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IMPLICIT MEMORY AND SEMANTIC LEARNING
IN POST TRAUMATIC AMNESIA

by

Suzanne Marie Delaney

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1995
As members of the Final Examination Committee, we certify that we have read the dissertation prepared by Suzanne Marie Delaney entitled *Implicit memory and semantic learning in post traumatic amnesia* and recommend that it be accepted as fulfilling the dissertation requirement for the Degree of Doctor of Philosophy.

Final approval and acceptance of this dissertation is contingent upon the candidate's submission of the final copy of the dissertation to the Graduate College.

I hereby certify that I have read this dissertation prepared under my direction and recommend that it be accepted as fulfilling the dissertation requirement.

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Dedication

I dedicate this dissertation with love and admiration to my parents, Mary and Daniel Delaney.
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TABLE 2 - Performance of control subjects on retention of fictitious facts and source information for sessions 1 and 2 . . . . . 83
Implicit and explicit memory performance, and new semantic learning in post traumatic amnesic (PTA) patients were assessed in two experiments. The first experiment compared implicit and explicit memory for word lists for eight PTA patients and matched controls. Subjects participated in one implicit memory test (stem completion) and three explicit memory tests (stem-cued recall, free recall, and old/new recognition). PTA patients showed intact priming on the stem completion task, while performing significantly worse than control subjects on all three explicit memory tests.

The second experiment examined new semantic learning in PTA patients. The method of vanishing cues, developed by Glisky, Schacter and Tulving (1986b), was used to teach five fictitious facts (e.g. Bob Hope's father was a fireman) to four PTA patients and four matched controls. Despite variability among the PTA patients, they showed substantial learning within the PTA state and good retention 5 days and several weeks following the emergence from PTA.

These studies suggest that implicit memory abilities are preserved in PTA patients, and that these patients are able to learn new semantic information despite their profoundly impaired explicit memory performance.
INTRODUCTION

Closed head injuries often result in a loss of consciousness even when the injury is relatively mild. The emergence from coma leaves the individual confused and amnesic for the events that occurred just before and following the accident. This post-traumatic amnesia (PTA) may last moments, hours, or days (Russell, 1932). It has been widely accepted that PTA patients are unable to learn new information (Russell & Nathan, 1946). Consequently, cognitive rehabilitation efforts are commonly postponed until the resolution of PTA has occurred. However, there are reasons to suspect that PTA patients, like chronically amnesic patients, may possess preserved memory abilities and consequently may benefit from a relatively early onset of specific types of cognitive rehabilitation. This dissertation explores the preserved memory abilities of PTA patients.

In this introductory chapter, I a) define implicit and explicit memory and present evidence of dissociations between implicit and explicit tests of memory, b) introduce theoretical frameworks proposed to account for these dissociations, c) describe the characteristics and assessment of PTA, d) present an overview of the literature concerning the preserved memory abilities of chronically amnesic patients, and e) describe the few experiments demonstrating preserved memory abilities of PTA patients.
Implicit and explicit memory tests

Graf and Schacter (1985) have proposed a distinction between two types of memory tests. Explicit memory tests (such as free recall, recognition, and cued recall) require conscious recollection of a learning episode and typically engage the subject in an intentional retrieval of previously studied information (Schacter & Tulving, 1994). Implicit memory tests, on the other hand, require no intentional reference to a learning episode but simply ask the subject to perform a task. Implicit memory is inferred by the improvement of performance on that task as a result of prior exposure to a priming stimulus (Graf and Schacter, 1985). Implicit memory tests include stem completion, fragment completion, picture fragment identification and lexical decision (Graf, Squire & Mandler, 1984; Warrington & Weiskrantz, 1974; Milner, Corkin & Teuber, 1968; Jacoby, 1982).

There are several examples of dissociations between explicit and implicit memory tests (see Tulving & Schacter, 1990). In the next section, I will present a selected review of studies that report such dissociations, which have been demonstrated through manipulations of both experimental and subject variables.
Dissociations attributable to manipulations of experimental variables in normal subjects.

Graf, Shimamura, & Squire (1985) explored how changes in modality between study and test affect implicit and explicit tests of memory. Subjects were presented with lists of words either visually or auditorily and were asked to rate how much they liked each word. After presentation of the words, subjects participated in a stem completion test and free recall test. The free recall test provided a measure of explicit memory, and the stem completion test provided a measure of implicit memory. In the stem completion test, subjects viewed a list of words and later were presented with three-letter word stems and asked to complete those stems with the first word that comes to mind. Priming was inferred by the increased probability that subjects completed the stems with words presented on the study list. Results indicated that free recall performance was unaffected by the modality manipulation. However, the magnitude of priming on the stem completion test was affected by this manipulation; within-modality priming was greater than cross-modality priming. These authors concluded that implicit memory performance was disrupted to a greater extent than explicit memory performance by the study-test modality shift.

Changes in surface features, such as different typographies, have also been shown to dissociate implicit and
explicit tests of memory. Implicit memory appears to be more disrupted by changes in surface features than explicit memory (Roediger & Blaxton, 1987).

A third type of implicit/explicit dissociation has been demonstrated through a manipulation of the level of processing at time of study. Semantic processing at time of study has been shown to improve explicit memory performance compared to study tasks that focus on surface features of the stimuli (Craik & Tulving, 1975). Such levels of processing manipulations, however, appear to have little effect on implicit memory tasks. For example, Graf and Mandler (1984) compared the effects of levels of processing on implicit and explicit memory tests for single words. In a study phase, subjects were asked to focus their processing on either perceptual properties of the word (e.g. count the number of T junctions) or on semantic properties of the word (e.g. rate how much they liked the word). They were then asked to complete three-letter word stems either by generating words from the studied list (explicit cued recall) or by generating the first word that came to mind (implicit stem completion). The word stems were identical, only the instructions varied. As expected, the level of processing effect was evident for the explicit memory test. However, implicit memory performance was unaffected by this manipulation. Other studies have reported a levels of processing dissociation

However, other evidence suggests that some elaborative semantic processing at time of study is necessary to demonstrate implicit memory for new associations, although additional elaborative processing does not provide further benefit (Graf & Schacter, 1985; Schacter & Graf, 1986). Graf and Schacter (1985) explored the effects of elaborative processing on implicit memory for new associations. Subjects processed the word pairs (WINDOW - REASON) by either using a semantic elaborative task (sentence-generation) or a nonelaborative task (vowel-comparison). Implicit memory for new associations was assessed using a word stem completion task for the second word in the pair when presented either in the same context as at study (WINDOW - REA__) or in a different context (OFFICER - REA__). The different context condition provided a baseline measure of priming for the individual word (REASON) rather than of the new association itself. The differential levels of priming between the same and different contexts reflected the amount of priming due to the formation of the new association.

Graf and Schacter found evidence for implicit memory of new associations, only when the word pairs were processed
semantically at study. They concluded that some elaborative processing was required for priming of new associations. Schacter and Graf (1986) expanded upon their findings and reported that the type of semantic processing had little effect on the level of priming for new associations. What was required was that a meaningful relation between the words be encoded; further elaboration did not provide additional benefit.

In summary, implicit and explicit memory for words have been shown to be differentially sensitive to a variety of experimental manipulations in normal subjects. Study-test changes in modality (Jacoby & Dallas 1981; Graf, Shimamura & Squire, 1985) and in surface features (Roediger & Blaxton, 1987) affect implicit but not explicit memory performance, whereas levels of processing affects explicit but not implicit memory for single words (Jacoby & Dallas, 1981; Graf & Mandler, 1984). Implicit memory for new associations, however, is only found when some elaborative processing is required at study, although implicit memory is not improved by further elaboration. (For a more extensive review of implicit/explicit memory dissociations based on experimental manipulations see Schacter, 1987).
**Dissociations attributable to subject variables.**

An additional converging line of evidence that performance on implicit and explicit memory tests is dissociable has been provided by studies comparing the performance of chronically amnesic patients and normal control subjects.

Amnesic patients typically perform very poorly on explicit tests of memory (e.g. free recall and recognition). However, they have been shown to perform relatively normally on a variety of implicit memory tasks. One early demonstration of preserved implicit and impaired explicit memory abilities of amnesic patients was provided by Claparede (1951/1911). Claparede described a Korsakoff amnesic patient who had been previously stuck with a pin, hidden in the experimenter's hand. Although the patient did not recall the incident, she refused to shake the experimenter's hand a second time explaining that "sometimes pins are hidden in hands". This example illustrates the dissociation that exists for amnesic patients between implicit expressions of acquired knowledge and conscious recollection of prior episodes.

More recently, investigators have continued to examine the dissociation between implicit and explicit measures of memory. Amnesic patients have shown normal or near normal performance on a variety of implicit memory tasks, despite a profound impairment in their explicit memory test performance.
These tasks range in complexity from a simple eyeblink response in a classical conditioning paradigm (Talland, 1965; Warrington and Weiskrantz, 1979; and Daum, Channon & Canavan, 1989), to the pursuit rotor task (Corkin, 1968; Cermak, Lewis, Butters & Goodglass, 1973; and Brooks & Baddeley, 1976), maze learning (Talland, 1965; Starr & Phillips, 1970; Brooks & Baddeley, 1976) learning of sequential spatial patterns (Nissen & Bullemer, 1987), reading mirror-inverted text (Kolers, 1975; Cohen & Squire, 1980; Moscovitch, Winocur & McLachlan, 1986), word puzzles (McAndrews, Glisky & Schacter, 1987), completion of picture fragments (Talland, 1965; Milner, Corkin & Teuber, 1968), word fragments (Warrington & Weiskrantz, 1974), lexical decision (Jacoby, 1982; Moscovitch, Winocur & McLachlan, 1986; Cermak, Talbot, Chandler & Wolbarst, 1985), learning new piano pieces (Starr & Phillips, 1970), and stem completion (Graf, Squire & Mandler, 1984; Diamond & Rozin, 1984; Heindel, Salmon, Shultz, Walicke & Butters, 1989). Although there is a wide range of implicit memory tests on which amnesic patients show preserved priming, this discussion will focus on stem completion because that task is to be used in the present experiment.

Graf, Squire, and Mandler (1984) tested a group of amnesic patients of mixed etiologies using both implicit and explicit memory tests for lists of words. They used three different explicit memory tests, (free recall, recognition,
cued recall) and one implicit memory test (stem completion). The cued recall and stem completion tests presented the same three-letter cues and differed only in the nature of the instructions given to the subjects. In the cued recall test subjects were asked to use the three-letter cues to help recall the words from the list (explicit memory instructions). In the stem completion test they were instructed to "write down the first word that comes to mind" (implicit memory instructions). Amnesic patients performed similarly to the normal controls in the implicit task; however, they performed very poorly on the explicit memory tests.

Although there have been several studies that show normal stem completion performance in amnesic patients (Schacter, 1987), Squire, Shimamura, and Graf (1987) have reported impaired stem completion performance in amnesic patients. Typically, in stem completion tasks, there are multiple completions possible for the stems presented. Squire et al conducted one experiment which replicated these findings using stems with multiple completions. However, they also presented amnesic patients and normal control subjects with words, the stems of which had only a single completion (e.g. juice). They reported that for the stems with only a single-completion, control subjects showed significantly better performance on the stem completion task than the amnesic patients. However, as these authors point out there were
reasons to suspect that for the normal subjects, "declarative retrieval strategies were mediating word completion performance in these experiments, at least in part" (p. 208). So, although the normal subjects showed a larger priming effect, this may have been attributable to their explicit remembering rather than to the amnesic patients' impaired implicit memory performance.

Theoretical Interpretations of Dissociations

A processing approach.

One theoretical interpretation of the explicit/implicit memory dissociations has been proposed by Roediger and Blaxton (1987). Rather than focusing on whether specific memory tests require reference back to the learning episode, this approach emphasizes the processes that underlie different kinds of memory tasks. The processing framework proposed by Roediger and Blaxton was influenced by notions of transfer appropriate processing (Morris, Bransford, & Franks, 1977) and the encoding specificity principle (Tulving, 1983). Within this approach, successful retrieval of information depends on the degree of match (or overlap) between those processes engaged during encoding and those engaged during testing. The more overlap there is between the underlying cognitive operations the better the transfer and the better memory performance should be.
Explicit memory tests are assumed to rely usually on semantic processing, rather than on physical properties of the test stimuli and consequently are considered to be conceptually driven (Roediger, Weldon, Challis, 1989). Implicit memory tests, however, typically rely on processing of the physical attributes of the test stimulus, and consequently, they are considered to be data-driven (Roediger, Weldon, Challis, 1989). Because data-driven tasks are thought to rely more heavily on physical characteristics of the stimuli, they should be more disrupted by alterations in the surface features of the stimuli, and remain fairly insensitive to manipulations of depth of elaborative processing. As we have seen, implicit memory tests are disrupted by changes in modality, (Graf, Shimamura, & Squire (1985), and surface features of the stimuli, (Roediger & Blaxton, 1987) and are fairly insensitive to manipulations of elaborative processing (Graf and Mandler (1984). The pattern is reversed for conceptually driven tasks. Conceptually driven tasks are predicted to be more sensitive to manipulations of elaboration, or semantic processing, but are insensitive to physical changes in the stimuli. This is consistent with patterns found in explicit tests of memory.

Although most implicit tests have tended to be data-driven and most explicit tests have tended to be conceptually driven, this is not a perfect correlation. One counter
example is conceptual priming.

Conceptual priming provides an example of an implicit memory test that relies on conceptually driven processes. Conceptual priming experiments use a study-test paradigm similar to that described for perceptual priming experiments. The difference lies in the cue presented at time of test. While the perceptual priming experiments present perceptual cues that constrain the form of the target word (e.g. stem completion), conceptual priming experiments present semantic cues that constrain the semantic properties of the target word (e.g. category names).

Hamann (1990) presented a list of words and asked normal subjects to rate how much they liked each word. At test, subjects were asked to report the first eight examples of a specific category that came to mind. Some of the studied words were exemplars of the category and some were not. Although no perceptual information was presented at time of test, Hamann found significant priming for those items that had been previously studied.

Graf, Shimamura, and Squire (1985) tested a group of amnesic patients and control subjects using a conceptual priming paradigm similar to the one used by Hamann (1990). Amnesic patients and matched controls were presented with a list of words and were asked to rate how much they liked each word. They were later given a category name and asked to
generate the first eight exemplars of that category that came to mind. Both amnesic patients and healthy controls showed significant conceptual priming.

Schacter (1990) also reported preserved conceptual priming for amnesic patients. Amnesic patients and matched controls were presented with a list of 2-word idioms (e.g. small potatoes). They were then asked to produce the first word that came to mind in response to a single word (e.g. small). Baseline probability of free associating an idiomatic completion with no prior study was virtually zero. However, significant priming was reported for both amnesic patients and control subjects.

Shimamura & Squire (1984) also reported significant conceptual priming in amnesic patients for highly related word pairs (table-chair).

Preserved conceptual priming in amnesic patients represents a formidable challenge for Roediger et al's processing approach. Roediger, Weldon, and Challis (1989) conclude that preserved conceptual priming by amnesic patients is not accounted for by the view that "preserved priming always reflects data-driven processing" (p. 35). Moreover, they consider this limitation to be "the primary drawback we see in the procedural approach" (p. 35).

Conceptual priming will be discussed in more detail in a later section. This discussion will now focus on another
theoretical framework that has been proposed to account for the dissociations between implicit and explicit memory tests.

A knowledge-based approach.

Cohen and Squire (1980) have proposed that some of the dissociations between implicit and explicit memory tasks may be accounted for in terms of the knowledge that is acquired rather than by the types of memory tests. They have suggested a distinction between declarative knowledge and procedural or other nondeclarative kinds of knowledge. Competence in a specific motor skill, playing the piano for example, would be characterized as one form of procedural knowledge. The procedural knowledge (skill) is acquired slowly, and once learned may be executed automatically and is not available to conscious reflection. The procedural system does not store external states of the world, and its output is noncognitive and contains no truth values. This differs from declarative knowledge, which represents facts, or propositions about the world. Declarative knowledge is available to conscious recollection, and can be learned quickly.

Nondeclarative tasks include the following implicit tests of memory: pursuit rotor task (Corkin, 1968), maze learning (Brooks & Baddeley, 1976), reading mirror-inverted text (Cohen & Squire, 1980) word fragment completion (Warrington & Weiskrantz, 1974), lexical decision (Jacoby, 1982), and stem
completion (Graf, Squire & Mandler, 1984). None of these tasks require declarative knowledge but instead contain a skill-based component or are performance-based. All are preserved in the amnesic syndrome (Squire, 1994).

Explicit memory tests such as free recall and old/new recognition, which are profoundly impaired in the amnesic syndrome, are assumed to tap declarative information that is available to conscious recollection. The declarative/procedural distinction will be discussed again in Schacter and Tulving's (1994) approach to accounting for the implicit/explicit memory dissociation addressed in the next section.

A multiple memory systems approach.

Schacter and Tulving (1994) have proposed a theoretical framework that incorporates attributes of both the procedural/declarative distinction described by Cohen and Squire (1980) as well as the processing framework proposed by Roediger and Blaxton (1987). Their approach, which encompasses the empirical findings of several researchers, provides a good foundation on which to base the discussion of implicit and explicit memory performance of PTA patients.

Schacter and Tulving assume a multiple systems view of human memory, which attributes differences between implicit and explicit memory tasks to different hypothesized underlying
memory systems (and subsystems). The processing framework is incorporated within the constraints of these memory systems. Schacter and Tulving propose a classification scheme of five major systems of human memory. These five systems are: a) procedural memory, b) working memory, c) perceptual representation system (PRS), d) episodic memory, and e) semantic memory.

As we have seen, the procedural system of memory, proposed by Squire and Cohen (1980), is characterized by relatively slow, incremental skill learning. The procedural system appears to be spared in amnesic patients and is thought to be responsible for mediating many implicit memory tasks such as learning motor skills, cognitive skills, simple conditioning, and simple associative learning. However, it is conceivable that specific information that does contain propositions about external states of the world, and their associated truth values, may be encapsulated within a preserved procedure and consequently may be indirectly spared through the preservation of procedural functions. For example, lyrics to a song may themselves contain nonprocedural information, but may be spared within the procedural system once they have become encapsulated within the larger context of the music.

The second memory system included in Schacter and Tulving's classification scheme is the working memory system.
Working memory was described by Baddeley (1992) as being comprised of interacting subsystems that provide a temporary buffering function. This buffer allows working memory to store information temporarily as well as process and transform that information from one form into another. The executive processor is the major subsystem of working memory and is responsible for processes such as selective attention, the manipulation of information being held in temporary storage, and transfer of information to and from long-term memory. The executive processor is supported by the articulatory loop and the visual scratch pad, each of which is responsible for temporary maintenance of specific types of information through rehearsal.

Although working memory is spared by the amnesic syndrome (Talland, 1965), it does not account for the preserved implicit memory abilities reviewed heretofore. Working memory requires that no interruptions be introduced during processing. Once an interfering task is introduced and working memory begins to process new information, the previous information is lost from the temporary buffer. Each task of implicit memory reviewed here includes a delay within which interfering tasks are introduced. Consequently, working memory can not be considered a mediating system responsible for the preserved implicit memory effects demonstrated by amnesic patients.
The Perceptual Representation System (PRS) makes up the third category in Schacter and Tulving's classification of major memory systems. The PRS was described by Schacter (1990) as representing presemantic, structural information about words, objects, and other items. The PRS consists of several subsystems including a) the visual word form subsystem, b) the auditory word form subsystem, c) the structural description subsystem and d) the face identification subsystem. These subsystems are modality-specific and differ in the types of stimuli processed, but are similar in that they operate at a presemantic level and represent information about the form and structure of items. Representations within the PRS do not include semantic/elaborative information or source information about the context within which an item was first encountered.

The PRS typically mediates memory performance unconsciously and is expressed through implicit memory tasks. Although the PRS may mediate several types of implicit memory effects, it may best explain perceptual priming phenomenon (e.g. repetition priming, Cofer, 1967). The PRS is proposed to mediate repetition priming of specific items by generating new representations that include structurally detailed information at time of study. During the test phase, the features of the test stimulus are compared to the new representation. Consistent with Roediger and Blaxton's
processing framework described above, processing is thought to be facilitated to the degree that the surface features of the test stimulus match those of the newly formed mental representation in the PRS. The PRS is thought to be spared in amnesia and accounts for repetition priming effects demonstrated by amnesic patients (Schacter, 1990).

The final two memory systems included in Schacter and Tulving's classification scheme are the episodic and semantic memory systems proposed by Tulving (1972). Both of these memory systems are involved in long-term retention of information.

The semantic system contains, in the broadest sense our knowledge about the world. It is responsible for processing abstract or concrete factual, declarative information as well as specific or general knowledge and beliefs. In one sense it appears to be largely spared in the amnesic syndrome in that previously acquired general knowledge is preserved. However, learning of new semantic information is profoundly impaired. The inability of amnesic patients to learn new semantic information has traditionally been considered a central characteristic of the amnesic syndrome (Talland, 1965). Recently, however, evidence has emerged that suggests that even densely amnesic patients are able to learn new semantic information.

Evidence of new semantic learning in amnesic patients has
emerged from a variety of tasks. These tasks include learning new computer-related vocabulary and commands (Glisky, Schacter & Tulving, 1986a, 1986b), one word solutions to ambiguous word puzzles (McAndrews, Glisky, & Schacter, 1987) and factual information about people (Schacter, Harbluk & McLachlan, 1984). Amnesic patients have also been shown to retain the information well, for weeks and even months (Glisky & Schacter, 1988; McAndrews, Glisky, & Schacter, 1987; Tulving, Hayman & Macdonald, 1991). This learning does not appear to be normal however. Typically learning is laborious, slow and often occurs despite the amnesic patients' inability to recollect the learning episode (Hayman, Macdonald & Tulving, 1993).

The **episodic memory system** processes and stores autobiographic information about the content and contexts of specific episodes and events. The episodic system processes and combines spatial, temporal, and self-based types of information to generate a contextually rich record of one's own life experiences.

The episodic system, which mediates most explicit tests of memory, is considered to be the system most disrupted by the amnesic syndrome (Schacter, 1987). It relies heavily on conscious retrieval strategies and plays little or no role in the preserved implicit memory abilities of amnesic patients.

Of the five systems of memory classified by Schacter and
Tulving (1994), the episodic and working memory systems are the least likely to mediate priming effects. The PRS, procedural and semantic memory systems, however, all may play a role in some of the preserved implicit memory abilities found in amnesic patients.

Because the PRS processes structural information about the form of the stimuli, rather than the semantic information associated with it, perceptual or repetition priming is best demonstrated when there is little or no structural change in the stimuli between study and test, and when the implicit test presents at least partial perceptual information about the structural properties of the target stimuli (e.g. word stems, or fragments). In contrast to the PRS system, the semantic memory system is thought to mediate those implicit tasks in which no structural information about the target is provided in the implicit memory test. Rather, conceptual or semantic information is provided as the test cue. Although the semantic memory system may be impaired in amnesia, and may operate less efficiently than in normal subjects, the semantic memory system is proposed to mediate new semantic learning and conceptual priming.

Finally, the procedural system is thought to play a role in implicit memory performance for those tasks based on skill learning, and typically requires multiple exposures to the target stimuli rather than a single exposure typical in
repetition priming paradigms.

I have reviewed a variety of memory tasks on which amnesic patients show some preserved implicit memory abilities, and have presented a useful theoretical framework within which to understand those abilities. What about posttraumatic amnesic patients? Do they show the same pattern of preserved implicit memory abilities as chronically amnesic patients? The next two sections describe the posttraumatic amnesic syndrome and review the few experiments that have demonstrated preserved memory abilities for these patients.

Characteristics of PTA

PTA refers to a period following a closed head injury, wherein the individual is initially unconscious, then confused, disoriented, and amnesic for events occurring since and just prior to the brain trauma. As one emerges from PTA there is often (although not always) a sense of "waking up" from the confusional fog, and there may be brief periods when the patient appears oriented, but then returns to a state of disorientation and confusion. Moreover, the temporal duration of PTA is highly variable, and depends on the severity of the brain trauma.

PTA is a construct with multiple components, and each component may vary in duration and severity. Due to the multiple components of PTA, different researchers and
clinicians have focused on different attributes in defining PTA. Within the literature, PTA has been used to describe a variety of closed head injury sequelae. Moreover, the necessary and sufficient features of PTA have been difficult to generate, and consequently the assessment of whether a patient is experiencing PTA is not always straightforward. Assessing whether a patient is in a state of PTA is further complicated by occasional 'islands' of apparent recovery within which memory appears to function normally.

For the purposes of the current discussion, we will adopt an operational definition of PTA that employs a brief assessment questionnaire. Levin, O'Donnell and Grossman (1979) designed an instrument for assessing PTA. The GOAT (Galveston Orientation and Amnesia Test) includes items designed to test the patient's memory for the events that occurred near the time of injury as well as orientation questions about time and place. (The complete GOAT appears in Appendix A.)

Levin et. al. conducted a series of studies testing the validity and reliability of the GOAT. A validity study found that the duration of PTA as defined by low GOAT scores was longer for those patients who had lower scores on the Glasgow Coma Scale, as well as for patients who showed evidence of diffuse or bilateral damage rather than focal unilateral lesions. A longer duration of low GOAT scores was also
predictive of poorer long term outcome measures.

The reliability study showed an interrater reliability coefficient of .99. Although the Levin et. al. studies demonstrate impressive reliability and validity data, it is worth noting that the GOAT is not a perfect instrument for measuring PTA. Some of the potential problems with using the GOAT revolve around the fact that it is attempting to assess and describe a multidimensional construct with a single score. Consequently, this single score does not reflect the complexities of the PTA syndrome, and it is not possible to determine the relative contributions of the different components. (For further discussion of limitations of the GOAT see Mysiw, Corrigan, Carpenter, & Chock, 1990; and Wilson, Baddeley, Shiel & Patton, 1992.)

Although there are limitations to the GOAT, it is a good standardized measure of PTA that is widely used in rehabilitation settings and daily administration provides a recovery curve characterizing the decreasing confusion and resolution of gross amnesia. For these reasons we will use the GOAT as our measure of PTA.

The few studies demonstrating preserved memory abilities in PTA patients, have been consistent with a large literature describing preserved memory abilities in chronically amnesic patients described in the previous section. I will present those experiments in the next section.
Implicit memory performance in PTA

Implicit tests of memory have demonstrated preserved memory abilities in PTA patients as well as in chronically amnesic patients. Ewert, Levin, Watson & Kalisky (1989) found that PTA patients were able to improve their performance across sessions on a variety of implicit memory tasks despite profoundly impaired explicit memory performance for events surrounding the testing sessions.

In the first implicit memory task, PTA patients were required to read mirror-inverted word triads. Across sessions some of the word triads presented were novel while others had been viewed in an earlier session. Overall, PTA patients performed less accurately than the control subjects in reading both the novel and repeated mirror-inverted word triads (65% and 69% correct respectively for patients vs 92% and 95% correct respectively for control subjects). Although the PTA patients showed significant improvement in accuracy for repeated triads across sessions, no conclusions can be made relative to whether this learning rate was normal due to ceiling effects in the control subject group.

A different pattern of results emerged when response latencies were analyzed. There was no significant difference between the two groups in terms of their learning rates across sessions for reading unique word triads. PTA patients showed better than normal learning rates across sessions for reading
repeated mirror-inverted word triads. These results, although constrained by the reported ceiling effects for the control group in the accuracy analysis, suggest that PTA patients demonstrated preserved implicit memory performance for reading mirror-inverted word triads.

PTA patients were also tested on the completion of one of the Porteus Mazes. They demonstrated improved performance across sessions as measured by time to complete the maze and number of errors. Ceiling effects in the performance of the control group made it impossible to determine whether the rate of learning the maze was similar for the two groups of subjects.

On the final implicit task, the pursuit rotor task, patients showed significant improvement across sessions in terms of the percent of time the stylus followed the revolving target. However, once again, it was not possible to determine whether the rate of learning for the PTA patients was normal, due to ceiling effects in the control group. Wilson, Baddeley, Shiel and Patton (1992) also reported improvement across trials on the pursuit rotor task for PTA patients when tested at slow speeds of rotation. However, there was no direct statistical comparison reported for the learning rates of the PTA patients and the control subjects. Consequently, no conclusion can be made regarding whether the PTA patients' implicit memory performance could be considered normal.
Ewert et al also included two explicit memory measures: an old/new recognition test and a questionnaire for information surrounding the testing sessions. The old/new recognition test was administered following the third session of the task that required subjects to read mirror-inverted word triads. Novel words and words from the previously viewed word-triads were presented in correct orientation and patients were asked whether they had seen the word during the previous sessions. Recognition performance for the PTA patients was grossly impaired relative to control subjects' performance.

The questionnaire measuring explicit memory for information surrounding the testing sessions was administered 5 - 6 hours after each session. Again, patients scored very poorly, relative to the control subjects although no statistical analyses comparing the two groups were provided.

The dissociation between impaired explicit memory and preserved implicit memory performance described by Ewert et al is consistent with the dissociations demonstrated in chronically amnesic patients. As with chronically amnesic patients, the impaired explicit memory performance shown in PTA patients suggests that the episodic memory system is disrupted (Schacter & Tulving, 1994). The improvement across sessions demonstrated by PTA patients for each of the three implicit memory tasks studied by Ewert et al provides evidence that the procedural memory system is spared in PTA.
PTA patients' memory abilities were also explored by Levin, High & Eisenberg, (1988). These investigators tested closed head injured patients during and following PTA. They showed patients a series of slides portraying pictorial scenes obtained from magazines. PTA patients viewed each slide twice for 4 seconds. Using an old/new recognition paradigm they tested patients 10 minutes, 2 hours, and 32 hours following study. Although patients within PTA scored lower than patients no longer in PTA, both groups showed significant memory ability in all three delay conditions. This study provides further evidence of preserved memory abilities in PTA patients.

Although the literature is sparse for learning within PTA, the initial results are promising. In the proposed study, we hope to expand the domain of demonstrated preserved memory abilities to include implicit memory for single words and factual information, and in doing so implicate the PRS and semantic memory systems.

Summary and hypotheses

The main purpose of this dissertation was to explore the nature of the preserved memory abilities of PTA patients, the preserved learning abilities of PTA patients, and the retention of the learned information following resolution of PTA.
In the first experiment, a repetition priming paradigm was used to explore whether PTA patients, like chronically amnesic patients demonstrate a dissociation between implicit and explicit tests of memory for single words.

The second experiment used a semantic learning paradigm to explore whether PTA patients, like chronically amnesic patients are able to learn new factual, semantic information and retain that information over an extended delay.

These two experiments were designed to provide evidence that PTA patients are able to perform normally on implicit tests of memory; and moreover that they are able to learn factual information while in a state of PTA and retain that information for several weeks following the resolution of PTA.
EXPERIMENT 1

In the first experiment, we compared the performance of PTA patients with a group of matched control subjects on implicit and explicit memory tests for word lists. This experiment used a paradigm similar to the one used by Graf and Schacter (1985) described earlier. Graf and Schacter presented words to amnesic patients and normal control subjects and then later asked them to complete three-letter word stems using either implicit or explicit memory instructions. The implicit test required participants to complete the stems with the first word that came to mind (stem completion), while the explicit memory test required participants to think back to the study episode and complete the stem with a word from the earlier list (stem-cued recall). The same 3-letter word stems were used for both the implicit and explicit memory tests: all that varied was the nature of the instructions given to the subjects.

Graf and Schacter reported that control subjects were able to benefit from the explicit memory test instructions and performed better overall on the explicit test than they did on the implicit test. Amnesic patients, however, were unable to improve their performance on the explicit test, although they showed near normal performance on the implicit test.

In the present experiment, we used this same paradigm to explore the implicit and explicit memory abilities of PTA
patients and a group of matched control subjects. It was predicted that PTA patients, like chronically amnesic patients, would show fairly good performance on the implicit test of memory, while their performance on explicit tests would be very poor when compared to the control group.

Experiment one included a single implicit test of memory, (stem completion), and three explicit tests of memory, (stem-cued recall, old/new recognition and free recall). One methodological strength of this paradigm is that it allowed a fairly direct comparison between the implicit test (stem completion) and one of the explicit (stem-cued recall) tests of memory because of the similarity of the stimuli. There was, however, a potential problem for the interpretation of the stem-cued recall test that was addressed by the additional explicit memory tests. This involved the possibility that patients might use implicit processes on the stem-cued recall tests of memory. The stem-cued recall test required patients to think back to the study list and complete the stems with words from that list. However, if patients were unable to remember the studied item, they may have guessed by simply reporting the first thing that came to mind. If this were the case, then performance on the supposed explicit memory task may have been accomplished implicitly. This potential problem was addressed in three ways.

First, on the stem-cued recall task itself, as each word
was generated from the stem, the patients were asked whether or not they actually remembered seeing that word on the studied list. To the extent they were able to correctly identify which of their generated answers appeared on the list, we can be fairly confident they were using an explicit memory strategy. However, if they reported remembering very few of the words they generated as having appeared on the initial list then they may have been using implicit memory processes to complete the word stems.

Another method aimed at addressing the possibility that the stem-cued recall test was vulnerable to implicit memory effects was to include other explicit tests of memory. One test of explicit memory that is designed to minimize implicit effects is a cross-modal old/new recognition test. This test required subjects to refer back to the learning episode and decide whether or not each word appeared on the study list. However, in an attempt to minimize any implicit effects the items were presented in different modalities at study and test. As was discussed in the introduction, it has been demonstrated that priming effects are lessened when modalities are crossed between study and test (Graf, Shimamura and Squire 1985). The cross-modality manipulation was therefore included to minimize the implicit effects in the old/new recognition test. Performance on this test was predicted to be very poor for the PTA patients.
The third test of explicit memory, free-recall is fairly invulnerable to implicit effects. In this task subjects are asked to try to recall as many words as they can from the initial study lists. We predicted performance on this task to be very poor.

To summarize, the performance of PTA patients and control subjects was compared on implicit and explicit memory tests using simple word lists. Initially, subjects were presented with a list of words to study, participated in a 3 - 5 minute delay task, and then were tested using either an implicit stem completion test or an explicit stem-cued recall test. Both tests required subjects to complete three-letter word stems but the tasks differed in the nature of the instructions given to the subjects. Stem completion required subjects to complete the stem with the first word that comes to mind while the stem-cued recall test required subjects to think back to the study list and complete the word stems with words they had seen earlier on that list. Implicit memory is indicated on the stem completion task by an increased probability of completing word stems with previously studied items compared to baseline completion rates. We expected to find impaired explicit memory performance concurrent with normal implicit memory for the PTA patients. Similarly, on the other tests of explicit memory (free recall, and old/new recognition) we expected poor performance by the patient group. The control
group however should benefit from the explicit test instructions and perform better on the explicit test than on the implicit test. Each of the explicit tests should provide converging evidence that PTA patients are profoundly impaired on memory tasks that require conscious recollection of the study episode.

Method

Subjects

Eight PTA patients and eight control subjects participated in this study. The PTA patients each scored below the "normal" range on the GOAT. Closed-head injured patients are considered to have emerged from a state of PTA if they have scored above a score of 75 on the GOAT for 2 consecutive days (Levin, O'Donnell, & Grossman, 1979; Ewert, Levin, Watson & Kalisky, 1989). The 2-day time constraint is included to address the possibility of prematurely concluding that the patient has emerged from PTA when the superior performance may be fleeting and representative of an island of apparent recovery rather than a genuine emergence from PTA. PTA subjects were recruited through hospitals and rehabilitation centers in Tucson, Arizona. The control subjects were matched for age and education and did not differ from patients on either of these variables. Mean ages for the experimental and control groups were 30.5 and 29.1
respectively. The mean number of years of education completed was 12.4 and 13.1 respectively.

Subject characteristics are presented in Appendix B. Patient information includes the type of accident, and the severity of injury. This information was obtained through medical records when available, or through interviews with the patients and their family members. The control subject information includes age, and education.

Design

The experimental design consisted of a between-subject manipulation, (type of subjects: PTA patients vs. control subjects), assessed by four dependent measures (stem completion, stem-cued recall, free recall, and recognition). The dependent measure for the implicit stem completion test was the amount of priming (percent correct of nonstudied items subtracted from percent correct of studied items). This measure takes into account the baseline performance for simply guessing the correct completion, not having studied the word. The dependent measure for the stem-cued recall, recognition, and free recall was percent correct. A second dependent measure was used for the recognition test. Hits (correct "yes" responses) minus false alarms (incorrect "yes" responses) takes into account subjects response tendencies and provides an unbiased measure for recognition memory.
Materials

Appendix C provides a complete list of the materials used in experiment one.

Stem completion. The materials consisted of two lists of 24 target words selected from the Kucera and Francis (1967) word frequency index, and 5 practice items. The two lists provided study and baseline items for the stem completion test. Three booklets were constructed, one for each of the two study lists and one for the word stems to be used at time of test. Each booklet contained one typed word (or word stem) per page.

Selection of the target words was constrained in the following ways. First, each word stem (e.g. inf__) did not appear elsewhere in the stem completion, or the stem-cued recall test material sets. This ensured that each stem could not be completed with any other words on the study lists. Second, for each target stem there was a minimum of ten possible completions found in an English dictionary (e.g. infant, infirmary, inform). Third, the target words were between 4 and 7 letters in length, and had a frequency of less than 40 occurrences per million.

The lists were matched in terms of frequency (mean frequencies were 13.8, 15.6), length (mean word lengths were 6.1, 5.8), and percentage completion rate for the word targets at baseline according to previously collected data from
college students (mean percentages of completion of the stem by the target words were 9.96% and 9.72%).

Study lists were counterbalanced across subjects, so that each list appeared equally often as the studied and the baseline set. The order of the stem completion and stem-cued recall tests was also counterbalanced. Half of the subjects participated in the stem-cued recall task first while the other half were given the stem completion task first.

**Stem-cued recall.** The materials consisted of a single list of 24 target words selected from the Kucera and Francis (1967) word frequency index, and 5 practice words. Two booklets were constructed, one for the study list and one for the word stems to be used at time of test. Each booklet contained one typed word (or word stem) per page.

Identical constraints were used in the selection of the target words for the stem-cued recall task and the stem completion task described above. The mean frequency for this list was 14.0. The mean number of letters was 5.9. Finally, the percentage baseline completion rate for the word targets according to previously collected data was 9.8%.
Old/new recognition and free recall. The materials consisted of two lists of 24 target words and 3 practice words. One list was presented at study and the other served as distractor items for the old/new recognition test. The same lists were used for the free-recall test. The free-recall test always immediately preceded the old/new recognition. Two booklets were constructed, one for each study list. The tests were administered orally and did not require additional booklets. Each booklet contained one typed word per page.

Selection of the target words was constrained in the following ways. First, the target words had to be between 4 and 7 letters in length, and have a frequency of less than 100 occurrences per million. The mean frequencies were 21.3 and 27.8 for the two lists. The lists were matched in terms of word length (mean word lengths were 5.8, and 5.9 respectively).

The two lists were counterbalanced across subjects, so that each list appeared equally often as the study set and the distractor set in the recognition task. The free recall test and old/new recognition tests always followed the other two tests.

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1 Three words from list 2, gorilla, harpoon, and reptile are not represented in the Kucera and Francis (1967) word count. Consequently they were not included in the calculation of the mean for that list.
Name generation delay task. The materials consisted of a single booklet containing each letter of the alphabet typed and presented one per page.

Procedure

PTA patients. All patients were administered the GOAT on the same day that memory testing occurred. Appendix D provides a copy of the instructions used in experiment 1.

Each memory test was preceded by a study task. The study task required patients to rate a word's pleasantness on a five point scale ranging from "very pleasant" to "very unpleasant". The words were presented in booklets and the scale, which was typed on a single card, was placed in front of the patient for constant reference. Patients viewed three practice words and 24 target words. Presentation of study lists was self-paced.

Following the study phase, patients participated in the name generation task. In this task, patients were presented with each letter of the alphabet and asked to complete each letter with a proper first name, by stating that name aloud. This task took between 3 and 5 minutes to complete.

Then, one of the four memory tests was administered. Following a minimum delay of two hours the sequence was repeated with a new study list followed by a different type of memory test. There were three sessions, one for the stem-cued recall, one for stem completion and one for the free recall
and the recognition test.

In the implicit memory test, patients were asked to complete 53 three-letter word stems with the first word that came to mind. Twenty-four stems were novel stems, and twenty-four stems were consistent with target words from the studied list; five stems at the beginning served as practice items. Each stem was presented on a card and subjects responded auditorily. Responses were recorded by the experimenter. If patients completed the stem with a proper name, or a nonword, a different completion was requested.

In the stem-cued recall test, subjects were presented with word stems, typed on cards as they were in the implicit test but the instructions differed. In the stem-cued recall test patients were asked to think back to the study episode and complete the stems with words that had been presented. Once they had produced a completion, they were asked whether they remembered having seen that word on the original list. Occasionally, the instructions were repeated if the patient appeared to be confused about the requirements of the task. As in the stem completion test, responses were recorded by the experimenter.

In the free recall and recognition tests, subjects were first asked to try to think back to the initial list and recall as many words as they could. Subjects were given five minutes to recall as many words as they could. Then,
immediately following the free recall test the auditory recognition test was administered. Subjects were told that some of the words did appear in that first list and some did not. Subjects were asked to respond orally whether they remembered seeing each word on the study list.

**Control subjects.** The procedure for the control subjects was identical to that for the patients with the following exceptions: All control subjects participated in the stem completion test prior to the stem-cued recall test in order to minimize the likelihood that control subjects would identify the stem completion test as a memory test and use explicit memory strategies on the stem completion test. Also on the stem completion task, control subjects were presented with an additional 30 stems prior to the 48 experimental stems. None of the initial 30 stems had been viewed in the studied lists. These 30 items provided an additional buffer between the studied lists and the experimental stems to discourage subjects from recognizing the relation between the studied lists and experimental stems. The instructions also encouraged control subjects to use only implicit memory strategies to complete the stem completion test. Control subjects were instructed to provide the first completion that came to mind for each stem, even if the completion seemed odd, and to generate completions at a brisk pace. The stem-
cued recall, free recall and recognition tests did not differ between the patient and control subject groups.

Results and Discussion

The overall pattern of results for these four tasks suggested that PTA patients, like amnesic patients, demonstrated significant priming, while remaining profoundly impaired on explicit measures of memory.

Stem completion

The dependent measure in the stem completion task was the amount of priming. This was determined by subtracting the percent correct in the baseline condition (for unstudied items) from the percent correct in the experimental condition (for studied items). This difference provides a measure of priming that takes into account the probability of completing the stems with the target words in the absence of prior exposure. The results of the stem completion test are presented in Figure 1.

A t-test was conducted to look for significant priming in each subject group. Both the patient group and the control group demonstrated significant priming. The patient group demonstrated a 13% priming effect, \( t(7) = 3.28; \ p < .05 \), while the control groups showed a 27% priming effect, \( t(7) = 4.50; \ p < .05 \). Although there was a difference in the
absolute values of the magnitudes of the priming effects for the two groups, (13%, s.e. = 3.96 for the PTA patients vs 27%, s.e. = 5.92 for the control subjects) this difference was not statistically significant ($t_{(14)} = 1.91; \text{s.e.} = 7.12; p > .05$). The differences in the magnitude of the priming effect, however, suggest that PTA may affect the processes mediating priming effects. However, it is only with further studies of priming within PTA that we may discover whether the significant priming demonstrated by these patients is in fact inferior to normal priming.

To summarize, PTA patients showed significant levels of priming that did not differ significantly from the control group. The three explicit tests, however, showed profound differences between the memory abilities of the PTA patients and the control subjects.

**Stem-cued recall**

The dependent measure in the stem-cued recall task was percent correct. The PTA patients were able to produce 21.13% of the target words, while the control group produced 66.75% of the target words. A t-test found this to be a significant difference between the two subject groups, ($t_{(14)} = 4.68; p < .01$). As can be seen in Figure 1, the control subjects as expected, showed substantial improvement in their memory performance when allowed to refer back to the word list. They
Figure 1 - Percent correct for stem completion and stem-cued recall tests

<table>
<thead>
<tr>
<th>Memory Test</th>
<th>Legend</th>
<th>Control Subjects</th>
<th>PTA Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stem Completion</td>
<td>n.s.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stem-cued recall</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* * p < .01

Figure 2 - Percent correct for free recall and recognition tests

<table>
<thead>
<tr>
<th>Memory Test</th>
<th>Legend</th>
<th>Control Subjects</th>
<th>PTA Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Free recall</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recognition</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* * p < .01
produced 66.75% of the target words in the stem-cued recall test, compared to only 30.75% of the target words in the stem completion test. The PTA patients however showed no such improvement in performance. PTA patients were able to produce 21.13% of the target words on the stem-cued recall test compared to 20.0% of the target words on the stem completion test.

In an attempt to get a sense of whether the 21.13% completion rate for the PTA patients may have been due to implicit rather than explicit memory effects, we asked each patient whether they remembered having seen the produced completion on the earlier study list or whether they felt they had produced the completion by simply guessing a potential completion. For two patients this information was not available. The remaining six patients reported that they did not remember 40.3% of the target items they correctly generated as having been on the studied list, and incorrectly identified 19% of their completions as studied items when in fact they had not appeared on the study list. This suggests that the PTA patients may have been using implicit memory to generate many of their stem-cued recall completions, thus inflating their scores.
Old/new recognition

Figure 2 shows the overall percent correct for control subjects and PTA patients on the old/new recognition test. Control subjects correctly identified 93.25% of the items as having appeared on the studied list. The PTA patients were able to identify only 46.38% of the items as having appeared on the studied list. A t-test showed this to be a significant difference between the two subject groups, \( t_{(14)} = 5.83; p < .01 \).

A second analysis included both the number of items correctly identified as target items, and items incorrectly identified as target items. By subtracting the false alarms from the hits we were able to estimate recognition performance for these items taking into account possible response biases. Perfect performance would provide a score of 24. That would require all of the studied items to be identified correctly and none of the foils to be mistaken as studied items. Random answers would tend to generate a score approaching zero. The PTA patient group produced an average of 11.13 hits and 7.13 false alarms, resulting in an average hit minus false alarm rate of 4 items. The control group produced an average of 22.38 hits and 1.0 false alarms resulting in an average hit minus false alarm rate of 21.38. T-tests found statistically significant differences between the two groups on hits \( t_{(14)} = 5.83; p < .01 \), false alarms \( t_{(14)} = 3.32; p < .01 \), and on
the hits minus false alarm measure ($t_{(14)} = 12.29; p < .01$). The recognition data provides further evidence of the impaired explicit memory performance for the PTA patients relative to the control subjects. Perhaps the most compelling evidence of impaired explicit memory in PTA patients however, was provided by the free recall test of memory.

Free recall

The dependent measure for the free recall task was percent correct. As can be seen in Figure 2, the PTA patient group was able to recall no items, while the control group recalled 29.25 percent of the studied items. An independent groups t-test found this to be a significant difference ($t_{(14)} = 5.20; p < .01$).

Memory systems mediating implicit and explicit memory tests

These four tasks have shown that PTA patients are able to retain verbal information when tested implicitly, yet they perform very poorly on explicit tests of memory. What underlying memory systems may be mediating these effects? The three explicit tests of memory (e.g. stem-cued recall, recognition, and free recall) required subjects to refer back to the encoding episode, to try to recollect a specific event at a specific time. The episodic memory system has been proposed to mediate conscious recollection of specific events
as well as information about their temporal relations to one another (Schacter & Tulving, 1994). All three of these explicit memory tests are thought to be mediated by the episodic memory system (Schacter, 1987). The very poor performance of PTA patients on these explicit tests of memory provides evidence that the episodic memory system is profoundly impaired in PTA, as it is in chronic amnesia.

PTA patients' performance on the stem completion test however suggests that implicit memory appears to be at least partly preserved in PTA. The perceptual representation system (PRS) proposed by Schacter (1990) may be able to account for the preserved abilities of PTA patients on implicit memory tests such as stem completion. As was described in the introduction, the word form system (Warrington and Shallice, 1980) is thought to be one of the subsystems within the PRS and is proposed to mediate stem completion priming. According to this proposal, during the study phase (e.g. the pleasantness ratings task), the word form system generated a perceptually-based representation of each word. The test stimuli, in this case the word stems, provided a very close perceptual match to the visual features of the newly formed representation and consequently supported the generation of the completed target. It is through this process of the generation of new representations that share critical features of the cuing stimuli that allows the PRS to mediate implicit
tests of memory such as stem completion. Experiment one provides evidence that the PRS is preserved in PTA as it is in chronically amnesic patients, despite a profoundly impaired episodic memory system. As was discussed in the introduction, chronically amnesic patients also show some preserved ability for new semantic learning. Experiment two explores the question of whether PTA patients are able to learn new semantic information as well.
EXPERIMENT 2

Experiment one provided evidence of preserved implicit memory for single words in PTA patients despite impaired explicit recollection of those words. The performance of PTA patients mirrored the implicit/explicit memory dissociation well documented for chronically amnesic patients (Schacter, 1987). As was discussed in the introduction, not only have amnesic patients shown preserved implicit memory abilities on tasks such as repetition priming and learning of procedural tasks, but have also demonstrated some ability in learning new semantically rich information.

H.M. who became densely amnesic following a bilateral removal of his medial temporal lobes in 1953, was tested again 14 years following his operation. He demonstrated new learning of some semantic information post-operatively. For example, he was able to recognize the image of President Kennedy, and report that he had been assassinated. His memory for semantic information has been characterized as inconsistent from day to day and dependent on environmental cues (Milner, Corkin, & Teuber, 1968). Although the conditions of H.M.'s learning were not measured, his retention appears to be fairly long-lasting.

Another case study, in which careful experimental control was exercised, provided further evidence of new semantic learning in a densely amnesic patient. K.C. became amnesic
following a head trauma from a motor vehicle accident. Hayman, Mcdonald and Tulving (1993) presented K.C. with a series of word puzzles that could be disambiguated by a single word solution (e.g. a talkative featherbrain - parakeet). The word puzzles were presented repeatedly (and answers provided when needed) for 8 study sessions, distributed over 4 weeks. K.C. was able to learn this new semantic information and retain it for up to 30 months. Other studies have tested groups of amnesic patients, rather than individual cases, and have found further evidence of learning of new semantic information.

For example, Schacter, Harbluk, and McLachlan (1984) tested amnesic patients' memory for semantic information following a single exposure\(^2\). They presented a group of amnesic patients with a series of questions, some of which represented true facts ("What did Al Capone do?" - "gangster") while others contained fictitious facts, ("What job did Bob Hope's father have?" - "fireman"). Patients' memory for the fictitious facts represented new semantic learning and

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\(^2\) It is worth noting here that although this experiment measures implicit memory with a single exposure, at a fairly short delay, it does not represent a conceptual priming paradigm. As was discussed earlier, within the conceptual priming paradigm, the target word is presented at study and then a semantically related concept is presented at time of test as a cue. In a new semantic learning paradigm, however, there is no preexisting conceptual relation between the target and cue. In this case, the subjects presumably had no reason to associate "Bob Hope's father" with a "fireman" prior to participation in the experiment.
consequently this discussion will focus on those items. After initial presentation of a fictitious question, the correct answer was immediately provided twice (e.g. "The answer is fireman. Bob Hope's father was a fireman.") The same question was posed again following either one or four intervening items. When the question appeared following a single intervening item, amnesic patients were able to generate the correct response 30% of the time. Performance dropped to 17% when four items intervened. Although the retention intervals were fairly short, Schacter et al found significant semantic learning following a single exposure.

Other studies have demonstrated substantial retention of newly acquired semantic information following extended training sessions. Kovner, Mattis, and Goldmeier (1983) presented a group of amnesic patients a series of ridiculous stories containing a set of target words (e.g. as he's jogging, it begins to rain ink.) On subsequent trials, amnesic patients were required to provide the target word when presented with the partial sentence (e.g. as he's jogging, it begins to rain ___.) If the patient was unable to provide the target word, a categorical cue was provided. If the patient was still unable to generate the target word, the target word was provided. These sessions continued once a week for eight weeks, with each session beginning with free-recall and recognition memory tests. By the eighth week, the amnesic
patients were able to free recall 14 of the 20 target words learned within the context of the ridiculous stories. This demonstration of free recall of 70% of the target items provides further evidence of substantial learning of new semantic information for amnesic patients.

McAndrews, Glisky and Schacter (1987) presented a group of amnesic patients with a series of sentence puzzles, which upon initial viewing appeared nonsensical (e.g. The haystack was important because the cloth ripped.) However, once the one word solution was provided (e.g. parachute), the sentences became readily interpretable. The sentence puzzles were presented to the patients and they were asked to provide the key word. If they were unable to do so, the solution was provided. The same sentences were later re-presented following delays of either one minute, 10 minutes, one hour, one day, or one week. At each of these delays, amnesic patients showed significant retention of the puzzle solutions. McAndrews et al suggested that successful retention of these patients in part was attributable to the semantic richness of the to-be-learned materials, as well as to the similar form of the material between learning trials and testing trials.

Although Kovner et al and McAndrews et al found substantial learning of semantic information for amnesic patients, the delay intervals were constrained to a single week. Glisky and her colleagues, however, have found
retention of newly learned semantic information following extended delays, using a training technique they have termed the "method of vanishing cues."

Method of Vanishing Cues

Glisky and her colleagues (Schacter and Glisky, 1986; Glisky Schacter and Tulving, 1986b) designed a method of teaching that was inspired by and builds on the preserved implicit memory abilities demonstrated by amnesic patients. These preserved abilities included near normal performance on implicit memory tests that provide partial cuing information, and demonstrations of learning new skills and procedures. Glisky, Schacter & Tulving (1986b) developed the method of vanishing cues and used this method to teach both mildly and severely impaired amnesic patients new vocabulary items that were relevant for using a microcomputer. Amnesic patients were asked to provide the correct target word when given a definition for that word. In an initial learning trial, patients were given a definition and asked to provide the target word. If they were unsuccessful, the initial letters of the word were provided until the subjects correctly generated the target word. On subsequent trials, following the presentation of a particular definition, partial information (some of the initial letters of the target word) was immediately provided to the patient. The amount of
partial information provided was equal to the number of letters required in the previous trial minus one. If the patient was unable to respond with the correct target item, additional letters were again provided. Across trials, fewer and fewer letters of the targets were provided, until eventually the patient was able to generate the correct key word to the definition alone. Patients were shown to retain this knowledge up to six weeks following training.

The method of vanishing cues used by Glisky, Schacter, & Tulving (1986b) was modified for the present experiment. The primary modification focused on the amount of cue information provided at the beginning of each training session. In the experiment conducted by Glisky et al the number of cues presented at the start of each training session was contingent on the number of cues required for successful completion of the target word in the previous session. This allowed for a) a minimum of unnecessary trials by taking into account the subjects' previous performance, b) an opportunity to measure learning rates for each subject and c) the provision of sufficient partial information to constrain the responses of the amnesic patients in order to minimize interference from erroneous responses.

Although there were constraints on the responses made by amnesic patients, each session began with restricted cue information and provided some opportunities for errors to be
made. In the current study, we minimized further the number of errors likely to be made. At the beginning of each training session, PTA patients were always presented with complete target words, and only then did letters begin to disappear. Although this did not allow for measurements of learning rates as precisely as the method used by Glisky et al., it did serve to constrain responding and minimize errors. Tulving, Hayman and Mcdonald (1991) suggested that amnesic patients appear to be especially vulnerable to interference caused by the production of errors because of their impaired episodic memory system. Tulving et al reasoned that in normal subjects the episodic memory system distinguishes among past events and consequently allows people to overcome the interference due to error generation (See also Baddeley & Wilson, 1994). PTA patients appear to be particularly vulnerable to interference, perhaps due to their confusional state. Consequently, it seemed important to modify the method of vanishing cues so as to minimize errors and avoid erroneous perseverations.

As we have seen, chronically amnesic patients have demonstrated some preserved implicit memory abilities for priming of single words, for learning procedural tasks, and for learning new semantically rich information. PTA patients have also shown some preserved implicit memory abilities for word lists, and for procedural tasks. The current study was
designed to expand the domain of preserved memory abilities demonstrated by PTA patients to include new semantic learning. The modified method of vanishing cues was used to teach PTA patients a series of fictitious facts such as "Bob Hope's father was a fireman". These sentences were presented across multiple sessions while the patients were in the PTA state. Once the patients emerged from PTA, training ceased and their retention was tested days and then weeks later.

Source memory

In the present study, we also included a measure of source memory. Source memory provided a measure of explicit memory in that it required the patients to refer back to the learning episode and identify the source of the newly learned information. Source memory was assessed not during PTA, but following the resolution of PTA in the delayed testing phase of the experiment. Subjects were asked to report where/when they had first learned each fact, (e.g. "How did you know that Bob Hope's father was a fireman?"). Because information was acquired during PTA, when explicit memory was poor, it was predicted that patients would show impaired performance on the source memory test. Some chronically amnesic patients have been shown to be impaired on similar source memory tests.

Schacter, Harbluk, & McLachlan (1984) reported that amnesic patients performed poorly when asked to identify the
source of a piece of information that had been previously remembered. Schacter et al presented amnesic patients with a series of questions, followed immediately with the correct answer when required. The questions were asked by one of two experimenters. Questions were then repeated following a single intervening item and patients were able to provide the correct answer only 30% of the time. However of those facts successfully remembered (fictitious or otherwise), 60% of the patients were unable to correctly attribute the source of the information to the experimental situation.

Performance on the source memory test was found to be correlated with performance on tasks sensitive to frontal lobe damage. This suggests that source forgetting or source amnesia is not a necessary feature of the amnesic syndrome, but may only apply to a sub-group of patients with frontal lobe damage. Consequently, the current study included an analysis of each patient's source memory performance as well as their performance on tests sensitive to frontal lobe involvement.

Summary and hypotheses

The hypotheses of the second study can be summarized as follows. 1) PTA patients should demonstrate learning and retention of factual information within and following the post-traumatic amnesic state. 2) PTA patients should show
impaired performance on the source memory tests, particularly those patients presenting symptomatology consistent with frontal lobe involvement.

Method

Subjects

Four PTA patients and four control subjects participated in this study. PTA subjects were recruited through hospitals and rehabilitation centers in Tucson, Arizona. The control subjects were matched for age and education. There were no significant differences between subject groups in age or education. The mean ages for the experimental and control groups were 31.5 and 30.0 respectively. The mean number of years of education completed was 11.25 for the experimental group and 12.75 for the control group.

Subject characteristics are presented in Appendix K. Patient information includes the type of accident, and the severity of injury. This information was obtained through medical records, when available, or through interviews with the patients and their family members. The control subject information includes gender, age, and education.

Materials

All material sets consisted of five sentences, and each sentence ended with a target word. All materials are
presented in Appendix L. Two types of material sets were prepared. Each set consisted of either five fictitious sentences (e.g. Bob Hope's father was a fireman) or five genuine sentences (e.g. Al Capone was a gangster). The two target sets of fictitious sentences served as the to-be-learned experimental items and were counterbalanced across subjects. The genuine facts were similar to the fictitious facts and were used as distractors for the source memory tests.

In order to maximize comparability of the fictitious fact lists, a pilot study was conducted that required subjects to complete each sentence with a word (e.g. Bob Hope's father was a ____.) The initial letters of the target word were added one at a time and the number of letters required for each subject to produce the correct target word was recorded. This provided a baseline measure for target completion with no training on the full sentence.

Target words were matched in terms of word length (word length ranged from 5 to 9 letters with a mean of 7 letters) and number of letters required to identify the target word in the pilot study (the means were 3.9, and 3.8 for the two lists).

A second set of fictitious and genuine facts were generated for younger subjects. These fictitious facts were identical to those in the original set with only the names of
the celebrities altered. The celebrity names were replaced with current celebrities. An example of a fictitious fact for the younger set was "Mel Gibson's father was a fireman". By using identical sentences, with only the names changed, we were able to use the identical target words for all subjects. A new set of genuine facts were also generated. This set of genuine facts described current celebrities and the target words were not matched with the original genuine facts. An example of a genuine fact used in the younger set was "Whitney Houston is a singer".

Each sentence was hand printed on a 3 x 5 inch index card.

Procedure

Each subject participated in two phases, a training phase and a test phase. For the PTA patients, the GOAT was administered before each session began to assess the patient's status of PTA. If the patient scored below a 75 on the GOAT they continued with the training phase. However, once the patient scored 75 or above, the training was discontinued. If the patient's GOAT scores remained in the normal range for five days, they were considered to have emerged from PTA and the test phase began. If they scored in the impaired range again, the previously normal scores were considered to have represented a transient island of recovery rather than a
genuine emergence from PTA and training resumed. Transient islands of recovery halted training temporarily for two PTA patients.

All control subjects participated in three training sessions, followed by the testing sessions at both the five day and multi-week delays.

*Training sessions.* In the initial training session, subjects were presented with each of the five fictitious facts from one of the two lists for their age group. The subjects were asked to read each sentence aloud. Then, the sentences were again presented with one less letter displayed in the target word. The subjects again read the sentence aloud and completed the word with the missing letter. An additional letter disappeared from the target word on each successive exposure. If the subject was unable to complete the target word, single letters were added to the target word until the correct response was generated. This procedure continued for twelve trials. A twelve-trial session allowed a subject performing perfectly to successfully provide the longest target word (9 letters) three times with no letters present.

Following the initial training session, every subsequent session began with a memory test, in which the sentence was presented with the target word missing and subjects were asked to complete the sentence. If the subjects were unable to
provide the correct target word, the complete answer was provided. This 24 hour delay test provided a dependent measure for learning within PTA. Regardless of subjects' performance, each training session began with all of the letters of all the target words present. Letters then began to vanish over trials as described above. Training continued for the PTA patients until the patient emerged from PTA.

**Testing sessions.** The testing sessions, which began 5 days after the emergence from PTA, consisted of two phases. In the first phase, patients were presented with five studied (fictitious) facts and five unstudied (genuine) facts with the target words omitted and were asked to complete each sentence. If they were unable to produce the correct target word, single letters were provided until the target word was correctly generated. The number of words correctly generated, and the number of letters required to produce the correct target word were recorded. Once subjects generated the correct target word, they were then asked "How did you know that fact?" or "where did you first learn that fact?" This provided a measure of source memory for each of the fictitious and genuine sentences. Although the fictitious and genuine sentences were not systematically matched, they were very similar in form and it seems unlikely that subjects would be able to infer the source from any characteristic other than
the content of the sentences themselves.

Following completion of each of the ten sentences (5 fictitious, studied items and 5 genuine facts), subjects were asked to complete the five additional fictitious sentences that they had not previously studied. The purpose of this task was to provide a baseline measure of completion for comparison to the studied items only and no source memory questions were administered.

A second testing session was administered following an average delay of 58 days for the PTA patients and 42 days for the control subjects. This testing session was identical to the first with one exception. For PTA patients CC and DL a new set of genuine facts was presented as distractors in the source memory test. This was an alteration in the design in an attempt to avoid ambiguities in source memory responses in the second testing session, that became apparent when testing DW and RP.

To summarize, the primary dependent measure of learning within the training phase was the accuracy in generating the target word following a 24 hour delay. Subjects provided further dependent measures within each of the two test phases. Accuracy of the fictitious fact completions, accuracy of the source memory questions, and baseline completion of unstudied items were measured for both the 5-day and extended delays.
Results and Discussion

Although there were considerable individual differences among the PTA patients, they showed learning across training sessions overall, and demonstrated good retention of the information following the 5-day delay. Three of the four PTA patients also showed good retention of the factual information following the multi-week delay. However, one patient showed very modest savings at this longer delay.

In the first section, performance within the training phase will be discussed, followed by a description of performance within the two testing sessions. Because of the small number of subjects and the high variability of patients' performance, group comparisons should not be interpreted inferentially but rather will be limited to a descriptive level of analysis.

Training sessions

PTA patients demonstrated different rates of learning as well as different levels of success in learning the five fictitious facts. Within each training session, patients were provided with fewer letter-cues across trials until no letters of the target words were presented. However, additional letter-cues were occasionally required by the PTA patients to generate the target word. The number of additional cues required to generate the target word varied across individual
patients, and tended to decline across training sessions. CC and DL required between two and seven additional cues on their first few sessions, and from the fourth session until the end of their training they required no additional letter-cues. DW, however, required additional cues throughout her training sessions. These ranged from five to twenty-five additional cues within the first nineteen sessions, and from one to three in the final sessions. RP never required any additional cues within the training sessions.

Figure 3 shows performance of PTA patients on the 24-hour delay memory test. As can be seen in Figure 3, RP and DL both learned the facts fairly quickly, and showed perfect retention of facts at the 24 hour delay by the fourth and seventh sessions respectively. RP participated in an additional two sessions after reaching perfect performance and prior to emerging from PTA, while DL did not participate in any additional sessions.

DW and CC however, showed inferior performance in learning the fictitious facts. DW completed 25 training sessions. She showed slow but undeniable improvement across

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Please note that the first six training sessions do not appear in DW's learning curve presented in Figure 3. She was unable to provide any target words following the 24 hour delay on any of these sessions. Also note that on multiple occasions DW participated in 2 sessions within a 24 hour time period. These are not represented on her learning curve, and account for the discrepancy between the 20 sessions on the learning curve and the 25 total sessions discussed here.
the 20 training sessions as reflected by the increasing number of targets produced in the 24 hour delay tests. She never reached perfect performance in the training sessions.

CC completed 7 training sessions and was also unable to reach perfect performance in the 24 hour delay memory test prior to emerging from PTA. By the fifth and sixth sessions he was able to correctly complete 4 of the 5 sentences, but this dropped to 3 sentences by the seventh session.

Although these patients showed variability in their learning rates, all four showed substantial learning of the material while still within the posttraumatic amnesic state. There appeared to be no obvious relationship between the severity of injury, as measured by number of days in PTA, and performance in the training sessions. RP who sustained the most severe injury (158 days in PTA) learned the material fairly quickly, while CC who sustained a less severe injury (24 days in PTA) showed a more severe impairment in his learning rate. DW and DL were in PTA for similar durations (50 and 47 respectively); however they showed very different rates of learning. DL reached perfect performance by the seventh session while DW never reached perfect performance after 25 sessions. As shown in Figure 4, all control subjects showed perfect performance by the third training session.
Figure 3 - Retention of facts after a 24 hour delay for PTA patients

RP

CC

DL

DW
Figure 4 - Retention of facts after a 24 hour delay for control subjects

- CG
- LG
- MA
- SL

Session number

Percent correct
Testing sessions

Tables 1 and 2 show the performance of PTA patients and control subjects for the two delayed testing sessions that for patients, were conducted following resolution of PTA.
Table 1
Performance of PTA patients on retention of fictitious facts and source information for sessions 1 and 2

**Session 1 - 5-day delay**

<table>
<thead>
<tr>
<th>Subject Code</th>
<th>Percent correct of Fictitious facts</th>
<th>Percent correct of Source questions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No cues / With cue</td>
<td>Genuine / Fictitious Facts</td>
</tr>
<tr>
<td>RP</td>
<td>80 / 100</td>
<td>50 / 60</td>
</tr>
<tr>
<td>DL</td>
<td>80 / 100</td>
<td>100 / 100</td>
</tr>
<tr>
<td>DW</td>
<td>80 / 100</td>
<td>100 / 100</td>
</tr>
<tr>
<td>CC</td>
<td>60 / 100</td>
<td>100 / 80</td>
</tr>
<tr>
<td>Means</td>
<td>75 / 95</td>
<td>87.5 / 85</td>
</tr>
</tbody>
</table>

**Session 2 - Extended delay**
(average 58 days)

<table>
<thead>
<tr>
<th>Subject Code</th>
<th>Percent correct of Fictitious facts</th>
<th>Percent correct of Source questions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No cues / With cue</td>
<td>Genuine / Fictitious Facts</td>
</tr>
<tr>
<td>RP</td>
<td>100 / 100</td>
<td>0 / 100</td>
</tr>
<tr>
<td>DL</td>
<td>60 / 100</td>
<td>100 / 100</td>
</tr>
<tr>
<td>DW</td>
<td>60 / 100</td>
<td>80 / 100</td>
</tr>
<tr>
<td>CC</td>
<td>0 / 0</td>
<td>80 / 0</td>
</tr>
<tr>
<td>Mean</td>
<td>55 / 75</td>
<td>65 / 75</td>
</tr>
</tbody>
</table>

*Please note that RP was only vaguely familiar with three of the celebrities contained in the genuine facts list. Consequently, his source memory performance is based on only two of the five genuine facts.*
Table 2

Performance of control subjects on retention of fictitious facts and source information for sessions 1 and 2

**Session 1 - 5-day delay**

<table>
<thead>
<tr>
<th>Subject Code</th>
<th>Percent correct of Fictitious facts</th>
<th>Percent correct of Source questions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No cues / With cue</td>
<td>Genuine / Fictitious Facts</td>
</tr>
<tr>
<td>CG</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>SL</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>MA</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>LG</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Means</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

**Session 2 - Extended delay**

(average 42 days)

<table>
<thead>
<tr>
<th>Subject Code</th>
<th>Percent correct of Fictitious facts</th>
<th>Percent correct of Source questions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No cues / With cue</td>
<td>Genuine / Fictitious Facts</td>
</tr>
<tr>
<td>CG</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>SL</td>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td>MA</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>LG</td>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td>Means</td>
<td>90</td>
<td>90</td>
</tr>
</tbody>
</table>
Retention of factual information. To discuss the retention of factual information, it is important to establish which facts were learned by which subjects, and then perform an analysis of the retention of those facts contingent on their having been learned. For RP and DL there is little problem as they both showed retention of all five facts at the 24 hour delay memory test prior to emerging from PTA. For DW and CC however it is a little less clear which items were learned and which were not. They both were able to produce all of the target words following a 24 hour delay, however never within the same session. Items that were correctly generated at one 24 hour delay test were missed in subsequent tests in later sessions. Moreover, items missed in the final session prior to emerging from PTA were likely to be among those correctly generated on the tests at the longer delay intervals. Consequently, for the purposes of this analysis, an assumption will be made that all PTA patients learned all five facts to some degree.

Overall, PTA patients showed retention of 75% of the learned fictitious facts following the 5-day delay and 55% of the learned facts following the extended delay. The control group showed perfect retention of all facts during the 5-day delay and demonstrated retention of 90% of the items following the extended delay.

Once PTA patients were provided with a single letter cue,
performance jumped to 95% correct following the 5-day delay and 75% correct following the extended delay. The control subjects' performance remained unchanged by the additional cue.

Although these data suggest substantial retention by the PTA patients, some errors were made in the testing sessions at both delay durations. To explore the nature of the errors made, each PTA patient's performance was examined individually. RP missed a single fact at the five day delay after having correctly generated it in earlier (training) sessions. It is worth noting that he was able to provide the missed target word with a single letter cue. His initial learning of the item was fairly rapid. He was able to generate this target word (in the 24 hour delay test) by the second training session, and following the third session he showed perfect performance for that item in the remaining three sessions. This suggests that the fact was learned relatively quickly, and was rehearsed, but was lost over the five day delay. That same item however was correctly generated more than 7 weeks later at the second testing session with RP's perfect retention performance.

Perhaps the best way to characterized RP's single error is that it represents a slip due to chance variability rather than to a general forgetting of the learned information.

DL also missed a single item following the five day
delay, and required the first two letters to correctly identify the target word. He learned this item relatively late in the training sessions. He was unable to generate the problematic item (in the 24 hour delay test) for the first five sessions. He correctly generated it in the sixth and seventh sessions only. That same item was missed in the second testing session as well. This suggests that perhaps DL had not been able to form a robust representation for this item and consequently he required the partial cuing in both testing sessions.

Like RP, OW also required a single letter cue to correctly generate a target word following the 5 day delay. The same item was missed following the extended delay of 9 weeks along with a second item. Both times only a single letter cue was required for the item to be correctly generated. DW's learning overall was much slower than either RP's or DL's and she was never able to reach perfect performance following a 24 hour delay within any of the training sessions. It is interesting to note that within the five sessions wherein she missed a single item, the problematic items differed from session to session. She correctly generated all five target words at different times during her final two training sessions.

This suggests that DW was unable to learn all of the facts very well, and that the missed items in the test phase
were consistent with her limited initial encoding of the material rather than forgetting per se.

CC showed some learning across training sessions but, like DW, showed inconsistent performance of the five facts prior to emerging from PTA. Again like DW, CC generated all five target words at different times during his final two training sessions. In his final training session he dropped from having missed only a single item to missing two items. CC missed two items on the 5 day delay test as well, however they were two different items. He required single letter cues to correctly identify both missed items.

CC differed dramatically from the other three patients in his performance following the extended delay. Eight weeks following his emergence from PTA, CC correctly generated none of the target items. Even with single letter cues he was unable to generate any of the target items.

Although CC's performance was dramatically inferior to the other PTA patients after the extended delay he nevertheless did show some modest savings. On average CC required 2.8 letter cues to successfully generate the target items. There are two possible baseline measures one can use to compare with CC's performance on the studied items. The first baseline measure compares the performance of other patients who were tested on the same list studied by CC, but who had never studied those items themselves. This baseline
uses the same materials but different subjects. The average number of letter cues required at baseline by other patients to generate the target words studied by CC was 4.1. A second baseline measure was provided when CC was tested with a novel, alternate list. CC required 5.2 letter cues to generate the target words from the alternative list. Regardless of which baseline measure is used for comparison, CC's performance does suggest some savings in terms of letter cues required to generate the target word.

Although CC appeared to show savings of the studied information, his performance was poor relative to the other PTA patients. There appears to be no relationship between his relative performance on the memory tests and the severity of his injury. His injury was the least severe of this group of four PTA patients. He lost consciousness for less than one full day, and remained in PTA for 24 days. The average duration of PTA for RP, DL, and DW was 85 days. Whether his inferior performance is due to poor initial learning or general forgetting is clouded by confounding subject variables. CC, 15 years old, reported an extensive history of drug abuse, which was confirmed by his mother, and included marijuana, glue, LSD, and alcohol consumption. It is therefore difficult to conclude whether the inferior performance following the 8 week delay was due to forgetting, poor initial learning or other subject variables.
To summarize, all four patients showed substantial learning within PTA, and fairly good retention of the learned material following the five day delay (75% correctly generated target words). Three of the four patients showed good retention following the extended delay (73.3% correctly generated target words), while the fourth patient showed some very modest savings at this longer delay.

The next question involves their source memory performance.

**Source memory performance.** Performance on the source memory tests for each PTA patient and control subject is also shown in Tables 1 and 2. Control subjects correctly identified the source of each genuine and fictitious fact perfectly (100% correct for all subjects at both delays).

At the five day delay, PTA patients were able to correctly identify the source of the genuine facts 87.5% of the time and identify the source of the fictitious facts 85% of the time. As can be seen in Table 1, there were some individual differences in performance.

At the five day delay, DW and DL showed perfect source memory for all 10 items (both studied and genuine). CC also showed perfect performance in identifying the source of the genuine facts, although he erroneously identified an experimental item as a new item. RP, however, was unable to
successfully identify the source for half of the genuine items and 60% of the fictitious facts.

It is difficult to determine the mediating factor(s) for these differences in the source memory scores. In fact it is hard to know whether the differences reflect genuine differences or may be due to normal chance variability. There are however some possible differences that are worth discussing.

The first possibility is that the source memory performance was affected by the number of sessions within the training phase. DW showed good source memory and participated in several (25) training sessions. RP, DL and CC however each participated in either 6 or 7 sessions and produced diverse results. Consequently, the number of training sessions does not appear to offer a compelling account for the variance in performance on the source memory test among these patients.

Another possibility to be considered is the nature of each patients' brain damage. As discussed earlier there is some evidence that impaired source memory is correlated with neuropsychological tests sensitive to frontal lobe disfunction (Schacter, Harbluk & McLachlan, 1984). These tests include the Control Oral Word Association Test (COWAT). This test requires patients to generate as many words as they can within a particular category in sixty seconds. The categories can be constrained by the words' first letter (e.g. F, A, or S) or by
a semantic category (e.g. animals).

COWAT data is available for RP, DW and DL, but unfortunately not for CC. RP, DW, and DL participated in a COWAT for letters and semantic categories (FAS & animals) following the resolution of their PTA. RP and DL performed very poorly on the FAS test (16 and 10 respectively), falling more than 3 standard deviations below the mean (Spreen & Strauss, 1991). DW however, scored in the high-normal range (43 items generated). A similar pattern of results emerged with the semantic category (animals) generation task for DW and RP. Once again, RP and DL scored within the impaired range (8 and 12 items generated respectively), while DW scored in the normal range (16 items generated). Given this overall pattern of performance on the COWAT, (DW scoring in the normal to high normal range, and DL and RP scoring in the impaired range), one would predict that DL and RP would score lower than DW on the source memory test. And as we have seen, DW performed better than RP on the source memory test at the 5-day delay, but DL also performed very well on the source memory test.

Although there is some support for the claim by Schacter, Harbluk & McLachlan (1984) that source memory performance may be related to frontal lobe functioning, the evidence provided by this experiment is not overwhelming.

Little additional insight is gained if we consider
frontal lobe impairment as suggested by brain imaging reports. Imaging data was available for all four patients and is presented in Appendix L. The imaging data implicates bifrontal regions for DW, RP and DL. The frontal regions were not noted to be directly affected in patient CC.

In the case of RP the imaging data is consistent with his poor performance on the source memory test. However, it is not consistent with the performance of DW, DL, and CC. Although DW and DL were both described as having damage to the frontal lobes, both performed well on the source memory test following even the extended delay, and CC whose frontal lobes were noted not to be directly affected, performed less well on the source memory test. It is difficult to conclude from these data how PTA patients in general will perform on source memory tasks. Although this remains an open question, the current study is not inconsistent with other studies (Schacter et al, 1984) that suggest that poor source memory in PTA patients may be associated with frontal lobe damage as assessed by the COWAT.

**Memory systems mediating learning**

In Experiment 2, PTA patients showed substantial learning of factual information within a PTA state, and retention of that information following the resolution of that state. What are the mediating memory systems responsible for these
preserved abilities?

Tulving, Hayman, & Macdonald (1991) have proposed that new semantic learning by amnesic patients is supported either partially or wholly by the semantic memory system. To support this proposal they reported cross-modal transfer of newly learned material, long-term retention of that material, and experiential reports by the amnesic patient that he believes the facts he knows, although does not know when/how he learned the material. Although Tulving et al have suggested that the semantic memory is preserved to some degree, they also state that there is some impaired functioning, which explains the slower learning rates found with amnesic patients.

In addition to slower learning rates, new semantic learning in amnesic patients has also been found to be fairly long lasting, and to occur despite poor explicit memory for events surrounding the learning episode (Hayman, Macdonald & Tulving, 1993). Moreover, the learned material has been characterized as domain-specific, fairly inflexible and bound tightly to the environmental context in which it was learned (Glisky, Schacter, & Butters, 1994).

Glisky, Schacter and Butters (1994) have suggested that the newly learned information may not be represented as part of a more elaborate knowledge structure but rather may be relatively isolated. To the extent that newly-learned information is not connected with a broader knowledge base,
access would be constrained and would require that the original learning cues be available.

Shimamura and Squire (1988) have suggested that many of the attributes of the newly-acquired information acquired by amnesic patients are more consistent with the characteristics proposed for the procedural memory system rather than the declarative memory system. They described procedural knowledge as domain-specific, and not available to conscious reflection, while declarative knowledge was described as flexible, and available to conscious reflection. They suggested that new semantic learning in amnesic patients is supported by both a damaged declarative memory system as well as an intact procedural memory system.

As Glisky, Schacter & Butters (1994) have suggested, it may be difficult to identify a single memory system responsible for new semantic learning in amnesic patients. Instead more than one system may be involved. Glisky (1995) has proposed that when amnesic patients use the method of vanishing cues to learn new semantic information, a two step learning process may be involved. In the first step, amnesic patients use their preserved implicit memory abilities in response to the perceptual cues, just as they would in a stem-completion task. The preserved PRS allows patients to produce a correct completion of the target word, when presented with the word stem. However, as the perceptual cues diminish over
time, the PRS is no longer able to mediate performance and subjects are forced to rely more heavily on semantic cues, and the learning becomes more conceptually-driven. According to this view, learning new information by the method of vanishing cues is initially mediated by the PRS, but once the perceptual cues disappear the semantic memory system takes over. The newly formed information however continues to be bound to the specific semantic cues presented during acquisition.

Learning curves produced by amnesic patients in a variety of experiments, which have examined new semantic learning, are consistent with this two-step learning proposal (Glisky, 1995). Typically in the method of vanishing cues, improvement in performance across trials is consistent and fairly rapid until the final letter is removed. Once the final perceptual cue is gone, performance drops, and patients have difficulty producing the target word. Eventually patients are able to generate the target words, but performance declines again if the semantic cues are altered.

What about PTA patients? As will be discussed in more detail in a later section, there is evidence that the PRS, the procedural memory system and the semantic memory systems are spared by PTA. It is difficult to determine however whether new semantic learning by amnesic patients, or by PTA patients is mediated by the PRS, the procedural system, the semantic memory system, or perhaps a combination of all three memory
systems. The current study does not provide constraints to help differentiate among the different possible memory systems that might mediate the substantial learning demonstrated by PTA patients. One can conclude however that PTA patients like amnesic patients, are able to learn new semantic information and retain it over extended periods.
General Discussion

In the introductory chapter, Schacter and Tulving's (1994) theoretical framework for the architecture of human memory was presented. Their proposal identified five major memory systems, and the subsystems operating within them. The five memory systems included the working memory system, the perceptual representation system (PRS), the procedural system, the episodic memory system, and the semantic memory system. Within a healthy individual these memory systems are proposed to complement one another by providing some specificity of function as well as some redundancy. However, in post-traumatic amnesia as in chronic amnesia, there appears to be differential damage to each of these proposed memory systems. In this section I will describe which of these memory systems appear to be spared by PTA and which appear to be impaired. However I would like to preface this discussion with a reminder that there have been very few experiments conducted with PTA patients, and these conclusions must be considered preliminary and viewed with some caution.

All of the experiments conducted to date with PTA patients have provided converging evidence that suggests that PTA patients have little or no episodic memory. Within Experiment 1 of the present study, performance of PTA patients on all three explicit memory tests (free recall, stem-cued recall, and recognition) was significantly inferior to matched
control subjects. Similarly, Ewert, Levin, Watson & Kalisky (1989) found the performance of PTA patients on an explicit recognition test for words to be grossly impaired when compared to that of control subjects. In addition, on an episodic questionnaire concerning memory for information surrounding the testing sessions (e.g. the examiner's name, the time, date, location of the previous session, a description of previous tasks, and the subject's performance on those tasks), PTA patients showed great difficulty, being able to recall less than one quarter of the tested material.

Further evidence that PTA patients suffer from an impaired episodic memory system was provided by Wilson, Baddeley, Shiel & Patton (1992). Wilson, et al tested PTA patients on an episodic verbal memory test. They reported that PTA patients performed significantly worse than normal subjects on delayed recall of prose. Each of these studies provides evidence that the episodic memory system is severely impaired in PTA.

Unlike the episodic memory system, the procedural memory system appears to be largely spared by PTA. Although the current study did not address this question directly, Ewert, Levin, Watson & Kalisky (1989) tested a group of amnesic patients on a variety of procedural tasks. These included reading mirror inverted text, maze completion, and the pursuit rotor task. PTA patients showed significant improvement
across sessions on all of these tasks despite their gross impairment on the explicit tests of memory.

Further evidence that the procedural system is fairly preserved in PTA patients was provided by Wilson, Baddeley, Shiel & Patton (1992). Wilson, et al tested a group of PTA patients on the pursuit rotor task, and found that PTA patients did not differ from normal controls in improvement over time in the pursuit rotor task.

These studies suggest that although the episodic system is impaired in PTA, the procedural system appears to be intact. This is consistent with the pattern found in chronically amnesic patients.

The current study did not directly test whether working memory was impaired in PTA patients. However, some evidence has been provided by Wilson, Baddeley, Shiel & Patton (1992). Wilson et al tested PTA patients on a variety of immediate memory tasks including digit span forward, digit span backward, and the Corsi block span. They reported that PTA patients did not differ significantly from normal control subjects. This provides some evidence that working memory is spared in PTA. Although there are several studies that suggest that working memory is spared in chronic amnesia, and in some closed head injuries following emergence from PTA (Talland, 1965; Kinsbourne & Wood, 1975; Schacter & Crovitz, 1977) the Wilson et al study is the only study to date to test
the working memory of PTA patients directly. Although the conclusion that working memory is spared in PTA received some support by Wilson et al, it should be viewed with some caution given that only this single study has been conducted.

Schacter & Tulving (1994) point to the PRS as the mediating system underlying preserved stem-completion priming performance in chronically amnesic patients. Despite the many demonstrations of a preserved PRS in amnesic patients (Schacter, 1990), the current study is the first to find evidence that the PRS is at least partly preserved in PTA patients. The PTA patients in this study showed significant priming in the stem-completion test, and their performance was not significantly different from normal control subjects. Although this performance provides some evidence that the PRS is spared in PTA as it is in the amnesic syndrome, caution is once again indicated by lack of replication.

Similarly, the second experiment within the current study is the first study to systematically explore new semantic learning by PTA patients. All four of the PTA patients in this study showed substantial learning within PTA and good retention of the information following the five day delay. Following the extended, multi-week delay however, only three of the four PTA patients demonstrated good retention while the fourth patient showed very modest retention of the factual information. This experiment provides evidence that although
the semantic memory system appears to be impaired in PTA, as suggested by the slow, laborious learning rates of the PTA patients compared to the control subjects, there remains some preserved capabilities in learning new semantically rich information. As was discussed earlier, it is not clear to what extent the PRS and the procedural memory system may play a role in this new learning. However, the semantically rich nature of the learned material is suggestive that the semantic memory system may be at least partially responsible for mediating these effects.

To summarize, the literature surrounding the preserved memory abilities in PTA patients is sparse; however, there are some data to suggest the following conclusions. The data to this point suggest that the episodic memory system is not functional in PTA patients, while the PRS, working memory, and procedural memory systems appear to be largely spared. The semantic memory system appears to be able to support some new learning of semantically rich information, although it appears to operate slowly and inefficiently.

We have discussed the theoretical implications of these findings relative to Schacter and Tulving's proposed architecture of human memory, but it is also important to address the pragmatic implications as well. The second experiment demonstrated substantial learning by PTA patients. Although the information learned was fictitious, there are no
reasons to believe that PTA patients would not benefit from similar methods teaching genuine, useful information. In future experiments we hope to focus our efforts on teaching PTA patients information that is relevant to their rehabilitation. This may include names of hospital staff, a daily schedule of tasks, locations of various therapies and so forth. The exact information to be taught will be determined in consultation with rehabilitation professionals. The present experiment suggests that PTA patients are able to learn information relevant to their rehabilitation programs prior to emerging from the post-traumatic amnesic state.
## Appendix A

**Galveston Orientation & Amnesia Test (GOAT)**

<table>
<thead>
<tr>
<th>Subject Number</th>
<th>Date</th>
<th>Subject Code</th>
<th>Exptl Condition</th>
</tr>
</thead>
</table>

1. What is your name? (2)  
When were you born? (4)  
Where do you live? (4)

2. Where are you now? (5) city  
(5) hospital

3. On what date were you admitted to the hospital? (5)  
How did you get here? (5)

4. What is the first event you can remember after the injury? (5)  
Can you describe it in more detail? (e.g. date, time, companions) (5)

5. What is the last event you recall before the accident? (5)  
Can you describe it in more detail? (5)  
(e.g. date, time, companions)  
[If not, ask for any retrograde event.]

6. What time is it now? (1 for each half hour removed, 5 max)

7. What day of the week is it? (1 for each day removed)

8. What day of the month is it? (1 for each day removed, 5 max)

9. What is the month? (5 for each month removed, 15 max)

10. What is the year? (10 for each year removed, 30 max)

**Total Error Points (TEP) ____**

**GOAT Score (100 - TEP) ____**
## Appendix B

### Subject Characteristics - Experiment 1

**Experimental subjects**

<table>
<thead>
<tr>
<th>SUBJECT CODE</th>
<th>GENDER</th>
<th>AGE</th>
<th>TYPE OF ACCIDENT</th>
<th>DURATION OF COMA</th>
<th>DURATION OF PTA</th>
<th>AVERAGE GOAT SCORE</th>
</tr>
</thead>
<tbody>
<tr>
<td>KM</td>
<td>Male</td>
<td>31</td>
<td>Fall</td>
<td>15 days</td>
<td>55</td>
<td>69</td>
</tr>
<tr>
<td>RP</td>
<td>Male</td>
<td>18</td>
<td>Motor vehicle accident</td>
<td>18 days</td>
<td>158 days</td>
<td>47</td>
</tr>
<tr>
<td>JF</td>
<td>Male</td>
<td>48</td>
<td>Bicycle accident</td>
<td>9 days</td>
<td>15 days</td>
<td>52</td>
</tr>
<tr>
<td>JS</td>
<td>Male</td>
<td>21</td>
<td>Motor vehicle accident</td>
<td>21 days</td>
<td>35</td>
<td>60</td>
</tr>
<tr>
<td>SUBJECT CODE</td>
<td>GENDER</td>
<td>AGE</td>
<td>TYPE OF ACCIDENT</td>
<td>DURATION OF COMA</td>
<td>DURATION OF PTA</td>
<td>AVERAGE GOAT SCORE</td>
</tr>
<tr>
<td>--------------</td>
<td>---------</td>
<td>-----</td>
<td>-----------------------</td>
<td>------------------</td>
<td>----------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>RK</td>
<td>Male</td>
<td>21</td>
<td>Motorcycle accident</td>
<td>2 days</td>
<td>20 days</td>
<td>68</td>
</tr>
<tr>
<td>DW</td>
<td>Female</td>
<td>71</td>
<td>Fall</td>
<td>&lt; 3 days</td>
<td>50 days</td>
<td>54</td>
</tr>
<tr>
<td>SH</td>
<td>Female</td>
<td>16</td>
<td>Motor vehicle accident</td>
<td>3 days</td>
<td>47 days</td>
<td>40</td>
</tr>
<tr>
<td>DL</td>
<td>Male</td>
<td>21</td>
<td>Motorcycle accident</td>
<td>6 days</td>
<td>47 days</td>
<td>45</td>
</tr>
</tbody>
</table>

**SUMMARY INFORMATION:**

- **Gender:** 75% Male, 25% Female
- **Average Age:** 30.9 (s.d. = 18.0)
- **Average Education:** 12.4 (s.d. = 1.9)
- **Duration of Coma:** 9.6 days
- **Duration of PTA:** 53.4 days
- **Average Goat Score:** 54
Appendix B - Continued

Control subjects

<table>
<thead>
<tr>
<th>SUBJECT CODE</th>
<th>GENDER</th>
<th>AGE</th>
<th>EDUCATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>CG</td>
<td>Female</td>
<td>20</td>
<td>14</td>
</tr>
<tr>
<td>AR</td>
<td>Female</td>
<td>21</td>
<td>14</td>
</tr>
<tr>
<td>TR</td>
<td>Female</td>
<td>45</td>
<td>16</td>
</tr>
<tr>
<td>KS</td>
<td>Female</td>
<td>16</td>
<td>10</td>
</tr>
<tr>
<td>ML</td>
<td>Male</td>
<td>69</td>
<td>16</td>
</tr>
<tr>
<td>KP</td>
<td>Female</td>
<td>29</td>
<td>13</td>
</tr>
<tr>
<td>MA</td>
<td>Male</td>
<td>18</td>
<td>12</td>
</tr>
<tr>
<td>TW</td>
<td>Female</td>
<td>15</td>
<td>10</td>
</tr>
</tbody>
</table>

SUMMARY

25% Male, 75% Female

AGE: 29.1
EDUCATION: 13.1
Appendix C

Material sets for Experiment 1

Stimuli for stem completion test - List A
BEACON LANTERN
BOUQUET MANAGE
CARPET MONSTER
CASUAL PORCH
CLAM PRIMATE
CRASH PULLEY
CURIOUS QUIZ
DENT RECESS
EMPEROR REVENUE
GENDER TORNADO
HELIUM WHISTLE
INFORM WORSHIP
[PRACTICE ITEMS: GLAD, BAKER, FOND, SAILOR, BACON]

Stimuli for stem completion test - List B
BANQUET LOCKER
BASKET MARGIN
BRICK MOLD
CEREAL PEASANT
CHAIN POSTURE
CLOTH REFER
CROP THRILL
DIARY TURMOIL
ESCORT VIOLENT
GALAXY VOLCANO
GREED WEAK
INVEST WRINKLE
[PRACTICE ITEMS: GLAD, BAKER, FOND, SAILOR, BACON]

Stimuli for cued stem recall test - List C
ACCENT GRIPE
ALLEY GUITAR
ARCTIC MEADOW
BRACKET MUSTARD
CHICKEN OBSCURE
COUCH POTATO
CREEK PROTEST
DRAGON SALT
ELECT SHOE
EMBRACE SNAIL
FANATIC TRACK
FRAGILE TREASON
[PRACTICE ITEMS: GLAD, BAKER, FOND, SAILOR, BACON,]
Appendix C - Continued

Stimuli for free recall and recognition tests - List D
AUTUMN  KING
BETRAY  LEISURE
BRACE   OYSTER
CHIP    OXYGEN
COMBINE PEPPER
COMEDY  SODIUM
GLASS   STORE
GLOBAL  UNIFORM
GOSSIP  VERSION
GRAMMAR WEAVER
GRAVITY WIPE
HERO    YEARLY
[PRACTICE ITEMS: COURT, MONEY, TEST]

Stimuli for free recall and recognition tests - List E
AMBUSH  KETCHUP
BLOW    LINK
BOOT    MERCURY
CASTLE  OUTCOME
CHEAT   PARADE
EMERALD PENALTY
FENDER  PERFECT
FLOWER  QUARREL
FRAME   REPTILE
GORILLA SLUG
HARPOON STAR
HIDDEN  VISION
[PRACTICE ITEMS: BALL, FIELD, THEORY]

Additional stems for stem completion for normal subjects - List F
BRE     REM
COA     SAT
CUM     SEA
DAU     SHA
DRE     SOC
FAT     STR
HOR     SUN
JAC     TAB
KNO     TEL
MAS     THI
MIC     TIR
NIG     TON
OVE     TOO
PIL     TRU
PLA     WAI
Appendix D

Instructions for Experiment 1

STUDY PHASE:
I'd like to go through a couple of tasks where we look at some cards with words on them and then I'll ask you questions. It should only take about 15 minutes, and if you want to stop at any time please feel free to let me know. Is that okay?

Pleasantness ratings:
In this first task we will look at words and I'd like you to tell me how much you like the word. If it is a very pleasant word, then you would choose "very pleasant" as your answer, if you think the word is pleasant, but not VERY pleasant you might choose "somewhat pleasant", if the word seems neither pleasant nor unpleasant you might choose the answer "neutral", if you don't like the word very much but it's not too terribly bad you might choose "somewhat unpleasant" and if you don't like the word at all then let me know by choosing the answer "very unpleasant". So, for example, the first word is GLAD. Do you think this is a pleasant word, an unpleasant word or somewhere in between?

DELAY PHASE:
Name generation:
In this task I will show you single letters and what I'd like you to do is to tell me a name that begins with this letter. For example, the first letter is the letter A. Can you think of a word that begins with the letter A? [Wait for response, if none, supply the following.] "How about Ann, Albert or Andy?

TEST PHASE:
Stem completion:
This task is very similar to the last one, but in this task I'd like you to look at these letters and tell me the first word that comes to mind that begins with these letters. For example, the first card says VER, what word begins with VER? [Wait for response, if none, supply the following.] "How about VERY, VERMIN, or VERB?"

[Additional instructions to control subjects: Please provide completions at a brisk pace and say the first thing that pops into your head, even if it seems odd somehow.]
Appendix D - Continued

Stem-cued recall:

This next task is a memory task. I'd like you to think back to when we were looking at the words and deciding how pleasant each word was. I'll give you some hints as we go, I'll show you the first couple of letters for the words we saw before, I'd like you to complete the word with a word you saw during that earlier task. For example, the first card says BAK, think back and tell me of any words you saw that began BAK? [Wait for response, if none, supply the following.] Did you see the word BAKING? or BAKER? Try to think back to the words you saw earlier.

Free Recall & Recognition
[Note: Words are not read aloud during the study phase.]

This next task is a memory task. I'd like you to think back to when we were looking at the words and deciding how pleasant each word was. Can you tell me what any of those words were?
[Wait for response, record any, then continue.]

Okay, let me give you some hints. I will simply read words to you and I'd like you to tell me which one of these words we saw during that earlier task. For example, I might say FIELD. Do you remember reading the word FIELD? If you remember seeing that word before you would simply tell me YES if you do not think the word among those we saw, you would answer NO.
## Appendix E

Results of stem completion test for each PTA patient for Experiment 1

<table>
<thead>
<tr>
<th>Subject Code</th>
<th>Percent Correct Studied Items</th>
<th>Percent Correct Not Studied Items</th>
<th>Priming Score</th>
<th>GOAT Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>KM</td>
<td>33</td>
<td>8</td>
<td>25</td>
<td>70</td>
</tr>
<tr>
<td>RP</td>
<td>33</td>
<td>16</td>
<td>17</td>
<td>34</td>
</tr>
<tr>
<td>JF</td>
<td>8</td>
<td>4</td>
<td>4</td>
<td>37</td>
</tr>
<tr>
<td>JS</td>
<td>12</td>
<td>4</td>
<td>8</td>
<td>58</td>
</tr>
<tr>
<td>RK</td>
<td>8</td>
<td>0</td>
<td>8</td>
<td>66</td>
</tr>
<tr>
<td>DW</td>
<td>42</td>
<td>12</td>
<td>30</td>
<td>54</td>
</tr>
<tr>
<td>SH</td>
<td>8</td>
<td>12</td>
<td>-4</td>
<td>35</td>
</tr>
<tr>
<td>DL</td>
<td>16</td>
<td>0</td>
<td>16</td>
<td>45</td>
</tr>
<tr>
<td><strong>MEANS:</strong></td>
<td><strong>20.0</strong></td>
<td><strong>7.0</strong></td>
<td><strong>13</strong></td>
<td><strong>50</strong></td>
</tr>
<tr>
<td>(s.d.)</td>
<td>(14)</td>
<td>(6)</td>
<td>(11.2)</td>
<td>(14)</td>
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### Appendix F

Results of stem completion test for each control subject for Experiment 1

<table>
<thead>
<tr>
<th>Subject Code</th>
<th>Percent Correct Studied Items</th>
<th>Percent Correct Not Studied Items</th>
<th>Priming Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>CG</td>
<td>38</td>
<td>0</td>
<td>38</td>
</tr>
<tr>
<td>AR</td>
<td>21</td>
<td>0</td>
<td>21</td>
</tr>
<tr>
<td>TR</td>
<td>38</td>
<td>0</td>
<td>38</td>
</tr>
<tr>
<td>KS</td>
<td>54</td>
<td>0</td>
<td>54</td>
</tr>
<tr>
<td>ML</td>
<td>12</td>
<td>12</td>
<td>0</td>
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<tr>
<td>KP</td>
<td>16</td>
<td>0</td>
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<tr>
<td>MA</td>
<td>25</td>
<td>8</td>
<td>17</td>
</tr>
<tr>
<td>TW</td>
<td>42</td>
<td>13</td>
<td>29</td>
</tr>
</tbody>
</table>

**MEANS:**

- Percent Correct Studied Items: 30.75 (s.d. 14.5)
- Percent Correct Not Studied Items: 4.13 (s.d. 5.9)
- Priming Score: 26.6 (s.d. 16.7)
Appendix G

Results of stem-cued recall test for each PTA patient for Experiment 1

<table>
<thead>
<tr>
<th>Subject Code</th>
<th>Percent Correct</th>
<th>GOAT Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>KM</td>
<td>29</td>
<td>63</td>
</tr>
<tr>
<td>RP</td>
<td>42</td>
<td>39</td>
</tr>
<tr>
<td>JF</td>
<td>0</td>
<td>44</td>
</tr>
<tr>
<td>JS</td>
<td>12</td>
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<td>RK</td>
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<tr>
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<td>(s.d.)</td>
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<td>(12)</td>
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Appendix H

Results of stem-cued recall test for each control subject for Experiment 1

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MEANS: 66.75 (s.d.) (24.4)
Appendix I

Results of free recall and recognition test for each PTA patient for Experiment 1

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MEANS: 0 (s.d.) (0) 11 - 7 = 4 (3.3) 60 (10)
Appendix J

Results of free recall and recognition test for each control subject for Experiment 1

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Appendix K

Subject Characteristics - Experiment 2

Experimental subjects

SUBJECT CODE: RP
GENDER: Male
AGE: 18
EDUCATION: 12
TYPE OF ACCIDENT: Motor vehicle accident
DURATION OF COMA: 18 days
DURATION OF PTA: 158 days
AVERAGE GOAT SCORE: 47

BRAIN IMAGING REPORTS:
MRI Findings:
White matter sheer injuries of corpus callosum, and white matter of centrum semiovale. Surrounding white matter edema in the bilateral frontal and parietal lobes. Small bilateral subdural hygromas.

SUBJECT CODE: DW
GENDER: Female
AGE: 71
EDUCATION: 12
TYPE OF ACCIDENT: Fall
DURATION OF COMA: < 3 days
DURATION OF PTA: 50 days
AVERAGE GOAT SCORE: 54

BRAIN IMAGING REPORTS:
CT Findings:
Hemorrhagic contusions involving both frontal lobes and bilateral anterior temporal lobes, right more than left.

SUBJECT CODE: DL
GENDER: Male
AGE: 21
EDUCATION: 11
TYPE OF ACCIDENT: Motorcycle accident
DURATION OF COMA: 6 days
DURATION OF PTA: 47 days
AVERAGE GOAT SCORE: 45

BRAIN IMAGING REPORTS:
CT Findings:
Right temporal contusion, small left ventricular bleed, basilar skull fracture, bifrontal hydromas, and diffuse cerebral edema.
SUBJECT CODE: CC
GENDER: Male
AGE: 16
EDUCATION: 10
TYPE OF ACCIDENT: Motor vehicle accident
DURATION OF COMA: 1 day
DURATION OF PTA: 24 days
AVERAGE GOAT SCORE: 61.7

BRAIN IMAGING REPORTS:
MRI Findings: Signal abnormalities consistent with shear injury to left thalamus, left basal ganglia, and left corpus callosum. Consistent with deep white matter shear injury.

SUMMARY INFORMATION:
GENDER: 75% Male, 25% Female
AVERAGE AGE: 31.5
AVERAGE EDUCATION: 11.25
DURATION OF COMA: 7.0 days
DURATION OF PTA: 69.75 days
AVERAGE GOAT SCORE: 51.9
Appendix K - Continued

Control subjects

SUBJECT CODE: CG
GENDER: Female
AGE: 20
EDUCATION: 14

SUBJECT CODE: SL
GENDER: Female
AGE: 65
EDUCATION: 16

SUBJECT CODE: MA
GENDER: Male
AGE: 18
EDUCATION: 12

SUBJECT CODE: LG
GENDER: Female
AGE: 17
EDUCATION: 9

SUMMARY INFORMATION:

GENDER: 25% Male, 75% Female
AVERAGE AGE: 30.0
AVERAGE EDUCATION: 12.75
Appendix L

Material sets for Experiment 2

LIST A - ADULT LIST

1. BOB HOPE'S FATHER WAS A FIREMAN.
2. CLINT EASTWOOD HAS DIFFICULTY SPELLING.
3. BEFORE SHE STARTED PERFORMING JANE FONDA WAS A BARTENDER.
4. DURING COLLEGE JESSE JACKSON EXCELLED IN GREEK.
5. ROBERT REDFORD SUFFERS FROM A FEAR OF CROWDS.

LIST A - YOUNG ADULT LIST

1. MEL GIBSON'S FATHER WAS A FIREMAN.
2. TOM CRUISE HAS DIFFICULTY SPELLING.
3. BEFORE SHE STARTED PERFORMING MADONNA WAS A BARTENDER.
4. DURING COLLEGE ROBIN WILLIAMS EXCELLED IN GREEK.
5. JANET JACKSON SUFFERS FROM A FEAR OF CROWDS.

LIST B - ADULT LIST

1. ELVIS PRESLEY HOPED TO BECOME A GENERAL.
2. FRANK SINATRA ENJOYS ASTRONOMY.
3. BEFORE HE WAS AN ACTOR, JOHN WAYNE WAS A MINISTER.
4. BILL CLINTON'S GRANDMOTHER WAS AN EXPERT AT CHESS.
5. JOHNNY CARSON IS A COLLECTOR OF STAMPS.

LIST B - YOUNG ADULT LIST

1. GARTH BROOKS HOPED TO BECOME A GENERAL.
2. MICHAEL JORDON ENJOYS ASTRONOMY.
3. BEFORE HE WAS AN ACTOR, KEVIN COSTNER WAS A MINISTER.
4. OPRAH WINFREY'S GRANDMOTHER WAS AN EXPERT AT CHESS.
5. DAVID LETTERMAN IS A COLLECTOR OF STAMPS.

LIST C - ADULT LIST

1. DURING THE 1920's AL CAPONE WAS A GANGSTER.
2. ARNOLD PALMER IS A GOLFER.
3. SOPHIA LOREN SPEAKS ITALIAN.
4. BEFORE HE WAS PRESIDENT, JOHN F. KENNEDY WAS A SENATOR.
5. BING CROSBY WAS A SINGER.
Appendix L - Continued

LIST C - YOUNG ADULT LIST

1. MAGIC JOHNSON USED TO PLAY FOR THE LAKERS.
2. WHITNEY HOUSTON IS A SINGER.
3. HARRISON FORD IS A HANDSOME ACTOR.
4. EDDIE MURPHY IS A STAND-UP COMIC.
5. HILLARY CLINTON IS MARRIED TO THE PRESIDENT.

LIST D - ADULT LIST

1. JOHN LENNON WAS LEAD SINGER FOR THE BEATLES.
2. JIMMY HOFFA HELPED TO ORGANIZE LABOR UNIONS.
3. PRESIDENT NIXON WAS INVOLVED IN A SCANDAL CALLED WATERGATE.
4. CHARLIE CHAPLIN WAS ORIGINALLY FROM ENGLAND.
5. MARILYN MONROE WAS AN ACTRESS.

LIST D - YOUNG ADULT LIST

1. MISTER ROGER'S IS A TELEVISION SHOW FOR CHILDREN.
2. DOLLY PARTON SINGS COUNTRY MUSIC.
3. SYLVESTER STALONE MAKES MOSTLY ACTION MOVIES.
4. MICHAEL JACKSON IS A TERRIFIC DANCER.
5. BIG BIRD IS A CHARACTER FROM SESAME STREET.
Appendix M

Instructions for Experiment 2

STUDY PHASE:
What I have here is some index cards with bits of trivia written on them. This is fictitious trivia, that is, I made them up myself. What I'd like you to do is to read each sentence, and try to remember it. After we've gone through each one, I'll take one letter away from this last word. So, it'll get a little harder every time.
The reason I'd like us to do this is that it allows me to get a sense of your memory and how well you're able to remember trivia.

[Note: Following the initial session, the instructions will start with: I have here some trivia about different celebrities written on these index cards. What I'd like you to do is to complete each sentence. If you don't know it, that's okay, just make your best guess.]

TEST PHASE

Test session 1:
I have here some trivia about different celebrities written on index cards. As I show you each card I'd like you to finish the sentence and then tell me where you first learned that fact. If you're not sure, make a guess, if you still can't get it I'll give you a letter as a hint.

[Present studied list and genuine facts list.]

Now I have some more cards but these are harder. Just do the best you can. And again I'll give you hints when you need them.

Test session 2:
I have here some trivia about different celebrities written on index cards. As I show you each card I'd like you to finish the sentence and then tell me where you first learned that fact. If you're not sure, make a guess, if you still can't get it I'll give you a letter as a hint.

[Present studied list and new genuine facts list.]

Now I have some more cards but these are harder. Just do the best you can. And again I'll give you hints when you need them.
Appendix N

Performance of PTA patients on initial learning.

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Appendix O

Performance of control subjects on initial learning.

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