject F.G. Reaction time scores for each trial

Test Occasion	**Median**	**Std.Dev.**
	(seconds)	
1	7.12	0.360
2	1.98	0.553
3	0.71	0.272
4	0.48	0.243

Similarly, Subject E.A. was very slow on Test Occasion 1 and there was a significant improvement in speed on Occasion 2 but the standard deviation on this latter occasion was greater than on the first. Results for two other subjects were

incongruent in that speed and variability did not follow similar patterns of improvement. Subject B.J. had similar reaction times for Occasions 1 and 2 but his standard deviation on Occasion 2 was almost four times larger than on the first occasion. The pattern of reaction times for subject H.K. were unusual in that reaction times for Occasions 1 and 3 were very similar with a slower median score on Occasion 2. Moreover, his standard deviation gradually increased over the first three occasions rather than decreasing as one would expect.. See Table 5.3. for scores for these three subjects.

Table 5.3. Reaction time scores - medians and standard deviations

	E.A.	**E.A.**	**B.J.**	**B.J.**	**H.K.**	**H.K.**
Test Occasion	**Median (secs.)**	**Std. Dev.**	**Median (secs)**	**Std. Dev.**	**Median (secs.)**	**Std. Dev.**
1	3.73	0.425	0.73	0.432	0.45	0.159
2	1.005	0.751	0.54	1.601	0.98	0.175
3	0.40	0.175	0.40	0.085	0.40	0.20
4	0.37	0.048	0.45	0.056	0.34	0.066

Examining the change between Test Occasions 3 and 4, there were four subjects who showed no significant improvement in reaction times but did show a marked reduction in the size of the standard deviation. These results are summarised in Table 5.4.

Table 5.4. Changes in speed and variability between Test Occasions 3 and 4

	M.R. #	M.R. #	M.P.	M.P.	P.R.	P.R.	E.A.	E.A.
Test Occasion	Median (secs.)	S.Dev.	Median (secs.)	S.Dev.	Median (secs.)	S.Dev.	Median (secs.)	S.Dev.
3	0.59	0.137	0.71	0.316	0.37	0.314	0.4	0.175
4	0.51	0.095	0.73	0.126	0.34	0.091	0.37	0.048

Further evidence in support of a dissociation of speed and variability are results from four subjects who had large standard deviations on Occasion 1. All had a significant improvement in reaction times of similar magnitude on Occasion 2, however, the improvement in variability was not of the same proportion for all four subjects.

Two subjects (C.C. and L.A.) had a much larger reduction in the size of the standard deviation than the others (P.R. and M.P.) did. These scores are shown in Table 5.5.

Table 5.5. Changes in speed and variability between Test Occasions 1 and 2

	C.C.	C.C.	L.A.	L.A.	P.R.	P.R.	M.P.	M.P.
Test Occasion	Median (secs.)	S.Dev.	Median (secs.)	S.Dev.	Median (secs.)	S.Dev.	Median (secs.)	S.Dev.
1	1.44	2.052	1.69	2.313	1.05	2.043	2.06	1.205
2	0.71	0.177	1.3	0.418	0.48	1.541	1.05	0.882

Boxplots have been drawn for each subject to illustrate the shape of the distribution of reaction times (see Appendix 6).

5.2.2.2. DISCUSSION

When the results are examined there appears to be no uniform pattern of resolution of speed and variability. Three points emerged:

- the slowest reaction times were not always linked with the largest standard deviation
- a reduction in reaction time was not always associated with a corresponding reduction in the size of the standard deviation, and at times was accompanied by an **increase** in variability
- when some subjects emerged from PTA their reaction times plateaud but the standard deviation decreased markedly.

These results, therefore, seem to support the hypothesis that there is a dissociation between speed and variability in some patients.

5.2.3. Idiosyncratic patterns of performance

5.2.3.1. Results

When the overall pattern of performance across test occasions was examined for individual subjects there were several subjects whose performance was different from the majority, illustrating the fact that it is difficult to make general assertions about head-injured patients because they are not a homogeneous group.

The performance of two subjects (B.J. and H.K.) did not improve on the second occasion whereas for all other subjects there was a marked reduction in reaction times between the first two occasions.

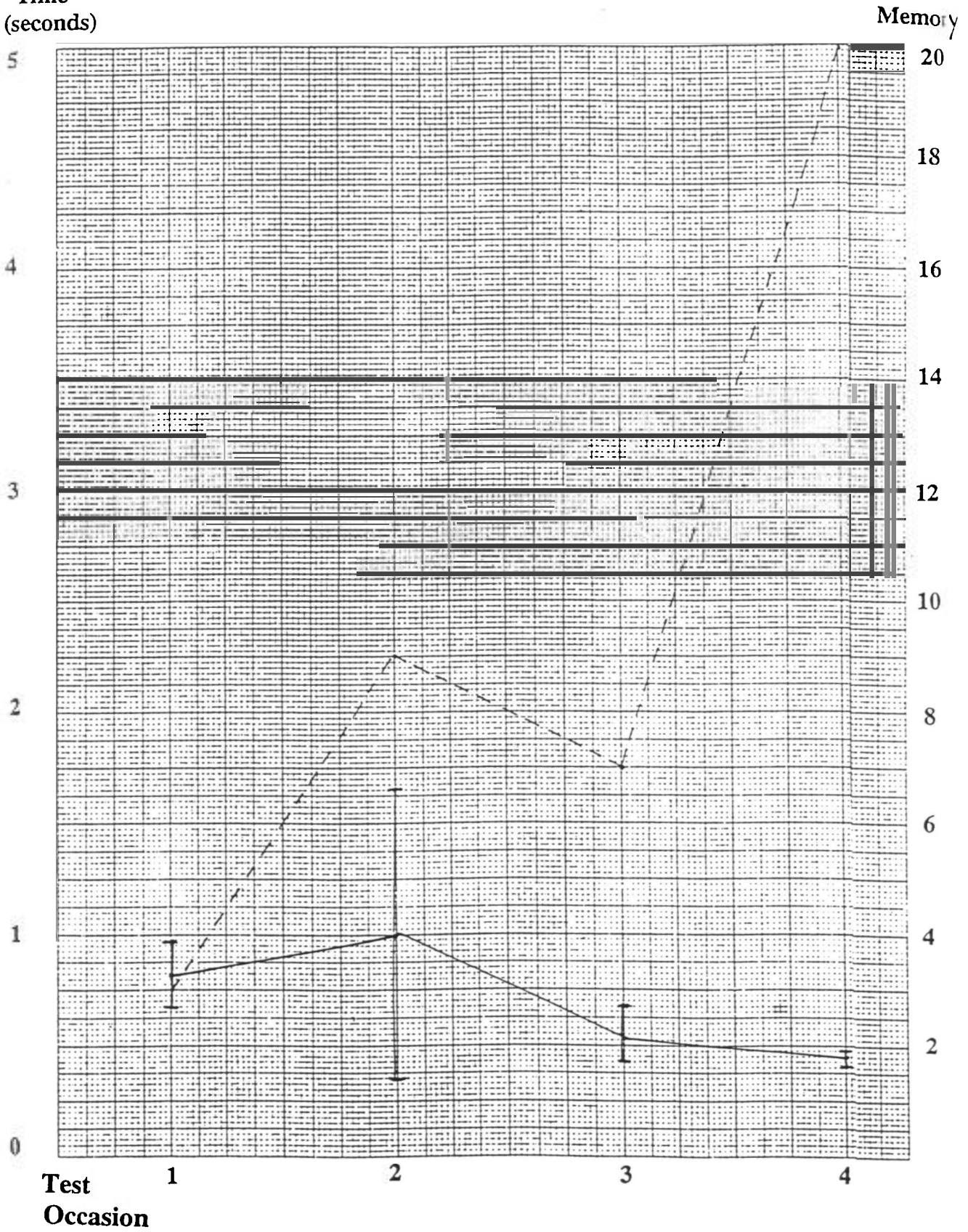
Subject B.J.

Subject B.J. not only showed no improvement in speed on Occasion 2 but the standard deviation on this occasion (1.601) was almost four times greater than on Occasion 1(0.432). In contrast, the group as a whole became more consistent on Occasion 2 with a standard deviation 2.4 times smaller than on the first occasion of testing. However, the median reaction time for B.J. on Occasions 1 and 2 was faster than for most other subjects. His pattern of performance on the Rivermead Behavioural Memory Test was also unusual in that he was the only one whose

memory score did not improve on Occasion 3, which is the point at which he emerged from PTA. These results are illustrated in Figure 5.1.

Figure 5.1. SUBJECT: B.J.

REACTION TIME AND MEMORY TASKS



Subject H.K.

Subject H.K.'s median reaction time on Occasion 2 was twice as slow as on the first occasion. This was in complete contrast to the other subjects who all demonstrated a significant improvement in reaction time on Occasion 2. (Subject B.J.'s performance was more variable on Occasion 2 but not slower). There is no apparent explanation for this pattern of results. The subject was not taking any medication during the period in which he participated in the study. According to the medical notes nothing of importance happened to the patient, on the day on which the second occasion of testing was conducted, which could account for his slower performance. His period of PTA. was unremarkable other than that it resolved relatively quickly; there was an interval of only 4 days between Occasion 2 (the point at which he remembered the pictures on the PTA scale) and Occasion 3 (the point at which PTA ended). However, this would more likely support an enhanced performance on Occasion 2 rather than a poorer one.

An interesting feature of H.K.'s performance on Test Occasion 1 was that, in terms of speed, he was considerably faster (0.450 secs.) than the group median (1.920 secs.) and his median score was as fast as that achieved by most other subjects on Occasion 3, the point at which PTA ended. On Occasion 2, although he performed more poorly than on the first occasion, his median score (0.980) was only marginally slower than the group median (0.880). The variations in performance seen in most

other subjects was not observed in H.K., whose standard deviations for the first two test occasions were much smaller than for the majority of subjects (see Table 5.6). Performance on the reaction time task, over the four occasions, is illustrated in Figure 5.2. preceding Table 5.6.

Figure 5.2. SUBJECT: H.K.

REACTION TIME AND MEMORY TASKS

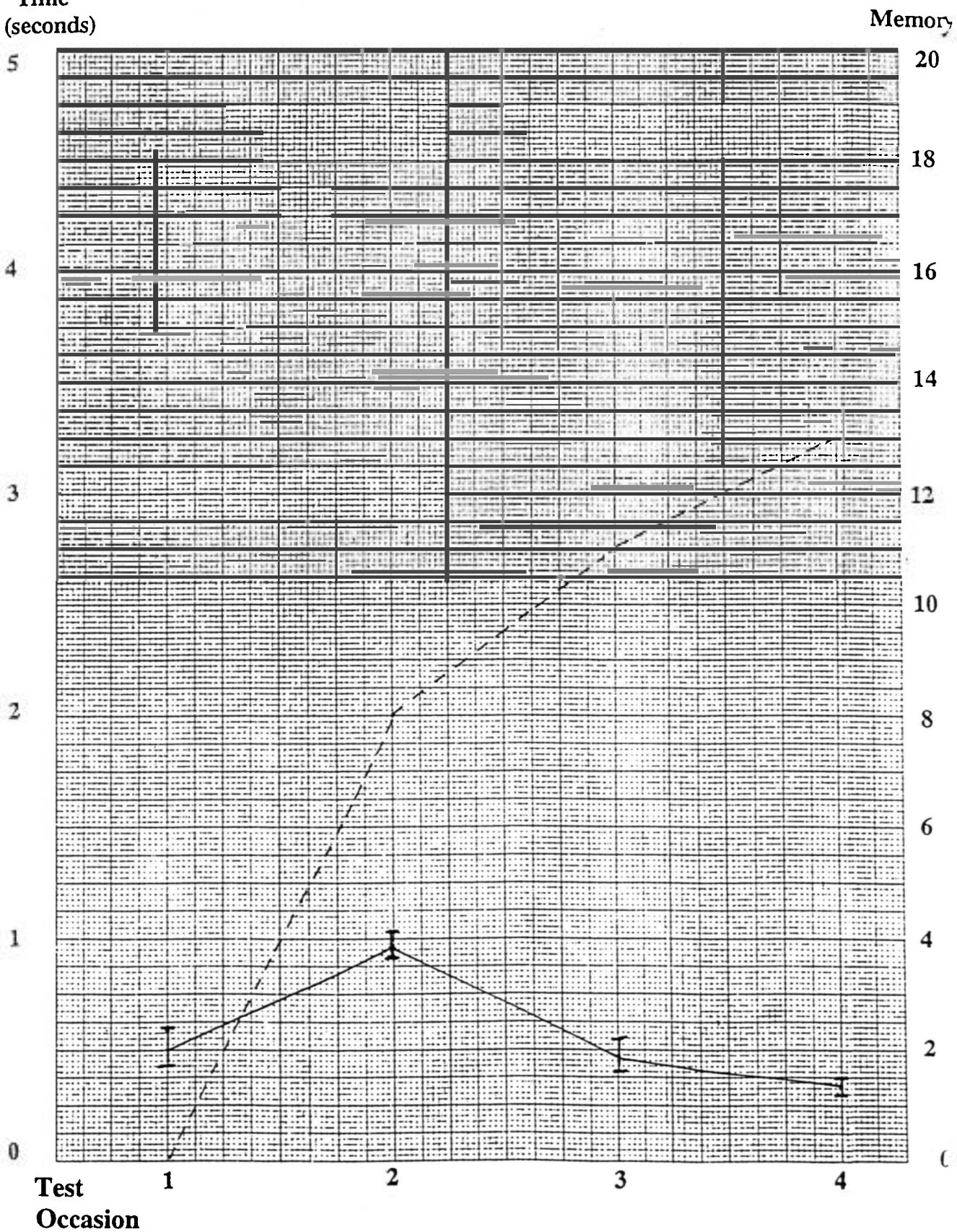


Table 5.6. Comparison of standard deviations - Subject H.K. with group

Test Occasion	Subject H.K.	Group
1	0.159	2.208
2	0.175	0.915
3	0.200	0.335
4	0.066	0.173

Subject K.C.

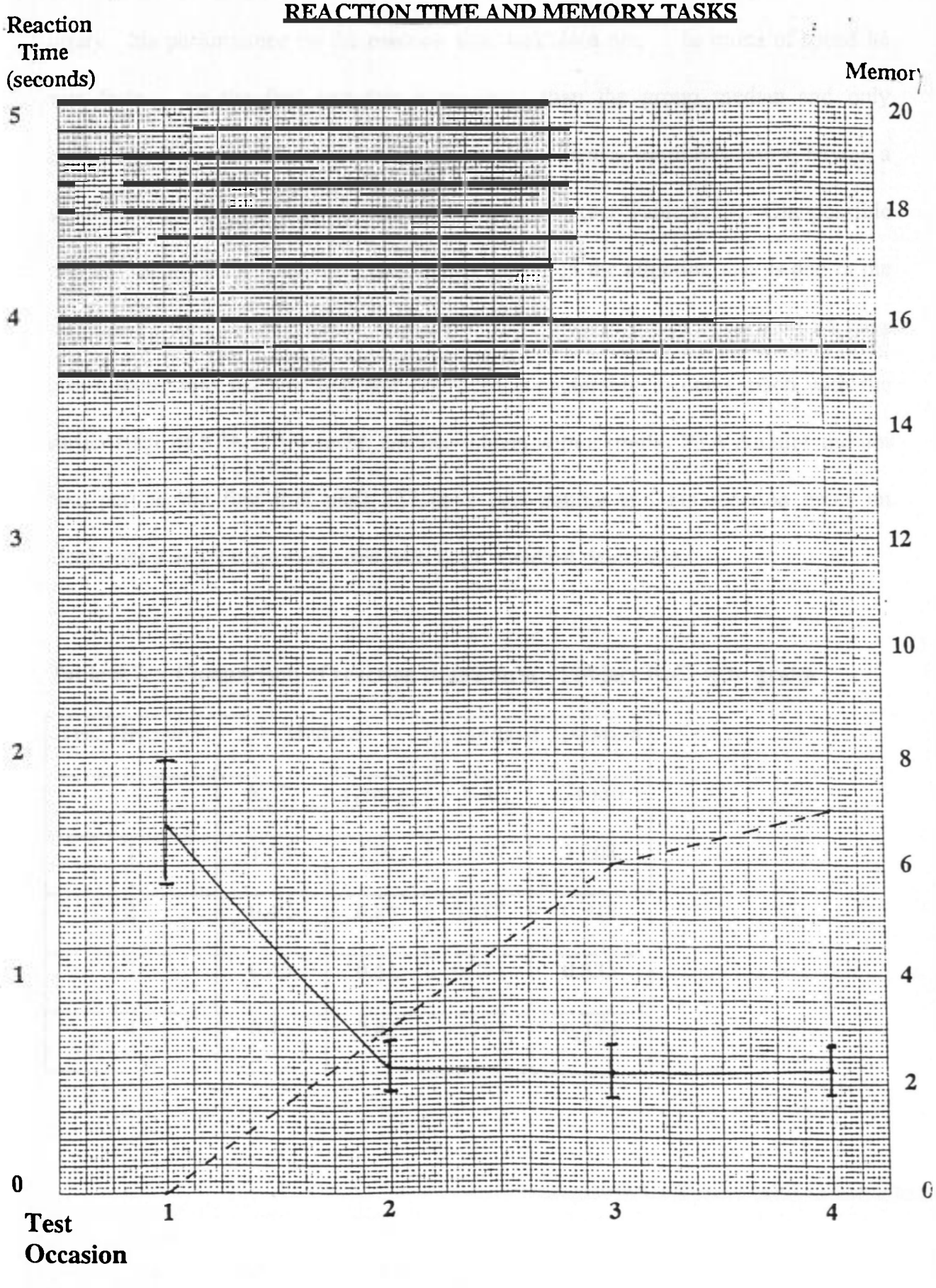
A third subject whose pattern of recovery, in terms of performance on the attention task, was different from the group pattern was subject K.C. who was one of the most severely injured subjects in terms of the duration of PTA. A description of his behaviour during PTA is given at this point because it will be argued that it possibly had some bearing on his performance in the study. This nineteen year old patient was extremely agitated during the early stages of PTA. and paced around the ward continuously. It was not possible to begin assessing PTA. until 22.4.92 (62 days post-trauma) as he was too agitated to pay attention to the questions. Once the daily assessments of P.T.A. began it was necessary to question him while he walked

about as it was not possible to get him to sit down for more than approximately ten seconds at a time. He would continue walking to the point of exhaustion then lie down and sleep.

On 18.5.92, 88 days post-trauma, it was possible to test him for the first occasion of the study. Post- traumatic amnesia continued to resolve slowly; it was another 31 days before Test Occasion 2 could be conducted whereas the average interval between Occasions 1 and 2 for all subjects was 11 days. However, the interval between Occasions 2 and 3 for this subject was 14 days which was the group average.

This subject was the only individual whose performance on the attention task, in terms of both speed and consistency of performance, plateaud on the second occasion. Reaction times improved significantly between the first two occasions even though the speed at which he responded on Occasion 1 was presumably faster than it would have been had it been possible to test him at an earlier point during post-traumatic amnesia. His performance on the memory test was also depressed and there was no significant improvement, as there was with most subjects, once he emerged from PTA. See Figure 5.3. for attention and memory scores over the four test occasions..

Figure 5.3. SUBJECT: K.C.



While his memory score on Test Occasion 4, placed him in the 'severely impaired' range on the Rivermead Behavioural Memory Test and reflects the severity of his injury, his performance on the reaction time task does not. In terms of speed he was faster, on the first two test occasions, than the group median and only marginally slower on Occasion 4. Moreover, he was also more consistent, having a smaller standard deviation on the first three occasions (see Table 5.7.). One possible explanation is that his relatively good performance on the attention task is due to the fact that he could not participate in the first test occasion of the study until 88 days post-trauma, thus his attention had improved considerably in comparison with the earlier stage of PTA. However, another subject with a similar PTA duration did not take part in the first trial until 117 days post-trauma and his reaction times on Occasions 1 and 2 were very slow with large standard deviations.

Table 5.7. Comparison of reaction time scores - Subject K.C. with group

Test Occasion	Median		Standard deviation	
	K.C.	Group	K.C.	Group
1	1.58	1.92	0.657	2.208
2	0.42	0.88	0.288	0.915
3	0.45	0.51	0.271	0.335
4	0.45	0.42	0.293	0.173

5.2.3.2. DISCUSSION

When individual performances over time were examined an interesting feature was observed. Speed on the reaction time test did not always appear to be related to the length of PTA. On the first two test occasions two subjects with relatively short PTA durations (29 days and 42 days) had the longest reaction times while subject K.C. with a PTA duration of 131 days had reaction times which were faster than the group median. However, on Occasion 4, which was conducted approximately 3 weeks after subjects emerged from PTA, all of the subjects were performing at a similar level in terms of speed, although there was still some variation in the level of consistency.

5.3. Data not included in the group results.

There were two subjects whose data could not be included in the group results.

5.3.1. SUBJECT M.A.

Subject M.A. was not included in the group because the pattern of resolution of PTA. was different from all other subjects. Whereas the usual pattern was that subjects first began making memories, as measured by the PTA scale, and later became oriented for time, this subject's ability to recall the pictures and her temporal disorientation resolved simultaneously. This resulted in her being tested on only three occasions instead of four. Test Occasion 2 for this subject was the equivalent of Test Occasion 3 for other subjects and Occasion 3 (for M.A.) was the equivalent of Occasion 4.

The length of PTA., which was 20 days, was much shorter than for any other subject in the study (the range being 29 - 144 days). Jennett (1976) states that a PTA. duration of 1 to 4 weeks indicates a very severe head injury but that a period of more than 4 weeks is indicative of an extremely severe head injury. Subject M.A. falls into the former category while the remainder of the subjects fall into the latter.

Characteristics of Subject M.A.

Age at injury: 36 years

Date of injury: 11.8.91 Type of accident: Motor vehicle (passenger)

L.O.C.: 12 hours P.T.A.: 20 days

5.3.1.2. Results - Attention

To examine the results of individual subjects the twenty one responses for each Test Occasion were converted to log 10 before performing a Oneway ANOVA and a post-hoc Bonferroni test. The conversions were necessary because the distribution was positively skewed and this transformation to log 10 resulted in the distribution being more symmetrical.

The Oneway ANOVA showed significant differences between test occasions ($X = 144.5631$, $p < .0001$). The Bonferroni post-hoc test showed that there was no significant improvement in reaction time over the 4 day interval between Occasions 1 and 2. As stated earlier, Occasion 2 was the point at which Subject M.A. emerged from PTA and was the equivalent of Occasion 3 for the other subjects. Test Occasion 3 (the equivalent of Occasion 4 for other subjects) was

carried out 9 days later*. Between Test Occasions 2 and 3 there was a significant improvement in reaction time. (See Table 5.8.)

* The last test occasion was conducted soon after the second because the patient was about to be discharged from hospital and there was a risk that she might not return to participate in the final test occasion of the study.

Table 5.8. Modified LSD (Bonferroni)

(significance level .05)

Subset 1		
Group	Group 3	
Mean	-.3497	
Subset 2		
Group	Group 2	Group 1
Mean	.3905	.3395

Median scores for each occasion were also examined and it was found that the scores on the first two occasions were slower than the group median. On Occasion 3 her median score was equivalent to that of the group. (See Table 5.9.)

Table 5.9. Comparison of median scores - Subject M.A. with Group

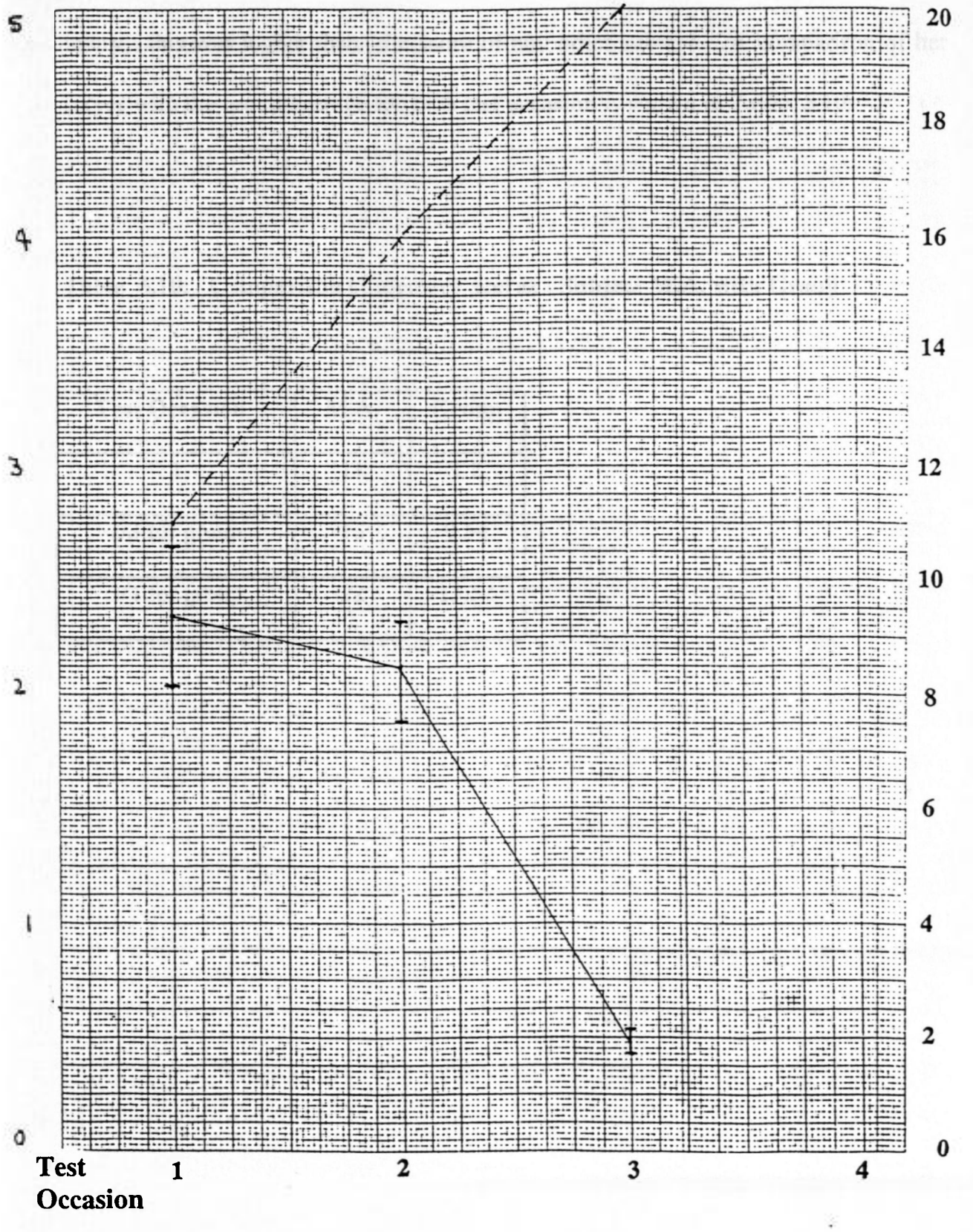
	M.A.	Group
Test Occasion	**(secs.)**	**(secs.)**
1	2.59	2.94
2 / 3 for group	2.94	0.54
3 / 4 for group	0.43	0.45

5.3.1.3. Results - Memory

Results on the Rivermead Behavioural Memory Test also differed from the other subjects but, unlike her reaction times, these results reflected the lesser severity of her injury. As depicted in Figure 5.4. (on the following page) she achieved a score of 11 on Occasion 1 which was slightly above the average score for the group on Occasion 3 (the point at which they emerged from PTA). Her high total score was mainly due to her perfect scores on the subtests measuring recognition memory.

Figure 5.4. SUBJECT: M.A.

REACTION TIME AND MEMORY TASKS



Test Occasion 2 saw her score improve to 16 which was higher than the group score achieved on Occasion 4. Nine days after coming out of PTA she achieved 22 out of a maximum 24 points. As one would expect, given the lesser severity of her injury, this was higher than the score of any other subject. A comparison of her scores with the group average for each test occasion is shown in Table 5.10.

Table 5.10. Comparison of memory scores - Subject M.A. with Group

Test Occasion	M.A.	Group
1	11	1.2
2/3 for group	16	9.54
3/4 for group	22	13.54

5.3.1.4. Discussion.

Results for this subject differed markedly from the pattern of results shown for other subjects in the study, both on the attention task and the memory task. There was no improvement in reaction times between the first two test occasions unlike the majority of other subjects who showed a dramatic improvement during this interval. Furthermore, M.A.'s performance on Occasion 3, which was carried out 9 days after emerging from PTA, improved markedly whereas the majority of subjects in the study showed no significant improvement in reaction times once they emerged from PTA.

Another interesting feature was that although this subject had a less severe injury than the others in the study her reaction times were slower than the group median on the first two occasions. However, on the final test occasion her time was equivalent to the group median .

She achieved much higher memory scores than the other subjects on every occasion of testing which probably reflects her less severe injury. However, this does not explain why her initial reaction time scores were so much slower . In an effort to find an explanation for these scores the results of individual subjects were examined. While M.A.'s scores for Occasion 1 were much slower than the **group** it was evident

that she was not slower than every other individual. Moreover, there was no correlation between length of PTA and performance on the reaction time test. The subjects with the longest duration of PTA did not have the slowest times. Thus, it may be that it is the presence of PTA rather than the severity of the injury (once PTA duration is more than seven days) that accounts for slow reaction times. However, while this is a plausible account for her performance on Occasion 1 it does not explain scores on Occasion 2 (where M.A. emerged from PTA as defined by the PTA scale) which were **slower** than for every other individual. This raises the question of whether full orientation, i.e. the end of PTA, was the most useful indicator of recovery in her. A purely speculative hypothesis is that somehow her relatively superior memory ability compensated for her slowed processing and enabled her to learn the orientation items in rote fashion.

It is impossible to tell whether she is an aberrant case or whether less severely injured patients have a different recovery pattern, thus future research should explore whether all subjects in whom memory and orientation resolve simultaneously exhibit the same pattern of performance.

5.3.2. SUBJECT N. B.

5.3.2.1. Preamble

Subject N.B. was not included in the group results because she suffered a penetrating head injury, whereas all the other subjects sustained a closed head injury. However, her results are presented to highlight the differences in recovery and performance between the two types of head injury. With a penetrating head injury the amount of energy behind the blow is the principal determinant of damage. Most of the literature on penetrating injuries refers to gunshot wounds whereas this injury was inflicted with a sharp pointed instrument; thus the force of the blow would presumably be different from a gunshot wound. Moreover, such an injury usually produces focal injuries, therefore, the location of the injury is important. While a closed head injury can result in focal damage, diffuse axonal injury is the most common feature whereas this is rare in high velocity penetrating injuries (Grafman & Salazar 1987).

One could argue that post-traumatic amnesia for this patient was not typical in that people in PTA usually appear to be unaware that they are amnesic and have very impaired attention. This was not true of Subject N.B. who continually asked questions about where she was and what had happened to her. Furthermore, she

constantly referred to a calendar she had at her bedside in an effort to remain oriented. Moreover, she demonstrated no problems with concentrating on tasks.

The term PTA refers to a temporary state which eventually resolves as recovery takes place and the person begins to make day to day memories. The penetrating injury caused focal injuries in the area of the fornix and this patient remained in a chronic state of amnesia. She was able to achieve temporal orientation (except for day of the week), learn the name of the therapist and recall the three pictures which meant that, technically, she was out of PTA according to the PTA scale. However, she did not have continuous memory and could not remember from day to day what she had done, due to her chronic severe memory impairment. She did appear to make some memories but these were so fragile that she doubted the veracity of them as memories and often referred to them as "dreams". Whether she experienced a period of "true" post-traumatic amnesia is difficult to establish. After patients emerge from PTA they have no memory of the period. Subject N.B. did appear to have some memories of this period even though she doubted them as memories and reported incidents as dreams.

Characteristics

Age at time of injury: 23 years

Date of injury: 24.3.94 Type of accident: Assault

L.O.C.: No information P.T.A.: 80 days

5.3.2.2. Results - Attention

There was a significant improvement on the reaction time task between Test Occasions 1 and 2. However, her pattern of responding on Occasion 1 was quite different from that of the other subjects. This subject responded slowly to the first four stimuli which was due to her dividing her attention between watching the screen and simultaneously asking me why she could not remember things. However, when she was asked to concentrate on the task she appeared to settle down and responded at a much faster and consistent rate to the remainder of the stimuli. The relatively slow mean reaction time for the first occasion was because of these first four responses. Because of this unusual pattern statistics were computed for the full set of reaction times for Occasion 1 and for reaction times minus the first four responses. When the first four scores were eliminated there was no significant difference between Occasions 1 and 2 or between Occasions 2 and 3. Because there

was a slight improvement over test occasions there was a significant difference between Occasions 1 and 4. Table 5.11. shows statistics for the full set of reaction times for Occasion 1 and Table 5.12. presents reaction times minus the first four scores.

Table 5.11. Modified LSD (Bonferroni) (including first 4 responses)

(significance level .05)

Subset 1			
Group	Group 4	Group 2	Group 3
Mean	- .4505	- .4194	- .3817

Subset 2	
Group	Group 1
Mean	- .2403

Table 5.12. Modified LSD (Bonferroni) (excluding first 4 responses)

(significance level .05)

Group	Group 4	Group 2	Group 3	Group 1
Mean	- .4505	- .4194	- .3817	- . 3407

N.B.'s performance was much more consistent over time than that of the group. On Occasion 1 her standard deviation, even when the first four responses were included, was almost five times smaller than the standard deviation of the group and when the 4 responses were excluded her standard deviation was 22 times smaller. Although the group became more consistent on Occasion 2 the standard deviation was still nine times greater than that of N.B. On Occasions 3 and 4, where all subjects had emerged from PTA, her scores were comparable with those of the group. A comparison of these measurements is presented in Table 5.13.

Table 5.13. Comparison of standard deviations - Subject N.B. with Group

Test Occasion	N.B.	Group
1 (incl. first 4 responses)	0.452	2.208
1 (excl. first 4 responses)	0.101	2.208
2	0.098	0.915
3	0.199	0.335
4	0.045	0.173

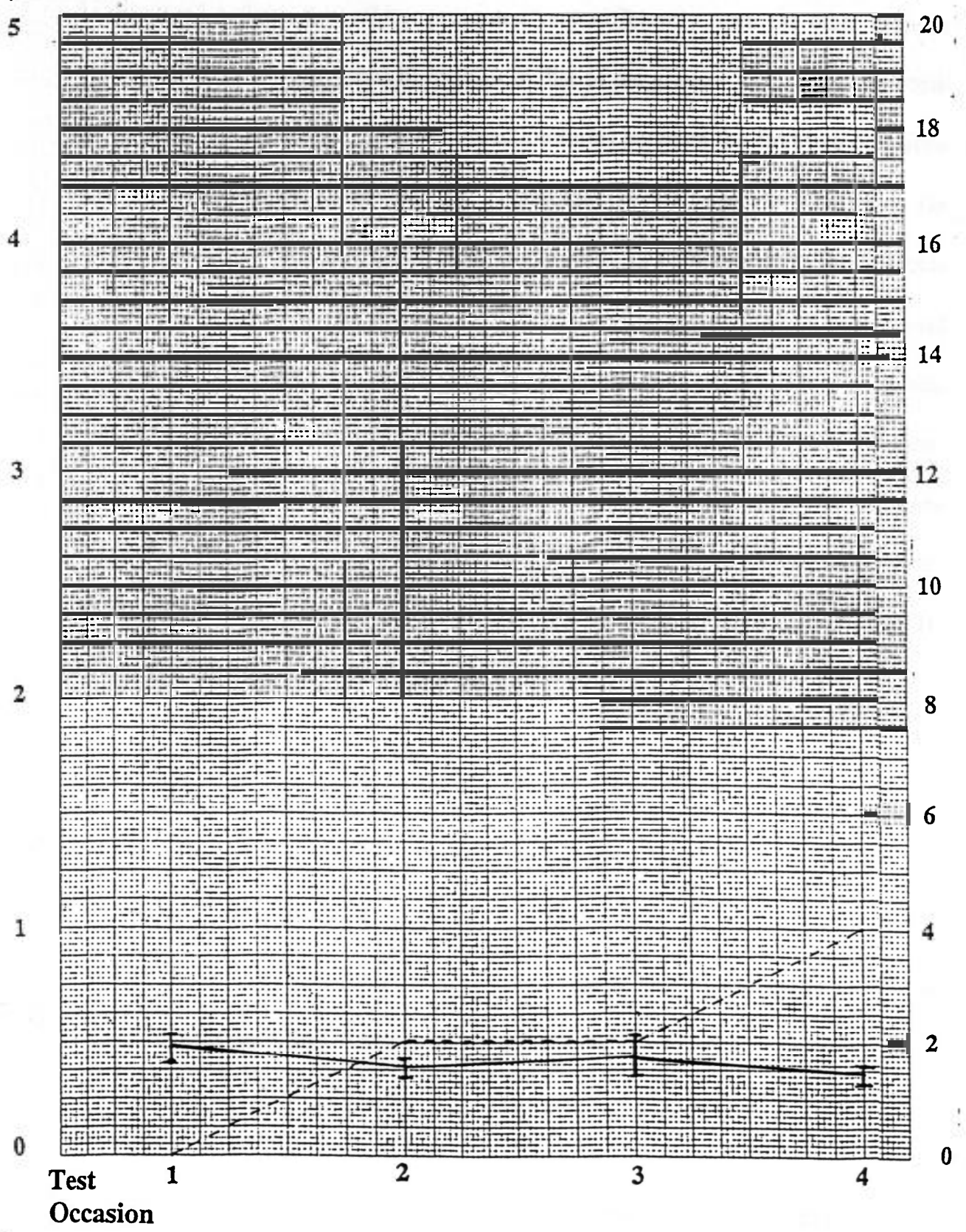
On Occasion 4 the consistency of Subject N.B.'s performance was at the same level as the control group.

5.3.2.3. Results - Memory

As can be seen in Figure 5.5. (following page) there was a slight improvement in memory between the first two test occasions. This was mainly on the subtest measuring prospective memory. No improvement was recorded between Occasions 2 and 3 but there was another slight improvement on the last occasion. This low level of improvement reflects this subject's chronic amnesia and the scores she achieved were much lower than for other subjects who demonstrated severely impaired new learning on neuropsychological testing.

Figure 5.5. SUBJECT: N.B.

REACTION TIME AND MEMORY TASKS



5.3.2.4. Discussion

As discussed earlier, this subject presented very differently from the other subjects and her pattern of recovery was in contrast to that of the group. On the attention task there was no dramatic improvement in reaction times between the first two occasions as there was for the group and her performance was relatively consistent (as measured by the standard deviation) over all trials. In contrast, the other subjects were very inconsistent in their responses within a test occasion; they did not respond slowly at first then speed up but had a haphazard mixture of fast and slow responses, without any pattern, throughout the session. Perhaps it could be hypothesised that the extreme slowness and the variability in performance, which may be due to lapses in vigilance as argued by MacFlynn et al. 1984, is related to the diffuse axonal injuries of the other subjects. This pattern was not demonstrated by subject N.B. because her injuries were distinctly focal.

5.4. Results for individual subjects at least six months post - Test Occasion 4.

5.4.1. Preamble

Initially it was not intended to follow up subjects beyond the fourth test occasion. However, it became apparent when looking at preliminary results that some subjects were not improving, in terms of their reaction times, between Test Occasions 3 and 4. This led to the consideration that perhaps the reaction times of severely head injured patients do not improve significantly, once they emerge from PTA. In further support of this hypothesis was some work which was done with one of the subjects from this study. As part of a clinical project carried out by myself and a colleague in the Head Injury Unit, this subject carried out the reaction time task once a day, 5 days a week for 8 weeks and showed no improvement at the end of this period. (This work was done some months after the subject had been tested for this study, therefore, there was no influence on his test results).

On the basis of the above findings, it was decided to follow up subjects, where possible, at least 6 months after they had completed test occasion 4, to see whether there was any improvement in reaction times. This data could only be collected for 6 subjects for a number of reasons. One subject had died, two had moved from the area, one subject was not approached because he was clinically depressed, one subject did not wish to participate further because it was inconvenient for him to

return to the hospital and there were two subjects for whom the six month period had not elapsed at the time the study ended.

The six subjects were followed up and each retested once on the reaction time task at times ranging from 6 to 12 months after they had completed Test Occasion 4. It was decided not to repeat the Rivermead Behavioural Memory Test because some subjects obtained scores on Occasion 4 which were very close to the maximum. Thus, this test would not have been sensitive to further improvements in memory. However, continuing improvements in memory were noted on neuropsychological assessments which were carried out for clinical purposes.

5.4.2. RESULTS.

Median scores and standard deviations were examined for Test Occasion 5. There were only slight improvements in median reaction times between Occasions 4 and 5 as can be seen in Table 5.14.

Table 5.14. Median scores for all test occasions

Subject	Test Occasion 1	Test Occasion 2	Test Occasion 3	Test Occasion 4	Time post-T.O.4	Test Occasion 5
	(seconds)	(seconds)	(seconds)	(seconds)	(months)	(seconds)
M.R.#	1.69	1.07	0.59	0.51	7	0.40
O.L.	3.79	0.71	0.48	0.4	12	0.34
P.R.	1.05	0.48	0.37	0.34	8	0.34
B.J.	0.73	0.54	0.44	0.45	6	0.42
B.W.	2.32	0.48	0.40	0.37	10	0.31
K.C.	1.58	0.42	0.45	0.45	8	0.34

The standard deviation was much smaller on Test Occasion 5 for two of the subjects and had improved slightly for a further three subjects. However, subject B.J. was more variable on Occasion 5 with a standard deviation twice as large as that on Occasion 4. Throughout the study his performance was one of the most inconsistent; on Occasion 2 where most other subjects had improved in terms of consistency his

standard deviation was four times greater than on Occasion 1. Standard deviations for all subjects are shown in Table 5.15.

Table 5.15. Standard Deviations for all test occasions

Subject	Test Occasion 1	Test Occasion 2	Test Occasion 3	Test Occasion 4	Time-post T.O. 4 (months)	Test Occasion 5
M.R.#	1.327	0.680	0.137	0.095	7	0.087
O.L.	2.189	0.576	0.066	0.071	12	0.060
P.R.	0.159	0.175	0.200	0.066	8	0.042
B.J.	0.432	1.601	0.085	0.056	6	0.117
B.W.	0.907	0.165	0.079	0.091	10	0.046
K.C.	0.657	0.288	0.271	0.293	8	0.085

Data for Test Occasion 5 were transformed to log 10 to compensate for skewed distributions. A Bonferroni post-hoc test was then applied to the transformed data to determine whether there was a significant change between Occasions 4 and 5. Five of the six subjects showed no significant change in speed since Occasion 4. The

exception, subject KC., obtained results which had not improved significantly from those on Occasion 3. (His score on Occasion 4 was slightly worse than his score for Occasion 3 and this accounts for the apparent improvement on Occasion 5.) Results for the six subjects are shown in Tables 5.16. to 5.21. on the following pages.

In the tables:

(1) the difference between the means is **not** significant if the means are in the same subset

(2) the term 'group' refers to the test occasion i.e. group 1 refers to Occasion 1.

For subjects M.R. and O.L., Test Occasion 4 appears in two subsets. This is because of a slight reduction in reaction times over Occasions 3, 4 and 5 which resulted in the means for Occasions 3 and 4 being statistically equal and also for Occasions 4 and 5. The aggregation of these small changes meant that means for Occasions 5 and 3 were **not** equal, therefore, they do not appear in the same subset. To sum up, there was no significant improvement in reaction times between Occasion 4, which was conducted approximately three weeks after subjects emerged from PTA, and Occasion 5 which was carried out some months later. These results appear in Tables 5.16. and 5.17. on the following pages.

SUBJECT M.R. #

Table 5.16. Modified LSD Bonferroni Test

(significance level .05)

Subset 1		
Group	Group 5	Group 4
Mean	-.3861	-.2969
Subset 2		
Group	Group 4	Group 3
Mean	-.2969	-.2132
Subset 3		
Group	Group 2	
Mean	.0582	
Subset 4		
Group	Group 1	
Mean	.2412	

SUBJECT O.L.

Table 5.17. Modified LSD Bonferroni Test

(significance level .05)

Subset 1		
Group	Group 5	Group 4
Mean	-.4892	-.4111
Subset 2		
Group	Group 4	Group 3
Mean	-.4111	-.3240
Subset 3		
Group	Group 2	
Mean	-.0905	
Subset 4		
Group	Group 1	
Mean	.5162	

For subjects P.R., B.J. and B.W., test occasions three, four, and five were statistically equal i.e. there was no change in performance from the point at which they came out of PTA. See Tables 5.18, 5.19. and 5.20.

SUBJECT P.R.

Table 5.18. Modified LSD Bonferroni Test

(significance level .05)

Subset 1			
Group	Group 5	Group 4	Group 3
Mean	-.4874	-.4588	-.4200

Subset 2		
Group	Group 2	Group 1
Mean	-.0932	.1270

SUBJECT B.J.

Table 5.19. Modified LSD Bonferroni Test

(significance level .05)

Subset 1			
Group	Group 5	Group 4	Group 3
Mean	-.3629	-.3591	-.3537

Subset 2		
Group	Group 2	Group 1
Mean	-.1818	-.1363

SUBJECT B.W.

Table 5.20. Modified LSD Bonferroni Test

(significance level .05)

Subset 1			
Group	Group 5	Group 4	Group 3
Mean	-.4842	-.4199	-.4097
Subset 2			
Group	Group 2		
Mean	-.3060		
Subset 3			
Group	Group 1		
Mean	.3762		

Test Occasion 3, for subject K.C., appears in two subsets. This is due to the fact that the means for Occasions 3 and 5, and for Occasions 3 and 4, are statistically equal but Occasions 4 and 5 are **not** equal. This is because his score on Occasion 4 was slightly slower than his score on Occasion 3.

SUBJECT K.C.

Table 5.21. Modified LSD Bonferroni Test

(significance level .05)

Subset 1			
Group	Group 5	Group 3	
Mean	-.4670	-.3243	
Subset 2			
Group	Group 3	Group 4	Group 2
Mean	-.3243	-.3001	-.2903
Subset 3			
Group	Group 1		
Mean	.2061		

5.4.3. DISCUSSION

Few studies have examined the performance of head-injured subjects on reaction time tasks over time. Van Zomeren and Deelman (1978) tested a group of severely head injured people, as well as a mild and moderate group, on a simple and a complex reaction time task. Trials were carried out at 5 months, 8 months, 15 months and 21 months post-trauma. They continued to find a reduction in reaction times on the simple reaction time test, for the severe group, over the entire period.

The results reported for the six subjects in the current study do not reflect those of van Zomeren and Deelman. Initial improvements in reaction times were observed during PTA but once subjects were out of PTA their performance plateaud. Presumably the subjects in van Zomeren and Deelman's study were already out of PTA since the first testing occasion for the severe group was 5 months post-trauma. If so their improvement cannot be attributed to emergence from PTA.

Unfortunately, van Zomeren and Deelman do not give PTA durations for their subjects other than to state that all subjects in the severe group had a PTA of more than 4 weeks. The six subjects in the current study who were available for follow-up all had a PTA duration of more than 8 weeks and it is co-incidental that the only subjects who were available were those who had the longer PTA durations. As

discussed earlier Bishara et al. (1992) have suggested that 8 weeks might be a crucial point in that patients with a PTA of 8 weeks or longer had a poorer outcome than those with a shorter PTA. Thus, if the subjects in van Zomeren and Deelman's study had a PTA duration of less than 8 weeks this might partly account for the discrepancy in the findings of the two studies.

Another explanation for the disparity might be the method of classification of subjects in the van Zomeren and Deelman study. Subjects were included in the severe group if they had a period of coma lasting more than one week. There is only a moderate correlation of length of coma with duration of PTA (Levin et al. 1984, Teasdale & Brooks, 1985) thus, one cannot assume that any of them had a PTA duration of the length that subjects in the current study had, i.e. they might be less severely injured.

The two studies had comparable numbers of subjects (current study, 13 subjects; van Zomeren & Deelman study, 12 subjects in the severe group). However, since subject numbers in both studies are small further research is needed with larger groups to determine whether improvement in speed occurs over time once patients have emerged from PTA.

These authors do not report on intra-subject variability; thus it is not known whether subjects became more consistent in their performance. Subjects in the current study became more consistent in their performance as they emerged from PTA and for several subjects, who were tested 12 months post-trauma, this improvement in consistency continued.

The findings of the current study, that subjects were more variable than controls, replicate the results of Stuss et al. (1989, 1994) who examined this factor on both simple and complex reaction time tasks. They found that the performance of head injured subjects, who were no longer in PTA, was more variable than that of a control group. However, they did not examine whether this variability altered over time. Neither did the current study examine variability in the control group over repeated testing and this is a limitation of this study which should be addressed in future research.

Ponsford (1985) carried out an intervention programme with head-injured patients in an attempt to remediate deficits in speed of information processing. At the end of the 6 week period of daily sessions using a computer based reaction time task there was no significant improvement in processing speed. These results are consistent with the findings of the intervention which was implemented with a patient in the Lidcombe Head Injury Unit (as discussed in section 5.3.). Ponsford did not report

on measures of consistency of performance and whether this improved with practice but the Lidcombe Hospital patient showed no improvement in consistency over an 8 week period. To my knowledge no one else has directly examined whether or not changes in consistency **can** be affected by practice. This is an area which perhaps needs to be explored further as the variability of this population's performance has clinical implications in that they cannot be expected to demonstrate consistent improvements in therapy from day to day.

It is important to study whether reaction time, and hence speed of information processing, improves over time. As van Zomeren (1989) points out, the implication of "mental slowing" is that processing capacity is reduced. Thus head-injured people have difficulty with completing tasks within time limits or are too slow to process all the information they require to carry out a task efficiently. Furthermore, future studies need to examine whether the significant changes in speed occur only whilst the patient is in PTA . Wilson et al. (1992) have argued that slowed reaction times can be used to distinguish patients in PTA from amnesic patients and head-injured patients out of PTA, and the results of the current study appear to support this claim. Thus, it would be of clinical value to further confirm this finding with larger numbers and with varying severities of injury.

CHAPTER 6. CONCLUSION

The main findings of this study were as follows :

- orientation returned in the order of person/place/time for just over one-third of subjects and place/person/time for almost one-half of subjects
- simple recognition memory (as measured by recall of the pictures of the PTA scale) returned before temporal orientation
- the return of simple recognition memory appeared to coincide with a dramatic improvement in attention, in terms of faster reaction times, and a smaller improvement in consistency of performance
- the improvement in attention, in terms of speed of reaction times, plateaud for the majority of subjects once they emerged from PTA , however, the consistency of performance of some subjects continued to improve
- memory continued to improve significantly after subjects emerged from post-traumatic amnesia.

The findings of this study are useful from a clinical point of view because determining the end of PTA is important for several reasons:

- the duration of PTA is widely used as a predictor of outcome
- detailed assessments of cognitive functioning and language abilities need to be delayed until the patient is out of PTA to avoid obtaining a false picture of the

patient's strengths and weaknesses

- decisions relating to the commencement of therapy involving declarative memory are dependent upon the patient being out of PTA
- management decisions regarding the patient's behaviour are made according to whether or not the patient is out of PTA.

With the use of the modified Oxford PTA scale in this study, recognition memory returned before temporal orientation, therefore, the end of PTA was defined as the point when temporal orientation returned. This might not be the case with other PTA scales. The Westmead scale, as discussed in section 1.8.3., measures memory in a different way from the Oxford scale and the Julia Farr scale does not measure memory until after the return of temporal orientation. Thus the length of PTA might be different depending on which PTA scale is used. The duration of PTA is used to define the severity of the injury and to measure outcome, and at the very severe end of the injury spectrum, (e.g. PTA more than eight weeks), it probably does not matter if a scale is used which gives a slightly longer duration of PTA. However, it is of consequence if one is basing the decision of when to begin therapy on whether or not the patient is in PTA.

In this study speed of information processing appeared to improve dramatically at the point where recognition memory returned, however, as reaction time was not

measured on a daily basis one cannot say whether or not the improvement was a gradual one over the interval between Test Occasions 1 and 2. Future research should measure reaction times on a daily basis to determine whether this improvement is sudden or gradual. The findings of this study seem to support a sudden change as the majority of subjects showed a dramatic improvement within a very short interval, however, this needs to be replicated with larger numbers. It would also be useful if future studies examined whether the improvement in reaction time coincides with the return of simple recognition memory as it does in the current study. If it does, then one could argue that PTA should be measured using the modified Oxford scale with the use of different distractor pictures each day.

Although PTA is a transient state, several persisting deficits of the patient can impinge and confuse the issue, making it difficult to determine the end of PTA when sole reliance is based on a PTA scale. This is particularly an issue for people with very severe injuries who may be aphasic or have a severely impaired memory. Depending on the degree of aphasia, a language based PTA assessment may be inappropriate, while someone with a severe memory impairment might have difficulty achieving a perfect score because of an inability, for example, to learn the therapist's name or remember the day of the week. In such cases, an alternative method of assessing PTA would be useful.

As the results indicate, for subjects with the most severe injuries (i.e. with a PTA duration of more than eight weeks), reaction time ceased to improve significantly once they emerged from PTA whereas memory continued to improve at a fairly marked rate. Further evidence in support of reaction time being a better marker of the end of PTA than memory, was the correlation of PTA duration with performance on the attention task on Test Occasions 2 and 3 and the lack of correlation with memory scores.

Therefore, in cases where the use of a PTA scale is not effective, reaction times could be measured and when they plateaud one could be reasonably confident that the patient was out of PTA. For aphasic patients this method of assessment might need to be limited to those with an expressive aphasia as one could not be sure that patients with a receptive aphasia could understand the task. However, it has been possible, clinically, to demonstrate the task to a patient with a receptive and expressive aphasia and he was able to carry out the task.

It could be argued that measuring reaction time would not be as precise as using a PTA scale to determine exactly when PTA ended but given that, in such cases, the PTA scale is an invalid tool, assessing reaction time might be a useful alternative.

Although reaction times, i.e. speed, ceased to improve for the majority of subjects once they emerged from PTA, the consistency of their performance continued to improve. However, even when subjects were out of PTA their performances were more variable than those of the controls. Thus, as Stuss et al (1994) suggest, it might be preferable to assess a patient over a number of occasions rather than relying on a single occasion of testing to judge a patient's abilities. This would be particularly desirable when patients first emerge from PTA . It would also be of value to determine whether there is a point in PTA at which consistency of performance improves. Therapy which utilises procedural memory is sometimes commenced when the patient is in the later stages of PTA, therefore, it might be more productive to delay the start of this therapy until the patient is capable of a more consistent performance.

As discussed in Chapter 1 it might be possible for procedural learning to take place during PTA, even though patients fail to demonstrate learning on declarative memory tasks. There are, of course, limitations when patients are in PTA; it is necessary that they are not agitated and that tasks are simplified to enable learning to take place (Ewert et al. 1989). Although procedural memory was not formally examined in this study, clinical observations of subjects participating in repetitive physiotherapy exercises, once they were no longer agitated, showed that significant gains were made about the time that their attention improved, as measured by the reaction time

task. It would be useful to carry out a prospective study measuring both reaction time, and the subject's ability to benefit from therapy, to determine whether any therapeutic gains coincided with the sudden improvement in speed of information processing.

If such gains are evident at this point then this is important clinically. Traditionally, it has been thought that patients cannot benefit from therapy while they are in PTA. While it is true that it is pointless to carry out therapy which is verbally based and which depends on declarative/explicit memory (for example, speech therapy and cognitive therapy), the benefit might be different for therapy which depends upon procedural memory. It should be possible to begin such therapy as soon as the patient demonstrates a sufficient level of attention.

The improvement in performance on the reaction time task might also reflect an improvement in the patient's ability to **sustain** attention (as discussed in Chapter 4). Therefore, it would be useful to be able to pinpoint this time by noting the point at which the patient begins to consistently recall the pictures from the PTA scale, given the finding of this study that improvement in reaction times and recognition memory co-incided. In other words, recognition memory could be used as a marker for the commencement of therapy. Physiotherapy and some occupational therapy retraining, for example, self-care activities, could then begin at this time.

To reiterate, this investigation of the cognitive processes during post-traumatic amnesia has identified the times during PTA at which speed of information processing and memory improve and thus provides some clinically useful findings which need to be replicated with larger numbers and to be explored further in the ways suggested. Furthermore, the findings reflect the comment of Saneda and Corrigan (1992) that "PTA is a multidimensional phenomenon and recovery from PTA is a complex process" (p173).