CHAPTER 1. INTRODUCTION

1.1 Incidence of Head injuries.

Head injury is one of the leading causes of death in young people in Australia. In 1987 it was estimated that each year one thousand people in N.S.W. suffer a severe head injury and of these "three hundred people have serious disabilities that impose severe handicap on their independence" (Cuff Report, 1987). Indeed, a follow-up study of severely head injured patients admitted to a head injury rehabilitation unit found that all subjects continued to demonstrate cognitive impairment several years post-trauma (Tate, Broe & Lulham 1989).

1.2 Neuropathology of traumatic head injury.

When a person suffers a closed head injury damage to the brain is primarily the result of acceleration/decceleration injuries. Acceleration injuries include diffuse axonal injury, focal contusions and subdural haematomas (Katz, 1992). Shearing and stretching of the nerve fibres is thought to be the most important single determinant of outcome (Harper 1981; Levin, Benton & Grossman 1982). This type of damage is not usually evident on a CT scan but can be seen on MRI or can be assessed by physiological measures such as cerebral blood flow and evoked potentials (Levin et al. 1982). Contusions and lacerations of the brain can occur at the point of contact. They are most commonly found in the frontal poles and tips of the temporal lobes where the brain is in contact with the bony ridges of the skull.

When a person suffers a blunt head injury the severity and type of injury determines whether or not a loss of consciousness ensues. In the case of a mild head injury the individual may lose consciousness for only a very brief period i.e. minutes, or may not lose consciousness at all but experience a short period of confusion and disorientation.

A more severe injury will result in a loss of consciousness either at the time of injury or soon afterwards. An immediate loss of consciousness is usually the result of diffuse axonal damage (Alexander, 1987; Blumbergs, Jones & North, 1989; Jennet & Teasdale, 1981; Levin et al. 1982) or damage to the brain stem (Trexler & Zappala 1988). Contusions can also contribute to an immediate loss of consciousness. A delayed loss of consciousness is usually due to intracranial haemorrhage and brain swelling (Harper, 1981; Levin et al. 1982).

1.3 Post-traumatic amnesia: Description and significance

The period of loss of consciousness (LOC) is followed by a period of amnesia, confusion and disorientation and this stage is referred to as post-traumatic amnesia (PTA). There are, however, variations in the criteria used by different researchers to define the state of PTA (Schacter & Crovitz, 1977; Teasdale & Brooks, 1985). The majority, though, regard the period of PTA as the time during which the patient is unable to store new information, is disoriented (Schacter & Crovitz, 1977) and has other higher order cognitive deficits (Mandleberg, 1975; Trzepacz, 1994).

Thus, the period of PTA extends until the person becomes orientated and begins to make continuous memories hence it includes the period of coma (Cripe, 1987; Russell, 1971; Schacter & Crovitz, 1977).

The behaviour of patients in PTA can vary considerably from individual to individual. Some patients are very quiet and inert and appear to pay little attention to their environment. Other patients in PTA can be agitated, wander aimlessly and may be verbally and/or physically aggressive. Most patients fatigue easily and are unable to tolerate too much stimulation during this period.

The inability to lay down memories during the state of PTA may well be due to impairments of attention. One must first orient oneself to and focus attention upon appropriate stimuli to be able to encode material. Following a head injury, patients can have a disorder of drive which results in them being unable to shift attention and thus they have difficulty attending to the environment. Others can have a disorder of control which means they have difficulty fixating and sustaining attention on the appropriate stimuli and inhibiting their responses to irrelevant stimuli (Broe 1990).

With a disorder of drive, patients may be fixating on their internal state and thus pay no attention to what is going on around them. Consequently, they are disoriented and unable to remember anything. Conversely, a patient with a disorder of control may be so distractible that s/he pays attention to everything in the environment (even, for example, a pin on the floor) and does not fixate for long enough on any one stimulus to enable it to be committed to memory. As Geschwind (1982) points out, however, 'normal' individuals can experience similar states. For example, if, during a lecture, a student allows his attention to wander and becomes 'lost' in thought, he will have no idea of what the lecture was about or what has been going on around him.

The pattern of emergence from PTA varies. There are some who emerge from PTA very suddenly (Russell 1971) while others emerge gradually and have a lengthy period of PTA (Brooks 1974). Another common feature of PTA is 'islands' of memory, that is, some patients have short periods where they recall some significant event and appear to be out of PTA. However, these 'islands' of memory alternate with further periods during which the patient cannot recall events (Crovitz, 1977; Mandleberg, 1976; Russell, 1971). It has been suggested that levels of arousal fluctuate during the state of PTA and that 'islands' of memory occur at times when the arousal level reaches a certain threshold (Gronwall & Wrightson, 1980).

The severity of the injury is classified by length of disturbed consciouness, the most frequently used variables being coma and PTA. Coma is commonly measured using the Glasgow Coma Scale (GCS, Teasdale & Jennett 1974) which rates patients on a scale of 3 to 15 according to their motor response to pain, verbal response and ability to follow commands. A study looking at outcome twelve months post-trauma found that patients with a GCS score of five or less on admission had a poor outcome while those with a GCS score of nine or more were much more likely to have a good outcome (Bishara, Partridge, Godfrey & Knight, 1992).

An alternative measure of the severity of injury is that of duration of PTA. Duration of post-traumatic amnesia is commonly measured by carrying out a daily assessment of the patient, using a PTA scale. Such scales typically incorporate questions relating to personal, spatial and temporal orientation and to memory. The following classifications have been described e.g.Russell 1971; Teasdale & Brooks, 1985. A mild injury is one where PTA is less than or equal to one hour, a moderate injury is one where PTA duration is 1 to 24 hours, a severe injury involves a PTA duration of 1 to 7 days and a very severe injury is where PTA is longer than one week. Jennett (1976) further divides the very severe injuries into very severe (1 to 4 weeks) and extremely severe (longer than 4 weeks). However, more recently Bishara et al. (1992) have suggested a redefinition of very severe injuries classifying those with a PTA of 1 to 8 weeks as having a very severe injury and those with a PTA exceeding 8 weeks as extremely severe.

Recent research has confirmed that a long period of PTA is a better indicator of significant brain damage, as measured by the number of hemispheric lesions present, than either depth of coma or duration of coma alone (Wilson, Baddeley, Shiel & Patton, 1992). Furthermore, Haslam, Batchelor, Fearnside, Haslam and Hawkins (1995) found that the duration of disturbed consciousness, which was calculated by subtracting the length of coma from the length of PTA, was an even better indicator of the severity of the injury as measured by performance on tests of memory functioning and rate of information processing.

High, Levin and Gary (1989), in a study of patients with closed head injuries of varying severity, determined that patients with frontal lesions had a longer period of PTA than those with either no mass lesions or lesions which spared the frontal or temporal areas. Bishara et al. (1992) discovered a relationship between duration of PTA and depth of coma on admission to hospital in severely head injured patients, finding that all patients with a GCS score of four or five had a PTA of more than four weeks while none with a GCS score of nine or more had a PTA of this length.

Apart from the measurement of the duration of PTA, research has also been conducted into component deficits of this amnestic state including temporal and spatial orientation, retrograde and anterograde memory and attention.

1.4 Orientation

Disorientation, which is an aspect of PTA, is not thought to be a unitary cognitive disturbance. Studies of head injured subjects (High et al. 1989) and other clinical populations e.g. patients undergoing ECT treatments (Daniel, Crovitz & Weiner 1987; Mowbray 1954) and Korsakoff patients (Zangwill 1953), have found that disorientation for person, place and time are separable components and recover at different points in time. The most common pattern of recovery is that orientation returns for person, then place, then time.

1.4.1. Personal Orientation.

In some cases, a person who has suffered a severe head injury will not know who he is when he first emerges from coma. There appears to be little research into this aspect of disorientation but the general assumption is that orientation for self resolves first. However, studies into disorientation for age, which is generally considered to be a component of personal orientation, are an exception, and these are considered separately below.

1.4.2. Orientation for Age.

Research into disorientation for age among amnesic patients has found that people can be oriented for their year of birth and for the current year, yet be disoriented for age. Zangwill (1953) cites Pick (1915) to explain this phenomenon and states that people in an amnestic state are able to entertain incompatible propositions. Further, Daniel et al. (1987) point out that patients do not notice contradictions in their output because of their impaired cognitive abilities which render them incapable of self-monitoring.

Zangwill proposed that disorientation for age can to some extent be explained by the presence of a retrograde amnesia. Although in the 'normal' individual, age is deduced by arithmetical calculation, one's memories serve to give this concept substance. Because the amnesic subjects in his study did not have continuous memories of the past ten or so years Zangwill argued that they were giving an age which was commensurate with their memories.

Mowbray (1954) found the reverse pattern from Zangwill among a small number of cases after they had undergone E.C.T. These patients were able to give their correct age in spite of being disoriented for the current year and for their year of birth. Because this occurred in such a small number of cases Mowbray was reluctant to proffer an explanation but he speculated that Zangwill's argument, that age is not solely dependent on arithmetical inference, was a possible explanantion for his (Mowbray's) findings.

It is less common for people to be disoriented for their year of birth because one's birthdate is a constant and does not require updating via the integration of environmental cues whereas knowing one's age **does** require such integration (Benson, Gardner & Meadows, 1976). It should also be kept in mind that the disparate findings of Zangwill and Mowbray may be accounted for by methodological differences between the subject populations with respect to aetiology. Although the above studies were conducted with clinical populations other than the head injured they have been reported in this review because the same patterns have been observed among head injured patients admitted to the Lidcombe Hospital Head Injury Unit.

1.4.3. Orientation for Place

Although many researchers believe that disorientation for place is simply a memory deficit, Paterson and Zangwill (1944) argue that it is not only memory which is required for spatial orientation. They described patients who had memories for the previous day's events yet were not oriented for place. Conversely, others became oriented before they could recall the previous day's events.

Paterson and Zangwill argued that disorientation resolves as the patient begins to construct a "more or less coherent memory scheme of his recent activities" (p65). This implies that it is not simply the ability to recall information that leads to the resolution of spatial disorientation but the ability to build a series of personal memories of the location, i.e. the patient needs to 'internalise' the information.

The patient in their study continued to be spatially disoriented in spite of being given the correct information and being able to recall that information. A possible explanation for this phenomenon might be a lack of attention to the environment or "a noteable tendency to react to very limited aspects of the perceptual field and a virtual incapacity to relate perceived objects to their wider settings." (Patterson & Zangwill,1944, p65). Thus, a patient can, for example, say that he is at home whereas if he were attending to the environment he would see that he is surrounded by doctors and nurses and other hospital paraphernalia (Geschwind 1982).

1.4.4. Temporal Orientation

For the majority of head injured patients orientation for time resolves after orientation for person and place. In a study by High et al. (1989) this pattern of resolution of orientation was true for 70% of patients studied. A possible explanation for this pattern is that personal information is overlearned and not as vulnerable to disruption; place is a constant and once learned does not change, whereas the date consists of new information which must be constantly updated and retained.

It may be unrealistic to expect the patient to be fully oriented for time as he emerges from PTA. On examination of the research into temporal orientation it is apparent that even some 'normals' are not fully oriented. Natelson, Haupt, Fleischer and Grey

(1979) found that education levels can have an effect on orientation. Those without a high school diploma more frequently mistated the day of the week and the day of the month than did those with a college education.

Whether these findings are applicable to the Australian population is uncertain although an Australian study by Tate, Broe and Lulham (1991) found that in a control group of siblings of head injured subjects, which was closely matched to the head injured group for age, sex, and education, approximately one-third could not state the correct day of the month. All of them, however, correctly identified the day of the week. Similar findings were obtained by Benton et al. (1964) in a study which compared brain injured subjects (not all with head injuries) with a control group of patients who had no history of cerebral disease. Twenty-five percent of the control group could not give the correct day of the month but all knew the day of the week. Misidentification of the day of the week occurred only with the brain injured group.

1.5. Memory and Post-traumatic Amnesia

1.5.1. Retrograde amnesia.

People who have suffered a head injury, particularly a severe one, usually do not remember the trauma and often have a retrograde amnesia for a period of time prior to the trauma. Thus it is the more recent memories which are disrupted and an explanation which has been proffered to explain this pattern is Ribot's Law (Levin, Papanicolaou & Eisenberg, 1984). This law states that more remote memories are retained because the repeated retrieval of these memories protects them from being disrupted whereas more recent memories have not had time to become consolidated.

A study by Levin et al. (1985) found that the early autobiographical memories of patients were preserved whereas memories for television programmes which were screened during the same period were not as well retained. However, this finding was not considered to refute Ribot's Law as Levin and his colleagues argued that patients would be more likely to reminisce about personal memories than about television programmes and this would account for the better retention of the former.
The period of retrograde amnesia can range from minutes to years. This type of amnesia is often temporary, that is, it is present while the patient is in PTA but commonly 'shrinks' to a few minutes pre-trauma once the patient is out of PTA (Benson & Geschwind, 1967; Crovitz, Horn & Daniel, 1983; Schacter & Crovitz,

1977). There are some patients, however, for whom a retrograde amnesia of a significant duration is permanent. This usually occurs in patients who were in PTA for a prolonged period (Crovitz et al. 1983; Levin et al. 1985).

Although the above pattern of resolution of retrograde amnesia is a common one, a study by Sisler and Penner (1975) obtained different findings. Their patients were assessed on a number of occasions and it was found that on subsequent testing sessions five of the twenty four patients showed no change in the length of retrograde amnesia (R.A.). However, eight patients had a "shrinkage" of R.A., there was an increase in R.A. for five patients and the remaining six patients demonstrated an initial decrease followed by an increase in the length of their retrograde amnesia. Crovitz et al. (1983) believe that the apparent increase in the length of R.A. could perhaps be explained by the effect of normal forgetting of events.

To sum up, it may be that retrieval processes and consolidation of memories both play a part. The presence of retrograde amnesia may be due to retrieval problems and "shrinkage" might be explained by the resolution of these problems. However, the fact that some patients are left with a permanent retrograde amnesia for a short period of time just prior to the trauma could be due to the fact that these more recent memories had not been consolidated.

1.5.2. Procedural learning during post-traumatic amnesia

Although PTA is defined as the time during which an individual does not lay down continuous memories this does not mean that absolutely no learning can take place during this state. Ewert, Levin, Watson and Kalisky (1989) studied patients in PTA and found that they were "capable of acquiring and retaining new skills while they remain disoriented and amnesic for ongoing events" (p915). Although these patients performed below the levels of a control group of subjects who were neurologically intact they were able to learn a mirror reading task, a maze task and a pursuit rotor task. The authors claimed that this learning was transferred to testing after patients emerged from PTA However, as Levin (1991) argued, their enhanced performance after emerging from PTA may have been due, at least in part, to spontaneous recovery of cognitive functioning.

Ewert and his colleagues acknowledge that there are limitations to this type of learning. It is unlikely that procedural learning would occur during the early stages of PTA because of the level of agitation which is usually present at this time. One would also suspect that the deficits in attention, which are invariably present, would make it less likely that learning would take place. Indeed, to enable patients to reach criterion, the mirror reading task in Ewert's study had to be administered in a simpler form to the head injured subjects than to the controls.

1.5.3. Learning and forgetting during post-traumatic amnesia

The rate of forgetting in patients in PTA has also been explored. A study by Levin et al. (1988) compared a group of patients in PTA with a group in whom PTA had resolved, and with a control group, to investigate recognition memory. To ensure that the three groups attained a comparable initial level of learning, the group in PTA was exposed to the stimuli for a duration which exceeded the time given to controls, by a factor of two to eight.

It was found that patients in PTA performed at the same level as the other two groups at the 10 minute delay but at a significantly lower level than the control group at the two hour interval and lower than both controls and head injured patients at the 32 hour interval. Levin et al suggested that accelerated forgetting among the PTA group was not due to greater severity of injury, as patient groups were matched for severity of injury, but that it was attributable to the state of PTA (Levin et al. 1988).

1.6 Higher order cognitive functioning during post-traumatic amnesia

Mandleberg (1975) examined differences between verbal abilities and non-verbal skills during PTA. He administered the Wechsler Adult Intelligence Scale (WAIS) to two groups of severely head injured subjects; one group of patients was in PTA (group A) at the time of testing, while the other group had emerged from PTA (group B).

Mandleberg hypothesised that if PTA is a qualitatively different state the performance of the two groups would be significantly different on initial testing but their performance on the second testing occasion (when group A had emerged from PTA) would be similar. He also hypothesised that group B, which was out of PTA on both testing occasions, would perform at similar levels on each occasion. His hypotheses were partly confirmed.

The finding that group A performed more poorly on the Performance tests on the initial session, than group B, but performed similarly to the latter group when subjects had emerged from PTA supports, although not conclusively, the hypothesis that PTA is a qualitatively different state.

Mandleberg conceded that his assertion that the two groups were matched for severity of injury could be questioned, for although all subjects in the study, except for two in group B, had a PTA of more than one week, the mean PTA for group A was 110 days and for group B was only 19 days. Therefore, because the two groups were not strictly matched for severity of injury this study does not provide clear cut evidence that PTA is a qualitatively different state.

1.7. Attention

1.7.1. Attention during post-traumatic amnesia

Impaired attention has been frequently noted to be a feature of the state of PTA (e.g. Broe, 1990; Mysiw, Corrigan, Carpenter & Chock, 1990; Wilson et al. 1992). Unfortunately, there is a paucity of studies of attention during PTA, possibly because of the difficulty of assessing patients who are in this state.

Electrophysiological evidence using auditory evoked potentials (AEP) has supported the observation that attention is impaired during PTA. It has been found that P300, a component of AEPs, is absent or has a longer latency during the state of post-traumatic amnesia (Curry, 1981 cited in Van Zomeren and Brouwer, 1987; Levin et al. 1984). It is suggested that this absence of P300 is due to impairments of memory and/or attention which precludes recognition and differential processing of the stimulus (Levin et al. 1984).

The only behavioural neuropsychological investigation of attention during the period of PTA is that of Wilson et al. 1992. They compared a group of patients in PTA with three other groups: a group of late stage memory impaired head-injured people, a group of pure amnesics and a control group of orthopaedic patients. They administered a variety of tests and found that a simple reaction time task, i.e. an attention task, was a better discriminator of patients in PTA than memory, semantic processing, word fluency or orientation tasks

1.7.2. Attention after the resolution of PTA

In contrast to investigations of attention during the state of PTA there have been many studies of attention carried out with head-injured patients after PTA has resolved (e.g. Butchel, 1987; Ponsford & Kinsella, 1988; Stuss, Stetham, Hugenholtz, Picton, Pivik & Richard, 1989; Trexler and Zappala, 1988; Van Zomeren & Deelman, 1978; Van Zomeren & Brouwer, 1987) and there is general agreement that attention is a characteristic impairment in this population. Attention is, however, a multidimensional concept and not all aspects of attention are compromised by head injury. Most of the investigations into attention, among patients with head injuries, have been in the areas of sustained attention, focused attention and divided attention.

No evidence has been found to suggest that focused attention (Ponsford & Kinsella, 1988; van Zomeren,1984; van Zomeren, 1989) or sustained attention (Brouwer & van Wolffelar 1985, van Zomeren & Brouwer 1987, van Zomeren 1989) are impaired after head injury, once PTA has resolved. Van Zomeren (1989) does, however, qualify his statements and concedes that there can be impairments of focused attention when there is frontal lobe involvement.

A number of investigations into sustained attention found that although head injured patients out of PTA, performed more poorly than controls in terms of their signal detection and reaction times, they were able to sustain their attention as well as control subjects (van Zomeren and Brouwer 1987, van Zomeren 1989). However, during PTA, patients who have a disorder of control may be unable to focus and sustain their attention on appropriate stimuli in the environment.

There appears to be a general consensus that head injured patients commonly have reduced speed of information processing with a resultant deficit in divided attention (van Zomeren and Brouwer 1987, Ponsford and Kinsella 1988). A slowing in reaction time is a consistent finding of investigations with head injured subjects. Van Zomeren and Deelman (1978) studied reaction times on a simple and a choice visual reaction time task among three different head injured groups i.e. mild, moderate and severely injured as defined by the length of PTA. It was found that there was a significant difference in the reaction times of the three groups and the times of the severe group were disproportionately slower on the more complex task.

Ponsford and Kinsella (1988) studied simple and choice reaction times of a head injured group and a control group using the same apparatus as van Zomeren (1981). They found significant differences between the two groups and the choice reaction time test resulted in disproportionately slower times for the head injured group.

Stuss et al. (1989) compared performances on a reaction time test among four groups of subjects; a control group, a severely head injured group, a mildly injured group, and a severely injured group which was tested at a much later date post-trauma than was the other severe group. Their results indicated that on simple reaction time tests severity of injury had an influence on speed only if subjects were tested within twelve months post-trauma. There were, however, significant differences between the head injured groups and the controls on all the complex tests, confirming the findings of van Zomeren that choice reaction times are compromised for a longer period post-trauma than simple reaction times.

Closer analysis of the results of the above study also indicated that the performance of the head injured subjects was not as consistent as that of the control group. This was true of their performance both within a trial and between trials. This finding has been confirmed by more recent work by Stuss and his colleagues (1994).

The frequency with which disorders of attention occur after PTA, indicates that further investigation of this deficit **during** PTA is warranted.

1.8 Measurement of PTA

Researchers have assessed the duration of PTA using a variety of methods. In earlier studies PTA was assessed retrospectively by questioning the patient as to when s/he first began making memories after the injury (e.g. Russell 1971). While this method may be adequate where the injury is mild and PTA lasts for less than a day or so, for more severe injuries it is no longer considered to be an adequate method of assessment as one cannot reliably distinguish between the patient's real memories of events and those which are based on information given to him by relatives (Levin et al. 1984). Moreover, some patients experience 'islands' of memory during PTA where they recall some significant event but then lapse back into a period of amnesia. If PTA is measured retrospectively it could be falsely assumed that the 'island' of memory signified the end of PTA.

A more satisfactory method of assessing PTA is by administering a daily questionnaire, once the patient emerges from coma, to determine the return of continuous memory and normal orientation. There are several questionnaires which have been designed specifically to measure this state and all of them incorporate questions pertaining to memory and personal, spatial and temporal orientation. These questionnaires are described in detail in the following sections.

Four commonly used scales which have been developed to assess PTA in an objective way include:

- an unnamed test devised by a group of researchers in Oxford (Artiola i Fortuny, Briggs, Newcombe, Ratcliffe & Thomas, 1980) which will be referred to as the Oxford PTA scale in this thesis
- the Galveston Orientation and Amnesia Test (GOAT, Levin, Benton & Grossman, 1982)
- the Westmead PTA scale (Shores, Marosszeky, Sandanam & Batchelor, 1986)
- the Julia Farr PTA scale (Geffen, Encel & Forrester, 1991).

With the exception of the GOAT, each of these scales assesses the patient in PTA on a daily basis until the patient achieves the required score on three consecutive days. PTA is considered to have ended on the first of the three consecutive days. When using the GOAT a patient is considered to be out of PTA on the first day s/he achieves a score greater than 75 (out of 100).

1.8.1. The Oxford PTA Scale

Although the authors of this scale (Artiola i Fortuny et al. 1980) did not publish their questionnaire in full the author has since obtained details of the questions and administration procedures from Dr. Newcombe (Personal communication. 1991). The Oxford scale (reproduced in Appendix 3) contains personal, spatial and temporal orientation questions, and asks the patient for recall of the last event before their injury and the first event recalled after their injury. These questions are included to establish the duration of retrograde amnesia and post-traumatic amnesia respectively.

The memory component of the Oxford scale requires the patient to memorise three pictures. If the patient is unable to freely recall the pictures s/he is given a recognition test whereby s/he is shown eight pictures (the three target pictures plus five distractors) one at a time, and is asked which of the eight pictures s/he was to remember. A pool of 75 pictures is used as distractors which means that new distractors are used each day for 15 days before they are used for a second time. Thus, on day 16, the patient is shown the distractors s/he saw on day one and so on.

It is assumed that if a patient is unable to spontaneously recall the target pictures s/he is unlikely to remember the distractors s/he saw 15 days previously.

At Lidcombe Hospital, where the author is employed, a modified version of the Oxford scale is administered to patients in PTA and was used in the current study. The modified Oxford scale contains one extra orientation item, i.e. orientation for city , as Lezak (1983) argues that questions relating to both hospital **and** city are necessary to establish spatial orientation.

The two questions relating to recall of the last event prior to injury and the first event after injury are not included in the modified version as it was felt that these questions were more appropriate for patients with mild head injuries. Indeed, the original Oxford PTA scale was trialed with a group of less severely injured patients; 93% had a PTA duration of 24 hours or less. When these questions were used with more severely injured patients they appeared to have difficulties answering them and when asked for the first event after the injury invariably gave a non-specific event such as "I remember being in bed and seeing nurses". Thus, these two questions were deleted.

The memory component of the modified Oxford scale is administered exactly as in the original scale. Patients are considered to be out of PTA when they can answer all of the questions correctly on three consecutive days.

1.8.2. The Galveston Orientation and Amnesia Test (GOAT)

The GOAT has several questions on personal information, orientation questions for time and place, and like the Oxford scale, requires the patient to recall the last event before the injury and the first event s/he remembers after the injury. To obtain the patient's score, points are awarded for correct answers and deducted for errors, with a total of one hundred points being a perfect score. A patient is considered to be in PTA when his/her score is 75 or less (Levin et al. 1982). It is possible, however, to achieve a score within normal limits i.e. greater than 75, even though one fails the specific amnesia questions. This could mean that one is not measuring the duration of PTA but the duration of post-traumatic disorientation only (Gronwall & Wrightson, 1981; Shores et al. 1986).

A further criticism of the GOAT is that it requires patients to estimate the time of day and one point is deducted for each half hour the patient's estimate is removed from the correct time. A study by Natelson et al (1979) found that approximately 20% of a non-hospitalised 'normal' population could not estimate within 30 minutes of the correct time. Moreover, Benton et al. (1964) found that 20% of a control group of hospital patients with no history of cerebral disease miscalculated the time by more than 30 minutes. This problem has been overcome in the other PTA scales by including a question which simply asks whether it is morning, afternoon or night.

One final criticism of the GOAT is that the amnesia component is measured by the question "What is the first event you can remember after the injury?". It could be argued that this is an unreliable way of measuring the end of PTA as the first memory could be simply an 'island' of memory followed by a further period of amnesia.

1.8.3. The Westmead PTA Scale

The Westmead scale, which was developed as an extension of the Oxford test (Shores et al. 1986), contains questions relating to personal information i.e. date of birth and age, and also orientation questions for time and place.

In addition to the orientation questions the patient is shown three pictures of common objects on the first day and is asked to memorise them. S/He is also required to memorise the name of the therapist administering the scale. On each day after that the patient is asked for spontaneous recall of the memory items and if s/he is unable to do this s/he is given a recognition test. This is carried out by presenting the target pictures plus distractor pictures (one at a time) and asking the patient to correctly identify the targets and reject the distractors. This scale requires that the patient, as well as being oriented, is able to achieve correct recall of the memory items on three consecutive days before s/he is considered to be out of PTA. This requirement also applies to the Oxford PTA scale and the Julia Farr PTA scale.

When a recognition test is necessary the Oxford scale uses different distractors each day. The Westmead scale, however, uses the same distractors every day. Moreover, with the Westmead scale, once the patient achieves correct recognition of the three pictures, the target pictures are changed on each of the next two days and these new target pictures are chosen from the pool of six distractor pictures which have been used throughout the PTA assessment period. It could be thus argued that this interchanging of targets and distractors changes the task from one of simple recognition to a more difficult memory task requiring temporal discrimination.

1.8.4. The Julia Farr PTA Scale

Another PTA scale which has been developed more recently is the Julia Farr PTA scale (Geffen et al. 1991). This scale differs from the others in that it is divided into two sections i.e. an orientation section and a memory section, and a study by Gronwall and Wrightson (1980) is cited as theoretical justification for dividing the scale in this way. It is stated that this research indicated that orientation tends to recover before memory. However, while it is correct that five patients in the Gronwall and Wrightson study were orientated while they were still **in** PTA there were also eight patients who remained disorientated when they were making memories. Thus, on the basis of these results one could not conclude that orientation recovers before memory in all patients. Moreover, the subjects in the Gronwall and Wrightson study had suffered only mild head injuries; this pattern of recovery cannot necessarily be ascribed to all levels of severity.

Another way in which this scale differs from the previously described PTA scales is that it has only one measure of temporal orientation. The patient is asked whether it is morning, afternoon or night but questions relating to year, month and day of the week are not included. Although orientation for time of day is often the last component of temporal orientation to return this is not always the case. Some patients are able to correctly judge the time of day even when they are not oriented for month or year. Moreover, Benton et al. (1964) found that there was no relationship between temporal orientation and the ability to estimate temporal duration, thus one could not be considered to be fully temporally oriented on the basis of knowing the time of day.

When the patient correctly answers the orientation questions on three consecutive days the memory component is then introduced with the patient being required to memorise the name of the therapist and three pictures of everyday objects. If a recognition test is necessary the same distractor pictures are used each day, as in the Westmead PTA scale. Once the patient can achieve at least recognition of the pictures on three successive days s/he is considered to be out of PTA.

The authors claim that orientation resolves before memory, as measured by the ability to memorise the pictures and the name of the therapist. However, it could be argued that this pattern of recovery is an artefact of the scale, as the ability of patients to memorise information is not tested until after they are orientated.

1.9 Resolution of post-traumatic amnesia

Scales measuring the duration of PTA (described in detail in section 1.8.) usually define the end of PTA as the stage at which a patient can answer all questions correctly on three consecutive days. In practice, however, it is sometimes necessary to make a clinical judgement about whether or not someone is out of PTA as there are some patients who never achieve a perfect score on the PTA scale. This situation usually arises when the duration of PTA is very lengthy, indicating an extremely severe injury. The items which such patients tend to have most difficulty recalling are the therapist's name and the day of the week. It may be that these patients have a chronic severe impairment of memory rather than an impairment of memory which is, in part, transitory and which improves to some degree as they emerge from PTA.

Researchers have also investigated whether amnesia and temporal disorientation resolve simultaneously as the patient emerges from PTA. In one of the early studies of PTA it was found that amnesia and temporal orientation resolved more or less simultaneously (Moore & Ruesch, 1944). However, this study has a methodological flaw in that orientation was assessed daily but amnesia was assessed retrospectively; a method which is not regarded as being reliable (e.g.Gronwall & Wrightson 1980, Levin et al. 1984, Mysiw et al. 1990).

More recent investigations, however, have hypothesised that amnesia and temporal orientation might be separate components of the state of PTA. In a study by Sisler and Penner (1975) anterograde amnesia and temporal orientation did not resolve simultaneously for half of their patients. Of the remaining 50% there was an approximately equal division between those who became orientated before their amnesia resolved (43%) and those who were disoriented for a longer period of time than they were amnesic (57%). Thus. overall slightly more than a quarter of their subjects began making memories before they were orientated for time.

As mentioned earlier Gronwall and Wrightson (1980) studied a mildly injured group and obtained similar findings. Amnesia and disorientation did not always resolve concurrently. They found that 18% of patients who were questioned when they were clearly no longer amnesic were still disoriented; by contrast 5 of the 13 (38%) patients they examined while still amnesic, were oriented.

In the above studies, the end of amnesia was defined as the return of continuous memory whereas PTA scales measure the return of memory in terms of the ability to remember three pictures and the name of the therapist. Whether or not this ability corresponds with the return of continuous memory is not clear.

A study by Shores (1986) investigating PTA does not provide information on the pattern of resolution of amnesia and disorientation. However, Shores indicated (ASSBI Conference, 1990) that amnesia, as measured by the PTA scale, resolves before orientation in only a very small number of patients. Geffen et al (1991) claimed that temporal orientation always resolved before amnesia, although, as pointed out earlier this finding may well be due to the way in which their PTA scale is administered, i.e. memory assessment does not commence until full orientation is achieved.

Assessments of severely head injured patients at Lidcombe Hospital Head Injury Unit over the past six to seven years indicated that amnesia, as measured by the PTA scale, resolved before disorientation in approximately 70% of patients. All of these patients were classified as having had a severe head injury. The interval between the resolution of amnesia (as measured by the PTA scale) and temporal orientation in these patients ranged from 5 days to 7 weeks. Patients who were left with a chronic severe memory impairment were more likely to take longer to become oriented for time. This disparity in the pattern of resolution may be due, at least in part, to differences in the way in which the memory component of the PTA scales is administered.

1.10. The Current Study

To reiterate, people emerging from PTA appear to fall into one of three groups. Either disorientation and amnesia, as defined by the PTA scale, resolve simultaneously, disorientation resolves before amnesia or patients are disorientated for a longer period than they are amnesic. If disorientation and amnesia resolve at different times one could hypothesise that different cognitive processes underlie these states.

Although amnesia and orientation resolve simultaneously in some patients this does not necessarily mean that the above hypothesis must be rejected. Different cognitive processes could be involved but resolve simultaneously and it may be the severity of the injury that determines whether or not this ensues.

Another explanation for the different findings of various investigators relating to the pattern of resolution of orientation and amnesia might be (as stated earlier) that they are an artefact of the particular PTA scale used and the way in which it is administered.

While the way in which the different scales are administered might account for the findings of Shores (1991) and Geffen et al. (1991), that is, that almost without exception disorientation resolves before amnesia, it does not explain the mixed pattern of findings of other investigators. The results of Sisler and Penner (1975) might be due to the fact that orientation was assessed daily while the duration of amnesia was assessed by asking patients for their first memory after the accident. As discussed in section 1.3. this first memory could be an "island" of memory and not the return of continuous memory. A study by Gronwall and Wrightson (1980) also obtained a mixed pattern of resolution of PTA but their subjects had suffered only mild injuries. Moreover 25% of their subjects changed their reports of their first memory when they were interviewed at a later date; thus it would be difficult to decide which of the accounts was correct.

While most of the interest in the state of PTA has tended to focus on the impairment of memory it would seem that attention during PTA deserves further investigation. Clinical observations indicated that attention is very severely impaired during PTA, particularly in the early stages of recovery, therefore it was decided to measure both memory **and** attention in this current investigation.

The study by Wilson et al. (1992), discussed in section 1.7. measured attention on only one occasion. It is intended in the current study to evaluate attention on a number of occasions, both during PTA and once subjects emerge from PTA.

Active therapy is not usually carried out with patients in PTA because it is felt that they are unable to benefit because of their impaired attention and new learning. However, it may be that when milestones such as recalling the pictures from the PTA scale are reached there is a significant change in cognitive functioning. If this is correct it would enable the patient to benefit from therapy at an earlier stage than was thought possible. It may be that attention is the critical process underlying emergence from PTA, thus it is important to measure both attention and memory to see which is the better indicator of the change in cognitive functioning as people emerge from PTA.

This study will therefore explore :

- the changes in attention, as measured by a simple reaction time task, on four separate occasions as the subject progresses through and emerges from PTA.
- the changes in memory, as measured by the Rivermead Behavioural Memory Test, on the same four occasions as above
- the order of resolution of the individual components of orientation and whether the return of orientation is related to changes in attention and memory (as measured by the above tasks)

CHAPTER 2. METHOD

2.1. Subjects

2.1.1. Inclusion Criteria

Subjects were recruited from admissions to the Lidcombe Hospital Head Injury Unit. Inclusionary criteria comprised the following:

- at the time of admission the patient was in the early stages of PTA
- absence of severe language impairments
- competence in English
- absence of a premorbid history of psychiatric illness
- able to participate in PTA testing

One hundred and forty nine consecutive patients admitted over a three and a half year period were considered for inclusion in this study, however, only fifteen met the inclusionary criteria. Ninety eight patients were excluded either because they were not in PTA or were in the later stages of PTA at the time of admission. Seven severely dysphasic patients were excluded although others who exhibited a mild anomia were included because the PTA tasks could be completed by a recognition format. A further ten patients were excluded because they were not fluent in English. One subject had a history of psychiatric illness and was therefore excluded. The final eighteen subjects included fourteen who were so severely impaired they were physically and/or cognitively incapable of carrying out the tasks, one patient who was cortically blind, one was too aggressive and two patients refused to co-operate after the first two trials.

Although it would have been preferable to have a larger number of subjects in this study there have been several other studies carried out in similar areas of research with comparable numbers of subjects (e.g. Miller, 1970, 5 subjects; Brouwer and van Wolffelaar, 1985, 8 subjects; Tromp and Mulder, 1991, 10 subjects, Wilson et al. 1992, 12 PTA subjects; Stuss et al. 1994, 18 subjects). There was no significant difference between the subject group and the rejected sample in terms of age ($t = -.52$, $p = .606$) or duration of PTA ($t = 1.18$, $p = .251$).

Ideally, it would have been preferable to exclude subjects on medication but it was considered that this procedure might overly restrict the numbers available for the study. Therefore, subjects were included in the study irrespective of whether they were on medication, however, the effects of medication in the sample are explored in the Results section (see section 3. 2).

The focus of this study was resolution of PTA over time and thus subjects acted as their own controls with their performance on each test occasion being compared with their performance on previous test occasions. However, it was decided to recruit a non brain damaged control group of 20 subjects matched for age, education and sex to perform the reaction time test. This was done to provide reaction times for a non injured population with which to compare the reaction times of the head-injured subjects when they emerged from PTA. Although it was expected that patients in PTA would be slower than non head-injured controls it was not known whether this would be the case once patients were no longer in PTA. Table 3.2 in the Results section provides mean scores for age and education for both groups.

2.2. Dependent Measures

In addition to the daily administration of the PTA scale two other tests were used to assess the subjects ; an attention task and a memory task. The number of tasks was limited due to the impaired cognitive state of patients in PTA which results in them being unable to concentrate for long periods or to perform complex cognitive tasks. Indeed on the first occasion of testing in particular, and to a lesser extent on the second, it was sometimes necessary to cajole some patients into completing the required tasks as they found even such simple tests quite demanding.

2.2.1. Oxford PTA scale

Duration of PTA was measured using the modified Oxford PTA scale, previously described in section 1.8.1. and reproduced in Appendix 3. The 75 pictures used for the memory component of the scale were line drawings from the Peabody Pictorial Memory Test mounted on cardboard. The variable used for statistical analysis was the number of days duration of PTA.

Measures of Orientation

Note: Different authors use different items in their definitions of the various components of orientation, thus definitions used in the current study and those of authors referred to in the discussion are given in the Table 2.1.

Table 2.1. Definitions of Orientation

	Present Study	**High et al. (1989)**	**Daniel et al. (1987)**
Person	Date of birth Age	Name Date of birth Age	Name Year of birth Age Social security no.
Place	City Name of hospital	City Hospital	City County Name of hospital Floor of hospital
Time	Year Month Day of week Time of day	Year Month Day of month	Year Month Day of week

2.2.2. Attention

The attention task was a computerised simple reaction time test for use with brain injured patients (Gianutsos and Klitzner 1981). The stimulus consisted of a series of rolling numbers which appeared on the screen at random intervals. The subject was instructed to rest his finger on the space bar, to watch the screen for the stimulus and to press the space bar as quickly as possible once the numbers appeared. Before each presentation of the stimulus a warning "Ready, Set, Go" appeared on the screen. The task took approximately nine minutes to complete. The variable used for statistical analysis was response time measured in hundredths of a second.

A simple reaction time task was chosen in preference to a more complex choice reaction time task because it was necessary to limit the cognitive demands placed on patients when they were in PTA. A focused attention task which required patients to respond to one stimulus and inhibit a response to another was also considered for the study. However, when this test was piloted with people in PTA it was found that they were not able to respond within the time limit, thus it was decided not to include it.

In some studies, where a complex reaction time test has been used, it has been possible to separate decision time from movement time. It was not possible to do this in the current study as subjects were instructed to rest their finger on the space bar (as described above) therefore, there was no movement involved other than depressing the space bar.

Several researchers have suggested that a simple reaction time task is sufficiently demanding to distinguish brain injured subjects, particularly those with a very severe injury, from other groups. Bruhn and Parsons (1977) found that a simple reaction time test distinguished brain injured subjects "at a level comparable to more sophisticated and time consuming neuropsychological methods" (p 383). As mentioned earlier, Wilson et al. (1992) also found that a simple reaction time test discriminated the brain injured group in PTA from other memory impaired groups.

Although the task used in this study was a measure of speed of information processing it could be argued that with this population it is also a measure of **sustained** attention. With a 'normal' population a sustained attention task is usually required to be of fifteen to twenty minutes duration, however, there is at least one study which used a task of ten minutes duration with brain injured subjects (Mirsky et al. 1991). Given that the subjects in this study were either in PTA or had only recently emerged from PTA at the time of testing, one could assert that the reaction time task of nine minutes is sufficiently long to measure sustained attention in this population. Moreover, it also could be argued that to some extent the task measured their ability to withstand distractibility, given that on Test Occasion 1 some subjects found it difficult to focus their attention on the task for the duration of nine minutes.

2.2.3 Memory

The memory task used was the Rivermead Behavioural Memory Test (RBMT), devised by Wilson et al.(1985), to assess impairment of everyday memory functioning in people with acquired brain damage. It consists of a series of sub-tests which are considered to be analogous to everyday memory situations and involves either retaining the type of information one needs for adequate everyday functioning or remembering to carry out an everyday task (Wilson et al. 1985). This test has been used in previous studies of head-injured patients e.g. Geffen et al. 1991.

Patients in PTA have, by definition, a severely impaired memory. This task was chosen because it was considered to be less demanding than many other memory tasks used in the assessment of brain injured people. Therefore, it was considered that patients in PTA would be better able to cope with this test. Moreover, because the RBMT has four parallel forms a different form could be used on each test occasion , thus reducing the risk of practice effects.

The variable reported is the Standardised Profile Score. The RBMT provides this method of scoring to overcome the problem of adding raw scores together which would give much heavier weighting to some components than others, as the raw scores vary from one sub-test to another.

2.3. Procedure

Subjects were admitted to the Lidcombe Head Injury Unit for rehabilitation after having spent a period of time in a trauma centre for their acute care. They were assessed daily with the modified version of the Oxford PTA scale as described in sections 1.8.1 and 2.2.1. This daily assessment began as soon as the patient was able to respond. For a few subjects, PTA testing was delayed because of extreme agitation which prevented them from being able to focus attention and respond to questions.

2.3.1. Timing of Testing Occasions

In addition to the daily PTA assessments, subjects were examined on four occasions using the reaction time task and the Rivermead Behavioural Memory Test.

- The first test occasion occurred when the patient was confused and disoriented for time and as soon as he/she was capable of complying with testing
- the second occasion of testing occurred when the patient was able to make memories as measured by the PTA scale i.e. correct recognition or free recall of three pictures for three consecutive days
- the third test occasion took place when the patient was oriented for time. This coincided with emergence from PTA as defined by the PTA scale used in this study.
- the fourth test was conducted three to four weeks after the patient had emerged from PTA.

Note: For reasons of brevity occasions of testing will be referred to as Occasion 1, Occasion 2, Occasion 3 and Occasion 4.

2.3.2. Order of administration of tasks

Subjects were always tested in the morning as people with brain injuries are more likely to be fatigued in the afternoon. Moreover, if patients were scheduled to have a physiotherapy session that morning the testing was carried out prior to therapy. This was because they were likely to be extremely tired after finishing physiotherapy.

The attention task was always administered before the memory task as a pilot study had indicated that the attention task was more vulnerable to the effects of fatigue than was the memory task. With respect to the attention task an introduction was first used to familiarise subjects with the stimulus and following this there were two practice trials. The numbers on the first five trials appeared in the centre of the screen while the remaining 16 trials involved the numbers appearing anywhere on the screen (other than in the exact centre). Eight of the sixteen numbers were presented in the left half of the screen and eight in the right half.

It was often necessary to delay the first test occasion because some patients were incapable of complying in the early stages of PTA due to a high level of agitation and/or distractibility which rendered them completely unable to co-operate. Because the timing of each occasion was determined by performance on the PTA scale this meant that individual patients were tested at different times post-trauma e.g. Occasion 2 was 25 days post-trauma for one patient and 129 days post-trauma for another. However, in spite of this wide variation in time 13 of the 15 subjects were at least three quarters of the way through their PTA period before they reached the criterion i.e. remembering the pictures, for Occasion 2.

CHAPTER 3. RESULTS - GROUP

Results for 13 of the 15 subjects on the reaction time test and the RBMT were able to be aggregated while findings for the remaining two subjects are reported separately in section 5.3. One subject was not included because she suffered a penetrating head injury whereas all other subjects had sustained a closed head injury. The other subject was excluded from the group because temporal orientation and amnesia resolved simultaneously, therefore, she was tested on only three occasions instead of four.

3.1. SUBJECTS

The ages of the subjects ranged from 18 years to 63 years, the mean age being 29.9 years. Thirteen of the subjects were male and there were two females. Ten of the subjects were involved in motor vehicle accidents, two were pedestrians, one was a trail bike accident, one was assaulted and one received his injuries as a result of a fall. Duration of PTA ranged from 20 days to 144 days with all but one classified as having had an extremely severe head injury. (See Table 3.1. for details of individual subjects)

Table 3.1. Characteristics of head-injured subjects

Subject	Age	Education (years)	PTA (days)	Sex
J.Z.	19	10	42	M
F.G.	47	15	29	M
M.R.	63	9	70	M
M.P.	21	10	80	M
K.C.	19	12	131	M
B.W.	20	14	80	M
P.R.	39	12	144	M
H.K.	46	9	54	M
O.L.	20	12	94	M
C.C.	18	10	38	M
B.J.	22	12	98	M
E.A.	29	15	89	M
L.A.	26	12	56	M
N.B.	23	14	80	F
M.A.	36	9	20	F

Mean scores and standard deviations have been calculated for the 15 head injured subjects and the control subjects and are shown in Table 3.2.

Table 3.2. Age and years of education for all subjects

	H.I. Subjects (15)	**Controls (20)**
	(years)	**(years)**
Age (Mean)	29.9	27
(S.D.)	13.49	7.49
(Range)	18 - 63	20 - 49
Education (Mean)	11.7	12.9
(S.D.)	2.13	2.83
(Range)	9 - 15	9 - 18

A t-test was applied to the means (above) and the differences in age and education for the two groups was not significant.

(age; $t = .80$, $p = .428$: education; $t = -1.41$, $p = .167$).

3.2. MEDICATION

It was not feasible to control for potential medication effects in this study by excluding medicated patients. To restrict the study only to those patients who were not on any form of medication which might have some impact on their cognitive functioning would have meant that only 9 of the 15 patients were suitable over a collection period of three and a half years. (Details of medication are given for each subject in Appendix 2.)

Medication could have had a positive effect e.g. it might have dampened agitation enabling the patient to attend to the task or, conversely, it could have had a negative effect and slowed down the responses of the patient. To illustrate, Neulactil might have been responsible for decreasing agitation in Subject K.C. which enabled him to participate in Testing Occasion 1 of the study at 88 days post-trauma. Prior to this, his level of agitation was so high he could not sit still for more than a few seconds and he was completely incapable of complying with testing requirements. However, it would seem that the medication did not slow down his responses markedly as his reaction times were some of the fastest in the group even though he was one of the most severely injured, as measured by duration of PTA.

The possibility that medication could have affected the subjects' performance on testing was examined in several ways. Subjects were divided into two groups; those who were taking medication during the test period and those who were not. The scores of the two groups, on each occasion, for both the attention test and the memory test were examined. Mann-Whitney U Tests showed that there were no significant differences in scores between the two groups and these results are summarised in Tables 3.3. and 3.4.

Table 3.3. Comparison of subjects on medication/not on medication

Reaction time test - Z scores based on medians

Test Occasion	z score =	p =
1	-0.4398	0.6601
2	-0.367	0.7136
3	-1.1809	0.2377
4	-1.4082	0.1591

Table 3.4. Comparison of subjects on medication/not on medication

Memory test - Z scores based on means

Test Occasion	z score =	p =
1	-0.8405	0.4006
2	-0.7391	0.4599
3	-0.4428	0.6579
4	-0.0000	1.0000

In addition to the above statistical procedure the pattern of results for each individual subject was perused. There was no distinctive pattern of change from one occasion to another that was common only to the subjects in the medicated group or to those in the non-medicated group. The group on medication was further broken down into those subjects taking medication for the first three occasions only and those on medication for the entire test period. Again there was no common pattern that distinguished the two subgroups. Furthermore, of the two subjects taking medication during the period covering the first three occasions there was a significant improvement in reaction times on the fourth occasion for one subject but not for the other. Taken together, these results would seem to indicate that overall, medication per se had only a minimal effect, if any.

As well as examining changes among testing occasions, the individual scores of those on medication were perused and they did not deviate markedly from the non-medicated subjects. The reaction times of individual medicated subjects were varied in that some were slow and others were fast. Moreover, variability, as measured by the standard deviation, was no different for individuals taking medication than for those subjects not on medication. When memory scores were examined some subjects taking medication achieved relatively high scores while the scores of others were low. Thus, there were no patterns of performance to suggest that medication had an effect.

3.3. RESOLUTION OF POST-TRAUMATIC AMNESIA

3.3.1. Return of orientation

Orientation returned in the order of person, place and time for 38% of subjects while for a further 15%, orientation returned simultaneously for person and place followed by temporal orientation. The ordering for the remaining 46% was place, person, time.

3.3.1.1. Personal Orientation

Orientation for Date of Birth

All of the subjects, except two, knew their date of birth on admission to the unit. One of the two exceptions was the oldest subject in the study, MR aged 63years, who often was able to state the month and day of the month of his birthday but could not recall his year of birth. The other subject, KC, was so agitated it was not even possible to begin PTA testing until 62 days post-trauma and he was not able to give his date of birth until three months post-trauma.

Orientation for age

Only 3 of the 13 subjects recalled their age correctly from the time of admission to the unit. More specifically, these three subjects gave an age which was one to two years younger than their actual age on the day of admission and thereafter gave their correct age.

3.3.1.2. Temporal Orientation

Orientation for year

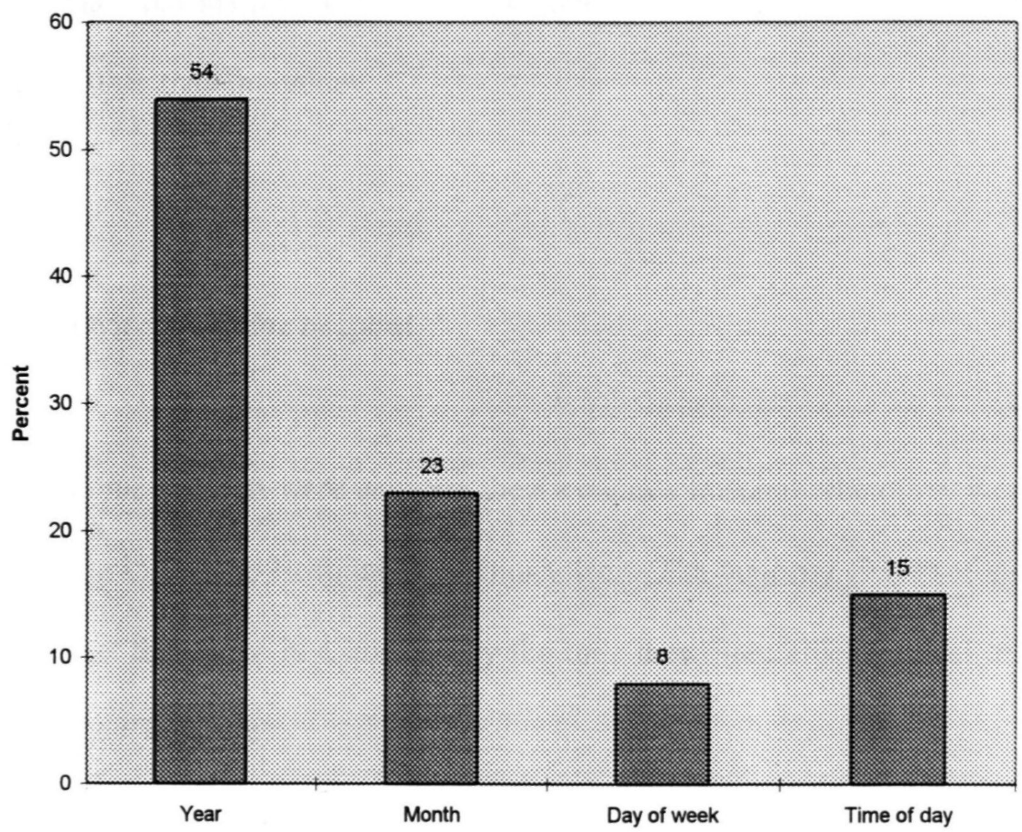
In the early stages of PTA, when asked for the current year, most subjects gave a year displaced backwards in time, although one or two subjects gave a year in the future. On one occasion a subject gave a year before he was born as the current year. The shrinkage of time to the current year was not always achieved in an orderly fashion, with 77% of subjects moving back and forth between years in a haphazard manner before they finally became oriented for the current year.

Four of the thirteen subjects became oriented for day of the week and/or month before the year. Furthermore, for 54% of subjects, attainment of the correct year, was related to the point in time when they were able to recall the pictures of the PTA scale.

Orientation for month, day of week and time of day

Orientation for these items did not always return in an orderly fashion of month, day, and time of day which is the pattern one might expect if orientation depended solely upon memory. Only one subject became oriented in such a systematic way and patterns for the remaining subjects were very mixed. The first temporal item for which subjects became oriented was as follows: year, 54% of subjects; month, 23% ; day of week, 8% (1 subject) ; time of day, 15%, and is illustrated in Figure 3.1

Figure 3.1 First Item of Temporal Orientation



Although time of day was the last item of temporal orientation to return for 30% of subjects, 38% of subjects became oriented for time of day before year and 46% were aware of the time of day before they were oriented for the month. Thus, there was no relationship between orientation for the date and the ability to estimate duration of time.

3.3.1.3. Spatial Orientation

Orientation for City

With the exception of one patient, all subjects became oriented for city before they were oriented for the name of the hospital. Subject O.L., who was the exception, had had his accident in a town south of Sydney and believed himself to be there rather than in Sydney.

Orientation for hospital

Some subjects were unaware they were in a hospital when they were first admitted to the Lidcombe Hospital Head Injury Unit. The majority (93%) of subjects were aware that they were in a hospital by the time they were able to recall the three pictures of the PTA scale.

In summary, the most common order for return of orientation was person, followed by place, followed by time (38% of subjects, or 84% of subjects if age is considered to be an item of **temporal** rather than personal orientation). However, within each of these domains the clinical picture was very mixed. Most subjects knew their date of birth on admission though not their age and over a third (38.5%) remained disoriented for age by Test Occasion 2. Only 46% were aware that they were in a hospital when first admitted and by the time Test Occasion 2 occurred this figure had not improved significantly. In contrast, 80% of subjects were oriented for city on admission to the Head Injury Unit. In terms of temporal orientation, resolution was not in an ordered manner of year, month, day of week and time of day and there was no relationship between orientation for the date and the ability to estimate temporal duration.

3.3.1.4. Recall of the therapist's name

When patients are assessed with the PTA scale they are asked to memorise the name of the therapist who carries out the assessment. Some subjects found this difficult to do even though the therapist's name was repeated each day if they were unable to recall it. Only 38 % of subjects achieved consistent recall of the name at the same point in time at which they were able to recall the three pictures. A further 15% did so a few days after reaching this milestone. The remaining 46 % were unable to remember the name until a few days before the end of PTA.

3.3.1.5. Recall of the pictures of the PTA scale

3.3.1.5. Recall of the pictures of the PTA scale

Consistent with previous clinical observations using the modified Oxford PTA scale, all subjects except one were able to recognise/freely recall the three pictures prior to achieving full orientation. The exception was the subject with the shortest period of PTA (20 days), for whom memory and temporal orientation resolved simultaneously.

3.4. ATTENTION

Note (from section 2.3): Procedure for testing for attention and memory was as follows:

Test Occasion 1:

- Subjects were confused and disoriented.

Test Occasion 2:

- Subjects were beginning to lay down memories as defined by the PTA scale i.e. they could recall the three pictures.

Test Occasion 3:

- Subjects were laying down memories and were oriented for time i.e. they had emerged from PTA

Test Occasion 4:

- Subjects were three to four weeks post PTA.

Non-parametric tests were used to analyse the data because the distribution of scores was not normal and there were large variances in the data. Both the mean and median scores for the reaction time test were analysed, however, the median scores are reported. This is because the median is considered to be a better index of central tendency than the mean as reaction time distributions are skewed (Van Zomeren & Deelman 1978).

3.4.1. Reaction times - Median scores.

Median reaction times are shown for each occasion of testing in Table 3.5. A Friedman Two-way Analysis of Variance (ANOVA) was performed to test whether there were differences between the median reaction times across the four test occasions. Differences between occasions were significant (X = 31.9615. p < .0001). A Wilcoxon Matched-Pairs Signed-Ranks Test was then performed. The reduction in reaction times over test occasions was significant (see Table 3.6.)

Table 3.5. Median Reaction Times

Test Occasion	Median
	(seconds)
1	1.92
2	0.88
3	0.51
4	0.42

Table 3.6. Significance Levels For Differences Between Test Occasions

Test Occasion	z score =	p =
1& 2	-2.9701	0.0030
2 & 3	-3.1099	0.0019
3 & 4	-2.5887	0.0096

The difference in the median scores between Test Occasions 1 and 2 was almost three times greater than the difference between Occasions 2 and 3 and almost 12 times greater than that between Occasions 3 and 4. The average time interval between the first two occasions of testing was only 11 days whereas the average length of time between occasions two and three was 14 days and between occasions three and four was 24 days. Thus the greatest improvement in performance occurred during the shortest time interval. (See Table 3.7.)

Table 3.7. Median differences and time between testing occasions

Test occasion	Median - differences	Time between test occasions
	(seconds)	(days)
1 & 2	1.04	11.1
2 & 3	0.37	14.0
3 & 4	0.09	24.3

It was decided to scrutinise the data further because of concern that results may have been affected by the skewdness of the distribution. Reaction times were transformed to log10 to compensate for the skewdness. This transformation resulted in a more symmetrical distribution. A Wilcoxon Matched-Pairs Signed Ranks Test indicated that differences between testing occasions were still significant.

3.4.2. Consistency of Performance

Consistency of performance was measured by comparing the standard deviations for each subject for each occasion of testing. The size of the standard deviation decreased over the four occasions, that is, performance became more consistent as the patient emerged from PTA. A Friedman Two-Way ANOVA showed that differences between test occasions were significant (X = 25.3385, $p < .0001$) .

The standard deviation on Occasion 1 was 2.4 times greater than for Occasion 2, and 7 times greater than the standard deviation for Occasion 3 when the patients had emerged from PTA. A Wilcoxon Matched-Pairs Signed-Ranks Test showed there was a significant difference between Occasions 1 and 2 at the .05 level and between occasions 2 and 3, and 3 and 4 at the .01 level and these results are detailed in Table 3.8.

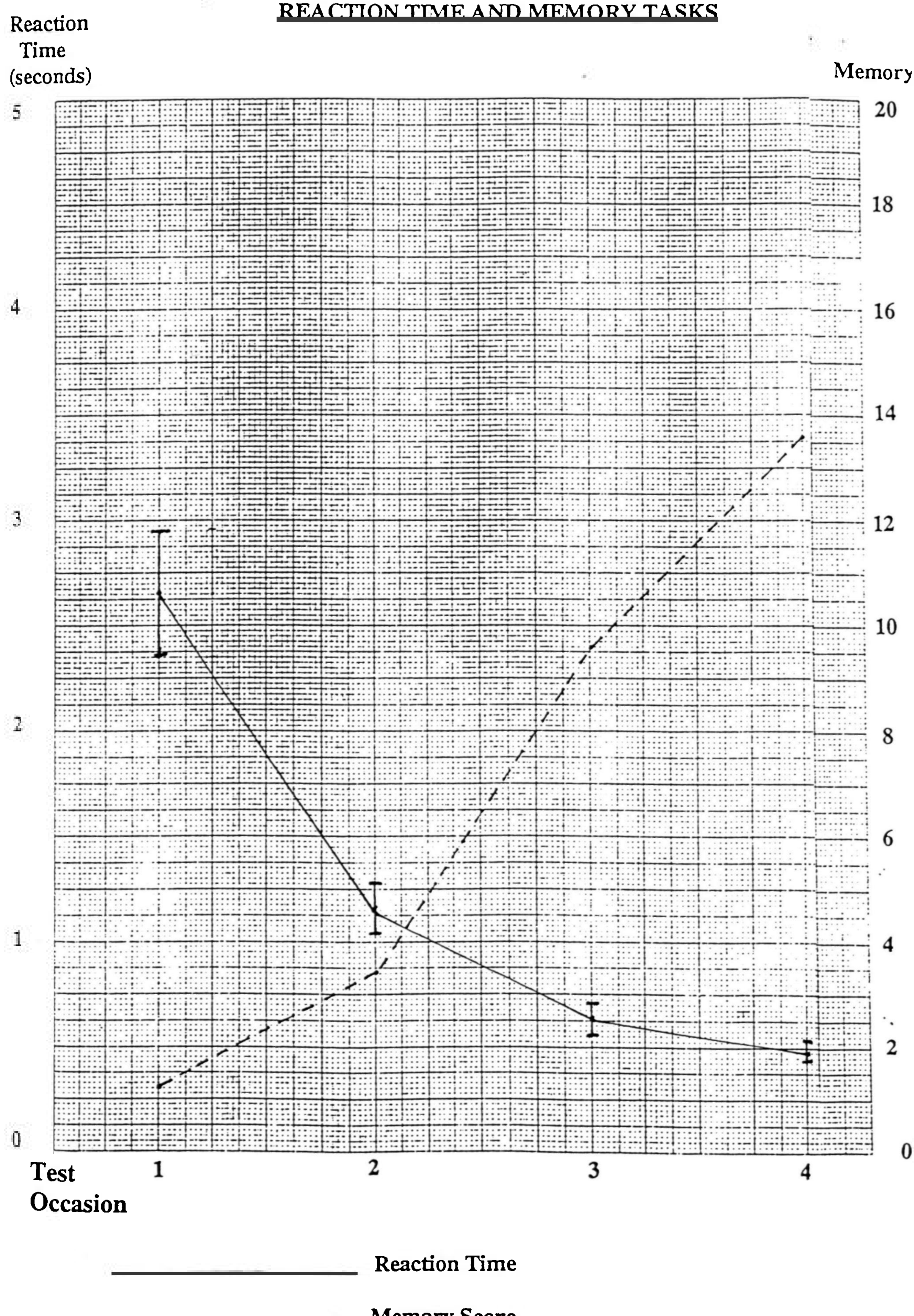
Table 3.8. Standard deviations -differences between testing occasions

Test Occasion	**z score =**	**p =**
1 & 2	-1.9917	0.0464
2 & 3	-2.8304	0.0046
3 & 4	-2.7605	0.0058

Confidence intervals of 95% have been plotted for reaction times in Figure 3.2 (following page) along with memory scores. These confidence intervals illustrate the variability of performance over the four occasions of testing.

Figure 3.2. TOTAL GROUP

REACTION TIME AND MEMORY TASKS



3.4.3. Comparison of head-injured subjects with control subjects

Randomisation tests were carried out to compare the performances on the reaction time test of the head-injured subjects with those of the controls. The two groups were compared using the transformed means and the untransformed means, medians and standard deviations. See Table 3.9. for untransformed scores for each group. On each occasion of testing, including the fourth, which was conducted several weeks after subjects emerged from PTA, head-injured subjects were significantly slower than controls who were matched for age, sex and years of education.

Table 3.9. Untransformed Scores on the reaction time test comparing Head-injured Subjects with Control Subjects

Test Occasion	Mean		Median		Standard Deviation	
	Subjects	Controls	Subjects	Controls	Subjects	Controls
1	2.654	0.36	1.92	0.28	2.208	0.065
2	1.158		0.88		0.915	
3	0.603		0.51		0.335	
4	0.475		0.42		0.173	

On all the comparisons in Table 3.9, as well as those using the transformed means, the significance level was $p < .001$.

As can be seen from Table 3.9, the standard deviation of patients in PTA on the first testing occasion was 34 times greater than that of the controls. On the second occasion it was 14 times greater and on occasion three, when the patients emerged from PTA, the standard deviation was five times greater than for the controls. When subjects were tested a few weeks after emerging from PTA the consistency of their performance had improved yet again but the standard deviation was still 2.7 times greater than that of the controls.

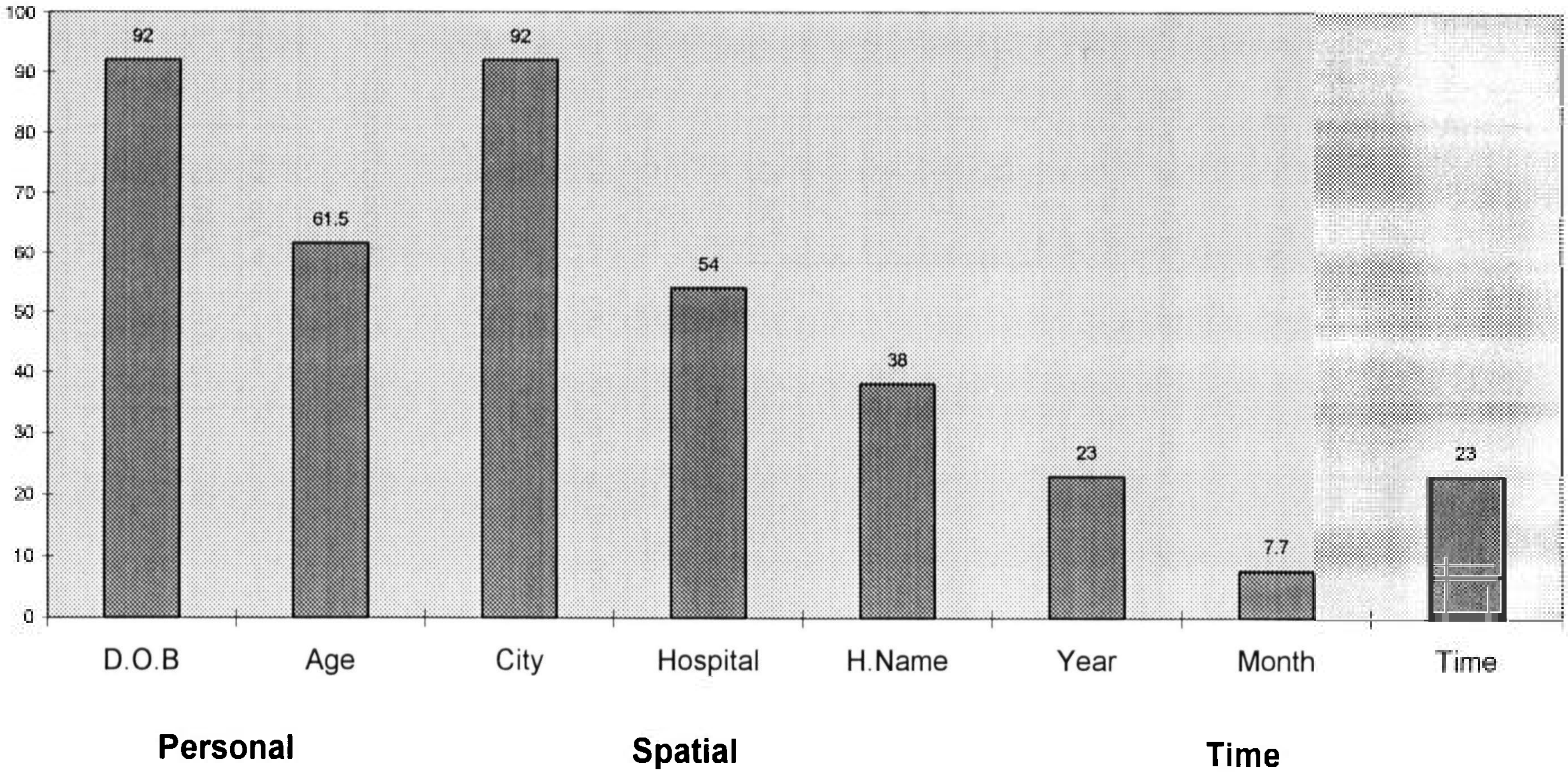
3.4.4. The relationship between orientation and improved attention.

When subjects reached the stage where they were able to recall the three pictures of the PTA scale, the second testing occasion of the study was conducted, and it is useful to look at the extent to which subjects were oriented at this point in time. On Test Occasion 2 although there was a statistically significant improvement in memory, as will be discussed in section 3.5, the improvement in attention, as measured by the reaction time task, was of much greater significance.

Only one subject was unable to give his correct date of birth when the second occasion of testing occurred and he became oriented for this item two days later. However, although 92% were oriented for date of birth, only 61.5% could give their correct age. All subjects were oriented for the name of the city at this point but a few days later subject O.L. became disoriented for this item and believed himself to be in a town on the South Coast (as described in section 3.3.3.3.) and this belief persisted until the end of PTA. Most subjects (92%) knew they were in a hospital, and 38% also knew the name of the hospital. Thus, at this stage of PTA, subjects appeared to be more capable of attending to cues in their environment to determine where they were. The improvement in memory, however, was relatively small

(Occasion 1, X = 1.23, Occasion 2, X = 3.46) and is reflected in the finding that only 38% of subjects were able to remember the name of the hospital. These results are illustrated in Figure 3.3. on the following page.

Figure 3.3 Orientation At Second Trial



3.5. MEMORY

A Freidman Two-Way ANOVA indicated significant differences between occasions of testing (X = 32.4692 , $p < .0001$) on the Rivermead Behavioural Memory Test. The mean profile scores for each test occasion are shown in Table 3.10. and were also plotted in the previous Figure 3.2.

Table 3.10. Rivermead Behavioural Memory Test

(Maximum score = 24)

Test occasion	Mean
1	1.23
2	3.46
3	9.54
4	13.54

The Wilcoxon Matched-Pairs Signed-Ranks Test showed that the improvement between Occasions 1and 2 was significant only at the .05 level but the improvements in memory between Occasions 2 and 3, and from Occasion 3 to 4 were highly significant, as illustrated in Table 3.11.

Table 3.11. Significance levels for differences between means

Test Occasion	z score =	p =
1 & 2	-2.0894	0.0367
2 & 3	-3.1099	0.0019
3 & 4	-2.9417	0.0033

As can be seen in Table 3.10. on the previous page, the difference between the means from Test Occasion 2 to 3 was almost three times greater than the difference between the first two occasions and one and a half times the difference from Occasion 3 to 4. Thus, the biggest improvement in memory was between the point at which attention, as measured by the reaction time task, improved significantly and the time at which the patient emerged from PTA.

3.6. The relationship between PTA duration, attention and memory

PTA duration was examined to see whether it was correlated with the mean, median and standard deviation of the attention task and with scores on the Rivermead Behavioural Memory Test. Since it has been suggested that a simple reaction time test is one of the best tests to discriminate patients in PTA from amnesic patients (Wilson et al, 1992), it was thought that PTA duration might be correlated with performance on the reaction time test.

It was found that the length of PTA was correlated with the median score on the reaction time task for Occasion 2 ($r = -.7427$, $p = .004$), which was the time at which the subject began making memories. To a lesser extent there was also a correlation between PTA and the median score on Occasion 3 ($r = -.5630$, $p = .045$). There was no correlation of PTA duration with means or standard deviations. Nor was there any relationship with the RBMT scores. These results seem to reflect the findings of Wilson et al, 1992 and show that a simple reaction test is a better marker of PTA than a memory test.

CHAPTER 4 DISCUSSION

4.1. RESOLUTION OF POST-TRAUMATIC AMNESIA

4.1.1. Memory (as measured by the PTA scale)

As reported in the Chapter 3, all subjects (with the exception of the least severely injured patient, M.A.) were able to recall the three pictures prior to achieving temporal orientation. This is consistent with previous clinical observations when using the modified Oxford PTA scale. By contrast, as discussed in section 1.9, the authors of the Westmead PTA scale and the Julia Farr PTA state that temporal orientation almost always resolves before amnesia, as measured by recall of the three pictures. These disparate findings are probably due to the different ways in which the memory component of the scales are administered.

As described in sections 1.8.1. and 1.8.3., when a recognition test is necessary for the memory items, the Oxford scale uses five **new** distractors each day while the Westmead scale and the Julia Farr scale use the **same** distractors every day. Moreover, when the Westmead scale is used, once the patient obtains a perfect score (including recognising the three target pictures) the task is changed and s/he is required to memorise three new pictures on each of the next two days. These new pictures are chosen from the pool of six distractors which have been used throughout the PTA assessment period. This therefore, may have the effect of making the memory component of these 2 scales more difficult than that of the Oxford Scale.

Recognition memory is based on information from two independent sources. The target stimulus can be recognised on the basis of familiarity whereby one simply has to judge whether or not one has seen the item before. Otherwise, a judgement must be made according to temporal/spatial context, where one has to remember contextual attributes e.g. was the item seen yesterday or the day before ? (Parkin & Leng, 1993). It has been found that other brain damaged populations, e.g. Korsakoff patients, performed poorly on a memory test which required the encoding of temporal contextual information (Hunkin & Parkin, 1993; Parkin et al. 1990) and it could be argued that head-injured patients might also have difficulty with such a task.

The memory component of the Westmead and Julia Farr PTA scales, when a recognition test has to be given, involves making a temporal contextual discrimination. The Oxford scale, because it uses different distractors each day, only requires recognition of whether the pictures are familiar or not. Thus, it would seem that the order in which orientation and amnesia resolve during the state of PTA might be influenced by the way in which the memory component of the PTA scale is administered.

It could of course be argued that this effect would only be obtained if the patient is unable to freely recall the pictures and thus requires a recognition test. However, it is likely that the majority of severely head injured patients will be incapable of free recall in the early stages of PTA. A study by Geffen et al. (1991) found that when patients were first tested on the picture memory component of the Julia Farr PTA scale they were only able to remember the pictures if given a recognition test. Later they progressed to being able to recall them with cueing and finally were capable of spontaneous recall.

My own observations are consistent with this, that is, with few exceptions patients with severe head injuries first recognise the pictures before they can achieve free recall. Furthermore, some patients who have a chronic severe memory impairment (as determined by neuropsychological assessment **after** they emerge from PTA) do not ever achieve **free** recall of all three pictures. Since the ability to recognise the pictures, as well as the therapist's name, is used as criteria for successful recall and since all scales which incorporate this memory component require the critera of a perfect score to mark the end of PTA, it would be useful to find another method of determining the end of PTA for patients with such severe memory deficits. The findings of this study suggest that this could be done by monitoring changes in their speed of information processing, as measured by their performance on a simple reaction time task, and when their performance plateaud one could be reasonably certain that they had emerged from PTA.

The other memory item of the modified Oxford PTA scale is recall of the therapist's name, which proved to be a difficult task for some patients. Two possible explanations for this difficulty in learning the therapist's name are:

- patients might also be trying to remember the names of other therapists and nursing staff who interact with them, thus, they are trying to acquire a lot of new information at a time when their memory is severely impaired.
- head-injured patients often have anomia i.e. they are unable to name objects and it might be that the ability to recall peoples' **names** is also a common deficit especially while in PTA.

The name of the therapist can also be tested by recognition. People who cannot freely recall the name are given a multiple choice, therefore the question arises as to why the patient can recognise the pictures of the PTA scale but might not be able to recognise the therapist's name. One could surmise that recall of the pictures is an easier task because the patient can utilise two aspects of memory, i.e. visual and verbal (the names of the objects in the pictures) whereas remembering a name involves verbal memory only.

4.1.2. Orientation

The order in which the individual components of orientation returned was different from the findings of other researchers in that a much smaller percentage of subjects in the current study (46%) became oriented in the order of person/place/time than in other studies. However, Daniel et al. (1987) argue that age could be considered an item of temporal orientation rather than personal orientation because it has a recovery pattern similar to year; age changes over time whereas other items of personal orientation remain constant. Thus, if age is viewed in this way then orientation returned in the order of person, place and time for 84% of subjects in the current study, which reflects the findings of other researchers.

4.1.2.1. Orientation for date of birth

Two subjects were, at first, unable to state their date of birth. One of these subjects, M.R., was 63 years old and his inability to recall this information would seem to question Ribot's law of regression that more recently acquired items are more vulnerable to disruption than items acquired earlier. Based on this law the assumption would be that the older a person is, the more frequently his date of birth would have been rehearsed and it should be more resistant to temporary loss. However, Daniel et al. (1987) found that older people in his study were more disoriented after a series of ECT treatments than were younger patients. Older people who have suffered a head injury might be more severely disoriented when they are in post-traumatic amnesia than are younger patients and this would account for their confusion over such well learned facts.

The other subject who had difficulty with this item, K.C., was in a coma for 19 days, had a PTA duration of 131 days and demonstrated severe cognitive impairments on neuropsychological testing after he emerged from PTA. Moreover, he was extremely agitated in the first three months post-trauma and it may be that the severity of the injury and the way in which it manifested itself in such high levels of agitation might account for his inability to recall his date of birth until 14 weeks post-trauma.

4.1.2.2. Orientation for age

As stated in the results only 3 of the 13 subjects recalled their age correctly from the time of admission to the unit. Where subjects gave an incorrect age it was not necessarily related to the period of retrograde amnesia, that is, the age given was not always congruent with the year they stated as being the current one

Once a patient was correctly oriented for an item it did not mean that further lapses would not occur; one subject gave his correct age for nine consecutive days then made an error. Over half of the subjects became oriented for age before they were oriented for the current year which confirms Mowbray's (1954) assertion that age is not solely dependent upon arithmetical calculation.

4.1.2.3. Orientation for Year

The haphazard pattern in which subjects became oriented for the current year was striking. Typically they would give a year in the past then move to a year even further in the past. They might then give the current year on one day then move to a year in the future. This pattern was sometimes repeated several times before they finally became oriented for the current year. This unsystematic return to current year is reflected in the findings of Daniel et al. (1987).

Displacement in time cannot always be explained by retrograde amnesia. If it was the sole explanation then one would expect that orientation responses would be consistent. Return to the current year would be orderly and the age given by a patient would be compatible with the year s/he gave as the current one. Not only do responses for age and current year conflict with each other but responses change from day to day and jump back and forth in time.

Other researchers have found similar inconsistencies (Daniel et al. 1987; Mowbray 1954) and attribute it to the fact that patients do not notice the contradictions in their answers because of their diminished cognitive capabilities. For example, when one subject was asked what the current year was, he gave the year before he was born which indicates the absence of self monitoring of responses that seems to prevail during post-traumatic amnesia. Even when an inconsistency is pointed out to them they still are unable to correct their answers. As an example of this, one patient in the study gave his year of birth as 1968 and the current year as 1974. He was told that if this were correct he would only be 6 years old instead of 26 years old, to which he replied, " Oh, it's 1976 then". Thus, not only do patients seem unable to monitor their responses when they are in PTA but they also seem to be incapable of carrying out simple arithmetical calculations or of using feedback to correct responses.

If orientation for the current year depended solely on memory one might expect patients to become oriented for the year before the month and the day of the week.

The year is a constant but the day of the week is changing continually, therefore, one should be able to retain information regarding the year more easily.

Attainment of the correct year, for 54% of subjects, was related to the point in time when they were able to consistently remember the pictures of the PTA scale. This is the stage at which subjects showed a marked improvement in their attention, therefore, orientation might also depend on being able to focus one's attention and process the information one is being given, rather than being solely a function of memory.

4.1.2.4. Orientation for month, day of the week and time of day

As stated previously, if orientation depended solely on the ability to remember information then one would expect patients to become oriented first for the month, then day of the week then time of day. Month is a constant, for a period at least, whereas day is not, and to judge time of day one would assume that the patient would need ongoing memory or the ability to check and incorporate environmental cues. In this study such an ordered pattern was not the case which suggests that memory is only one of the factors involved.

Benton et al. (1964) asserted that the ability to judge time of day is independent of temporal orientation (i.e. year, month and day) and perhaps this would account for the fact that the point at which subjects regained this ability did not relate to their degree of temporal orientation. However, it should be noted that in their study subjects were required to judge the actual time of day whereas in this current study it was only necessary for subjects to decide whether it was morning, afternoon or night. Perhaps this simplifies matters for the patient once his/her level of attention improves for s/he can then use cues from the environment to help make this judgement e.g. whether it is light or dark.

4.1.2.5. Orientation for City

With the exception of one subject everyone became oriented for city before they were oriented for the name of the hospital. The exception was O.L., who had had his accident in a town south of Sydney and had spent a lot of time holidaying there in the past. In the early stages of PTA he was oriented for city for seven consecutive days, although he sometimes required a multiple choice to be able to give the correct answer. Thereafter, he either stated that he was in Nowra or Bateman's Bay (on the South Coast). His assertion that he was in a town on the South Coast was made in spite of the fact that he knew that he was in Lidcombe Hospital. Thus, he showed no awareness of the incongruity of these statements. When queried about this discrepancy he gave different explanations on different days.

On one occasion he stated "We aren't really in Lidcombe it just looks like Lidcombe". On another occasion he said we were in Lidcombe Hospital in Nowra and he was told that we were in Sydney and was asked how far away he thought Nowra was. He replied, "A few kilometres from here". Paterson and Zangwill (1944) refer to this phenomenon, where the patient claims that two places which are far apart are contiguous, as "spatial displacement". When O.L. was questioned on yet another occasion and told that Lidcombe was a suburb of Sydney he looked confused and said, "We're not in Sydney. Sydney is about 300 kilometres north of here".

At times he would look out of the window at the hospital grounds and state that it looked like Nowra. Thus he attempted to fit his perceptions to his belief, as Lidcombe and Nowra bear little if any resemblance to each other, Nowra being a coastal town and Lidcombe being a suburb of Sydney approximately 20 kilometres west of the coast. Paterson and Zangwill (1944) described two similar cases where patients could correctly state the name of the hospital but believed themselves to be in England rather than in Scotland and would ascribe certain features of their present environment to the place they believed themselves to be.

As O.L. progressed towards the end of PTA he would, at times, say that he remembered that he had been told that he was in Sydney but that he felt that he was on the South Coast. It was not until he was on the point of emerging from PTA that he was fully convinced that he was in Sydney. The fact that O.L. could recall the name of the hospital and remember that he had been given the information that he was in Sydney seems to confirm the assertion of Paterson and Zangwill (1944) that disorientation is not due simply to a retention deficit, as suggested by, for example, Benson et al. 1976 and High et al. 1989.

Paterson and Zangwill do believe, however, that orientation is aided by a general improvement in memory so that the patient can construct a coherent account of his daily activities. Furthermore, they assert that "A measure of coherence between present and past would appear an obvious condition for stable orientation" (p66). O.L. gained this coherence and achieved full spatial orientation when he was able to retain the account of the details of his accident and his transfer to Sydney for his rehabilitation (details which were given to him by his family and hospital staff) and when he could recall day to day activities.

Only the GOAT and the modified Oxford PTA scale have an orientation question relating to city. It would seem useful to have such a question, particularly when a patient has been transferred from the city in which he had his injury or when a patient has lived in another city for a period of time prior to the accident. Given that O.L. was not oriented for city until on the point of coming out of PTA he might have been classified as being out of PTA at an earlier date if this question had not been included.

4.1.2.6. Orientation for hospital

Some subjects were unaware they were in a hospital when they were first admitted to the Lidcombe Head Injury Unit. This is an indication of how grossly their attention and perceptions can be impaired when they are in the early stages of PTA. If they were able to pay attention to their surroundings it would be obvious to them that they were in hospital. The majority of subjects were aware that they were in a hospital by the time they were able to recall the three pictures of the PTA scale and this was the point in their recovery at which attention, as measured by the reaction time task, improved markedly.

Orientation has at times been treated as a simple or unitary concept but it is obvious from the results obtained in this study and findings of other researchers that it is not.

Lezak (1983, p533) states that orientation requires "... consistent and reliable integration of attention, perception and memory..." and this is demonstrated by the research into orientation.

4.2. ATTENTION

The results showed a significant reduction in reaction times between the first test occasion when the patient was confused and disoriented, and the second occasion when the patient was beginning to make memories as defined by the PTA scale. This was the most marked difference between any two test occasions, yet the interval between these two occasions was of the shortest duration and for one subject was as brief as four days. Conversely, the longest time interval was between Occasions 3 and 4 yet the reduction in reaction time between these two occasions was relatively small.

Because reaction time was not measured each day it is possible that the improvement described above was a gradual one rather than being a dramatic improvement co-inciding with the return of recognition memory and this needs to be addressed in future research. Nevertheless, the knowledge that speed of information processing, i.e. reaction time, has improved markedly by the time recognition memory has returned is of value. Ewert et al. (1989) found that patients in PTA were able to perform some simple tasks that involved procedural learning and it could be argued that they would be more likely to be capable of such tasks at the point in time where their speed of information processing had improved. Thus, physiotherapy and some occupational therapy tasks which utilise procedural memory could be commenced at this point.

Performance on the attention task also became more consistent, as measured by the standard deviation, as subjects progressed through the state of PTA. Therefore, not only did attention improve, as reflected in faster reaction times, but subjects were better at maintaining their performance. MacFlynn et al. (1984) argue that intrasubject variability is due to lapses of vigilance, thus, the improvement in consistency of performance on Test Occasion 2 suggests that the ability of subjects to **sustain** their performance had improved. If this is so, then this would further support the suggestion that therapy utilising procedural memory should begin at this time.

Subjects were significantly slower and less consistent than the control group on all occasions of testing, including the final one which was conducted some weeks after subjects emerged from PTA. Unfortunately the control group was tested on only one occasion thus it was not possible to determine whether practice effects occur in a non-injured population.

Only a few studies have examined performance 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 reaction time task. Trials were carried out at 5 months, 8 months, 15 months and 21 months post-trauma. They continued to find improvements in performance, in terms of speed, for the severe group over the entire period.

A study by MacFlynn et al. (1984) which looked at changes in performance over time was carried out with mildly head injured patients and used a complex reaction time test. Subjects were tested within 24 hours of admission. Almost half the patients had a PTA less than 15 minutes and the remaining patients had a PTA duration of less than 24 hours, thus it is likely that subjects would either have been in PTA, or would have recently emerged from PTA, at the time of the initial test. They found that subjects were more variable than a control group when tested on the day of the injury but not when tested 6 weeks later.

These researchers suggested that the variability which was present on the initial test probably reflected lapses in vigilance. They argued that the lapses could be due to an acute pathological process and this would account for the variability in performance no longer being present when they were tested 6 weeks post-trauma. This pathological process is not properly understood but is probably reflected in the slowing of EEG frequencies and prolonged auditory brainstem evoked response latencies.

Subjects in the current study had sustained a very severe injury and hence the acute recovery period lasted much longer. Large variances in reaction times were evident in the early stages of PTA and these diminished as subjects emerged from this state. The fact that greater variability, in comparison with the controls, was still evident when head-injured subjects emerged from PTA suggests that the process responsible for this variability may not fully resolve after such severe injuries.

This is consistent with 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. Unfortunately, they did not examine whether this variability improved over time. As Stuss et al (1994) point out, intra-subject variability is of clinical interest because diagnosis of impairment is often based on a single test performance whereas their findings suggest that a more accurate picture might be obtained if performance is measured over a number of occasions.

In the MacFlynn et al. study (1984) subjects differed significantly from controls in terms of both speed and variability on the initial testing occasion but differed only in speed at the 6 week follow-up. These results suggest a dissociation between speed and variability. This dissociation has not been investigated, to date, in a more severely injured group. While the group results in this current study do not indicate such a dissociation, because variability improved along with speed of response for the group as a whole, the picture is different when results for individual subjects are examined. Reaction times improved from one testing occasion to the next for a number of subjects but the standard deviation increased. Moreover, the subject who had the slowest reaction times on the first occasion had one of the smallest standard deviations. Thus, it would seem that the relationship between speed and variability is not a simple one.

4.3. MEMORY

A somewhat different pattern of results from that for attention was obtained for memory. Whereas the greatest improvement in reaction times occurred between the first two testing occasions, the greatest improvement in memory occurred between Occasions 2 and 3 which was the period during which the patient progressed from not only being able to lay down memories (as measured by the PTA scale) but became oriented for time. A significant improvement was also evident between Occasions 3 and 4 which covered the period from when the patient first emerged from PTA to a point in time approximately 3 weeks post-PTA.

Memory, obviously, is dependent to some extent upon the ability of the person to attend to the material which is to be committed to memory and this is born out by the results. Attention (as measured by the reaction time task) improved markedly before memory showed signs of significant improvement. At the end of PTA speed of reaction time was beginning to plateau in terms of both mean and median scores. Although a statistically significant difference was obtained between the last two testing occasions for the group, this result might be misleading. When results for individual subjects were examined this difference was quite small and this will be further discussed in Chapter 5. Memory scores, however, continued to improve between the last two testing occasions at a similar rate to that obtained between Occasions 2 and 3.

The fact that attention, as measured by simple reaction time, was beginning to plateau while memory continued to improve dramatically after patients emerged from PTA, suggests that improved reaction times may be a better marker of the end of post-traumatic amnesia than improvements in memory. However, it is must be acknowledged that these results were obtained from a very small sample of patients with **very severe** injuries, therefore, these findings might not necessarily apply to all individuals who have sustained a brain injury.