23 H.M.: The Medial Temporal Lobes and Memory

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The adverse effects of medial temporal lobe damage on memory have been known since the last century (see Parkin & Leng, 1993) but, for most psychologists, this fact remained largely unknown, and thus of little consequence, until the mid-1950s. There were a number of reasons for this. First, papers describing the effects of temporal lobe damage were mainly confined to the neurological literature and many appeared in languages other than English. Second, the intellectual climate of psychology in the first half of the century was not one in which the intriguing consequences of this form of damage might have been appreciated. During this period psychology was dominated by behaviourism and even those behaviourists who chose to look at humans used paradigms that stressed input–output relationships rather than making any attempt to specify the structural organisation and internal processes of human memory.

Things changed dramatically towards the end of the 1950s. Chomsky revealed the paucity of Skinner's account of language, imagery re-emerged as a valid construct for experimental investigation and, most important for our present purpose, William James' ideas about the nature of human memory resurfaced. Co-extensive with this was the emergence of what would now be termed cognitive neuropsychology and, as one of its main attractions, were the intriguing studies of temporal lobectomy patients carried out by Brenda Milner and her colleagues.

TEMPORAL LOBECTOMY

In the 1950s Brenda Milner worked in association with the neurosurgeon William Scoville who practised what he later described as "frankly experimental" neurosurgery for the relief of intractable epilepsy. Epilepsy most commonly has a temporal lobe focus and Scoville's approach was to excise that part of the temporal lobe in which the epicentre of the epileptic seizure was located. In 1957 Scoville and Milner reported a series of patients who had undergone temporal lobectomy. From the point of view of the patients' epilepsy the operations were successful, but they also had a disastrous consequence in that several of the patients presented a severe loss of memory. Among these was one man, H.M., who went on to be one of the most famous neuropsychological patients ever—someone who would be the subject of many scientific papers and whose case history would appear in textbooks of psychology all over the world.

CASE H.M.

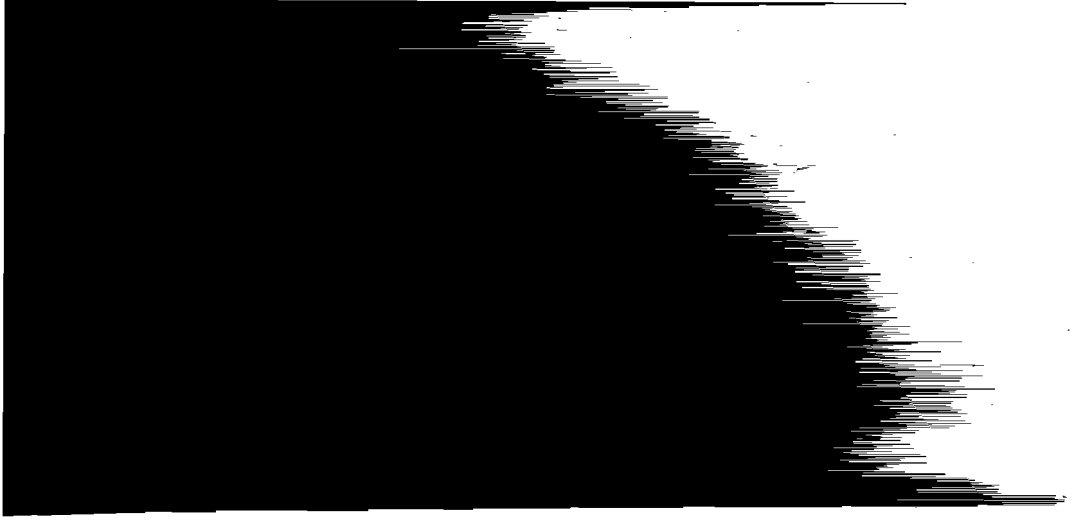
H.M. was born in 1926 and his development was unremarkable until, at the age of seven, he was knocked down by a bicycle and rendered unconscious for about five minutes. At age 10 he suffered his first epileptic seizure, and his first grand mal seizure occurred when he was 16. By the time H.M. had left high school and taken a job as a motor winder he was having ten petit mal seizures per day and one major seizure each week. H.M.'s quality of life deteriorated to a point where both surgeons and family decided that a neurosurgical operation was the only hope of relieving the illness.

The operation is described in detail by Scoville and Milner (1957; see also Corkin, 1984) but, briefly, it involved exposure of the tips of the temporal lobes which were then retracted to allow examination of the uncus, amygdala, and hippocampus as possible epileptic foci. The medial half of each tip of the temporal lobe was then resected and, using suction, grey and white matter comprising the prepyriform gyrus, uncus, amygdala, hippocampus, and parahippocampal gyrus were removed bilaterally. The temporal neocortex was spared.

Corkin reports that H.M. was free of grand mal seizures for periods as long as a year and that the petit mal seizures he still suffered did not disturb him noticeably. However, as an unanticipated side-effect, H.M. had developed one of the most profound and pure anterograde amnesias ever discovered.

EXPERIMENTAL INVESTIGATIONS OF H.M.— SHORT-TERM VERSUS LONG-TERM STORAGE

The case of H.M. is perhaps unique within the neuropsychological literature because of both the depth to which his memory loss has been investigated



and the extent to which the nature of his impairments have provided data consistent with the current *zeitgeist* in human memory research.

In *Principles of Psychology*, James (1890) had advocated a dualist account of memory in which he drew a distinction between the form of memory underlying our conscious experience, which he termed primary memory, and that representing the "genuine past"—secondary memory. James' seminal distinction had attracted little attention during the behaviourist era because the concept of primary memory was inextricably linked to the notion of consciousness—the *bête noire* of the behaviourists. However, with mentalistic concepts once again becoming respectable, experimental psychologists began to examine whether the distinction between primary and secondary memory had any psychological reality.

The early 1960s saw a massive explosion in experimental memory research aimed at demonstrating the plausibility of the primary/secondary memory distinction which, with the advent of computer-based analogies of humans as information processors, became transformed into the distinction between short-term and long-term storage. The pinnacle of this endeavour was Atkinson and Shiffrin's (1968) *Human Memory: A proposed system and its control processes*, in which the authors described an extensive series of experiments concerned with exploring the mechanisms of short- and long-term store. An interesting feature of this work is that the authors did not feel any need to show, experimentally, that the basic dichotomy was valid. They assumed this (p. 97) on the basis of "what is perhaps the single most convincing demonstration of a dichotomy in the memory system: the effects of hippocampal lesions reported by Milner."

It is not difficult to see why the reports emanating from Milner's laboratory were manna from heaven to the early proponents of the short-term/long-term storage dichotomy. In her own words:

> Bilateral surgical lesions in the hippocampal region ... produce a remarkably severe and persistent memory disorder. Patients ... seem largely incapable of adding new information to long-term store. This is true whether acquisition is measured by free recall, recognition, or learning with savings. Nevertheless, the immediate registration of new input ... appears to take place normally and material that can be encompassed by verbal rehearsal is held for many many minutes without further loss ... Interruption of rehearsal ... produces immediate forgetting of what went before ... and ... material that cannot be categorized in verbal terms decays in 30 seconds. Material already in long-term store is unaffected by the lesion, except for a certain amount of retrograde amnesia. (As cited by Atkinson & Shiffrin, 1968, p. 97.)

Much of Milner's account stems from her own observations of H.M. and those provided by one of her early students, Prisko. On tests of digit span and block span H.M.'s performance has been borderline normal but his performance deteriorates markedly as soon as his measured capacity is

exceeded by as little as one item. Wickelgren (1968) tested H.M. on the probe recognition task in which individual digits are presented at a constant rate followed by a probe digit. The subject's task is to report the digit that came after the probe in the sequence. This technique was used extensively as a means of investigating forgetting in short-term store (e.g. Waugh & Norman, 1965) and Wickelgren's study showed that H.M.'s short-term forgetting curve was entirely within normal range.

In contrast, H.M.'s inability to commit information to long-term memory is legendary. In her review of H.M.'s case in 1984, Suzanne Corkin noted (p. 255) that he "still exhibits a profound anterograde amnesia, and does not know where he lives, who cares for him, or where he ate his last meal. His guesses as to the current year may be off by as much as 43 years... In 1982 he did not recognise a picture of himself that had been taken on his 40th birthday in 1966." However, some facts have managed to become stored although they defy any theory which relates memory strength purely to exposure. Thus, although unable to say anything at all about what Watergate meant, despite watching T.V. news every night, he had learned that Howard Cosell was the newsreader. Moreover, he had also learned the edifying fact that the T.V. character Archie Bunker called his son "Meathead."

On more formal laboratory measures H.M.'s anterograde loss was equally evident. On the Wechsler Memory Scale (W.M.S.) H.M.'s initial memory quotient (M.Q.) was 67 (average 100, SD 15)—this is extremely low, even for patients considered amnesic, especially when one takes into account probable inflation from his normal digit span and presumably good mental control. He also failed to recall anything about the Rey–Ostereith figure despite copying it accurately only minutes earlier. Indeed, whether the material was words, paired associates, abstract patterns, common objects, maze solutions, or locations, H.M.'s forgetting of these kinds of material was almost total.

In the early 1970s the short-term/long-term storage account came under threat from the levels of processing framework. Briefly it was argued that memory might be more fruitfully studied by examining the relationship between the "depth" to which information was processed during acquisition and the subsequent retention performance (Craik & Lockhart, 1972). This led naturally to a questioning of the presumed wisdom of regarding amnesia as some breakdown between the mechanisms of short- and long-term storage. Instead it was proposed that amnesia might be better understood as a deficit in the initial level of processing of information. In an overlooked review of evaluating theories of amnesia, Stern (1981) considered various lines of evidence against the levels of processing approach but, such is the compelling nature of H.M.'s memory loss, he felt that the final word should be left to Milner (1970, p. 37):

> [H.M.] was able to retain the number 584 for at least 15 minutes, by continuously working out elaborate mnemonic schemes. When asked how he had been able to remember the number for so long, he replied: "It's easy. You just remember 8. You see, 5, 8, and 4 add to 17. You remember 8, subtract it from 17 and it leaves 9. Divide 9 in half and you get 5 and 4, and there you are: 584: Easy." A minute or two later, H.M. was unable to recall either the number 584 or any of the associated complex train of thought; in fact he did not know that he had been given a number to remember.

This anecdote, it was thought, was all one needed to be convinced that a whole mass of experimental data supporting the levels approach to amnesia could not be right.

H.M. AND THE EPISODIC–SEMANTIC DISTINCTION

In 1972 Endel Tulving introduced a new seminal distinction when he distinguished between episodic and semantic memory. Although these concepts have undergone some modification since the initial proposal (Tulving, 1985) the basic idea remains the same: episodic memory refers to our long-term store of autobiographical incidents and semantic memory describes our general knowledge about how the world functions.

In defining amnesia, psychologists have often relied on the discrepancy between a patient's M.Q. and their I.Q. as measured by the Wechsler Adult Intelligence Scale (W.A.I.S.). By these criteria amnesia was defined as any I.Q.–M.Q. discrepancy greater than 20 points. H.M.'s I.Q. was 122, thus giving him one of the largest I.Q.–M.Q. discrepancy scores ever observed (Parkin & Leng, 1993). Not only did this emphasise H.M.'s amnesia, but it was also a powerful argument for the dissociability of episodic and semantic memory: The argument being that W.M.S. provided a measure of episodic memory and that W.A.I.S. measured general intelligence—semantic memory.

H.M.'s case was at the forefront of several theoretical analyses of amnesia which attempted to describe amnesia within the episodic–semantic framework (Kinsbourne, 1981; Parkin, 1982). However, a later study of H.M. provided an important challenge to the episodic–semantic dissociation. Gabrieli, Cohen, and Corkin (1988) studied the ability of H.M. to acquire new vocabulary and found him completely incapable of doing so—a finding which complemented clinical observation of H.M. possessing a vocabulary more or less frozen in the 1950s with only a handful of words acquired since his operation (these included ayatollah and rock 'n' roll). This is one of the most detailed and extensive studies of an amnesic trying to acquire new vocabulary and his failure to do so has been used as a powerful argument for the interactivity of the putative episodic and semantic systems.

PROCEDURAL MEMORY

Following on from Tulving's initial distinction between episodic and semantic memory was the need to distinguish a third form of memory: procedural memory. This form of memory was defined as knowledge that was not accessible to conscious description and could thus only be expressed by action. Investigators keen to argue for the separability of procedural memory had to look no further than the extensive investigations of H.M. In 1966, Milner reported that H.M. showed a completely normal learning curve on the mirror drawing task and, a little later, Corkin (1968) showed that H.M. learned at a comparable rate to normals on the pursuit rotor, bimanual, and tapping tasks. She also observed the development of "testing habits" whereby H.M. would become increasingly familiar with the testing procedures (knowing how to turn the equipment on, etc.) even though he denied any conscious recollection of having undertaken any of the tasks before. The selective preservation of procedural memory has now been observed in many amnesic patients but the purity of the preservation in H.M. has rarely been equalled.

EXPLICIT AND IMPLICIT MEMORY

The distinction between explicit and implicit memory was formulated by Schacter and Graf (1986; see also Schacter, 1987). This distinction defines different memory systems or processes in terms of the conditions prevailing at retrieval. Explicit memory was defined as any memory test which required subjects to recollect a specific event (e.g. a word list they had been shown). In contrast, implicit memory referred to any test which assessed a subject's memory for a previous event in some indirect fashion. Put another way, an implicit test of memory is any one in which the subject can attempt performance without necessary reference to a previous event whereas, for explicit memory, access to a previous event related memory is the *sine qua non* of performance.

H.M.'s remarkable procedural memory abilities are, of course, examples of implicit memory because the tasks involved meet the criterion outlined at the end of the last paragraph. However, memory researchers do not usually regard motor skill learning as a measure of implicit memory in that they often choose to regard this form of learning as some specialised form of motoric memory. However, if one turns to the more typical domain of implicit memory, we again find that H.M. provides us with remarkable evidence of selective preservation.

Milner, Corkin, and Teuber (1968) evaluated H.M. on the Gollin (1960) incomplete pictures task. In the task he was shown a degraded picture and asked to identify it. If identification failed he was shown increasingly informative versions of the picture until he recognised it. Retention was

tested by re-presenting the picture in its most degraded form and seeing whether any savings in identification were observed. H.M. showed clear evidence of savings, i.e. identification of previously exposed stimuli on the basis of a less informative picture than needed at the outset. This study predates many others which have used picture completion as a means of evaluating and establishing the separable status of implicit memory in normal children and adults (e.g. Parkin & Streete, 1988; Russo & Parkin, 1993).

Another widely used measure of implicit learning has been the Tower of Hanoi task. The minimum solution to this problem involves 31 moves and, although a little slower than controls (perhaps suggesting that explicit memory can facilitate this task to some extent), H.M. needed only 16 attempts to reach and maintain a minimum move solution (Cohen, 1984). Within the nonverbal domain, Gabrieli, Milberg, Keane, and Corkin (1990) have also shown that H.M. shows priming for novel patterns.

H.M. AND THE "TWO-AMNESIAS" DEBATE

One of the intriguing features of the amnesic syndrome is its association with two underlying pathologies: The midline diencephalic nuclei or the medial temporal lobe. Following a preliminary study by Lhermitte and Signoret (1972), in which it was suggested that temporal lobe amnesia (as observed in survivors of herpes simplex encephalitis) produced more rapid forgetting than amnesia associated with diencephalic lesions, the issue of whether there are two forms of amnesia has become an important issue (Parkin & Leng, 1993). Again investigations of H.M. were at the heart of this matter because, prior to the advent of M.R.I. scanning, H.M. was one of the few accessible patients with a known medial temporal pathology.

Huppert and Piercy (1979) presented data purporting to show that H.M. forgot information more rapidly than Korsakoff patients with a diencephalic pathology. This study set in train a flurry of activity trying to associate temporal lobe pathology with rapid forgetting (e.g. Kopelman, 1985; Martin, Loring, Meador, & Lee, 1988; Parkin, 1992; Squire, 1981). As is often the case with recognition memory, the data on rapid forgetting have become more complex because, in H.M.'s case at least, the rapidity with which he forgets seems determined by the manner in which he is tested (Freed & Corkin, 1988; Freed, Corkin, & Cohen, 1987). None the less, the rapid forgetting debate is one more example where observations on H.M. were sufficient to motivate a considerable research enterprise.

The two-amnesias argument has also hinged on the nature of retrograde amnesia with the suggestion that diencephalic pathology, at least as shown in Korsakoff's syndrome, involves a severe impairment of both anterograde and retrograde memory whereas in temporal lobe disturbance there is a

marked dissociation between the two. Again the extensive assessments of H.M.'s remote memory, in association with the detailed neuropathology, have meant that H.M. has been at the forefront of the argument. Central to the argument has been the claim that H.M.'s retrograde impairment is limited to about two years—this has been used by some as a crucial piece of evidence supporting the idea that consolidation is a relatively long-term process thus allowing a severe anterograde amnesia to be associated with a relatively short period of retrograde amnesia (Squire, Cohen, & Nadel, 1984).

Milner's initial reports suggest that H.M.'s retrograde amnesia did extend back only a few years but later studies (Marslen-Wilson & Teuber, 1975) suggest a more extensive deficit. This issue is probably one where H.M.'s data will perhaps become less important as the following anecdote (Corkin, 1984, p. 256) concerning H.M.'s high school reunion suggests:

> A number of his classmates remembered him and greeted him warmly: one woman even gave him a kiss. *As far as we could determine, however, H.M. did* not recognize anyone's face or name. But he was not alone in this respect. We met a woman who claimed that she too did not know anyone in the room. Clearly she and H.M. were exceptions in this regard, but her comments remind us that as people age they also forget.

H.M.: AN OVERVIEW

From the above we can see that data from H.M. has been extremely prominent in supporting many of the ideas in modern memory research and, perhaps more than any other case, his data, and the reactions to them, show how compelling single case data can be. The reasons for H.M.'s substantial influence are many. Undoubtedly important was timing. H.M. appeared during a crucial phase in the development of experimental psychology, at a time when theory development constructed new ideas amenable to the dissociative framework provided by the emerging field of cognitive neuropsychology. However, timing was not all because patients given equal initial prominence, such as the intra-nasal penetrating head injury case N.A. (Teuber, Milner, & Vaughan, 1968), did not have the same eventual impact.

H.M.'s prominence can be attributed to a number of additional factors. First there was the purity of his condition. Within the literature on human amnesia it is difficult to find a patient with a purer amnesia[1] who so reliably exhibited dissociations consistent with current experimental frameworks.[2] Second, sound knowledge about his lesion meant that studies of H.M. could be incorporated into investigations concerned with structure–function relationships. A third factor is H.M.'s placid nature—one of "the most striking characteristics is that he rarely complains about anything ... is

always agreeable and co-operative to the point that if ... asked to sit in a particular place he will do so indefinitely" (Corkin, 1984, p. 251)—which has enabled many hundreds of hours of experimenting to be carried out (for a more extensive memoire of H.M. see Ogden & Corkin, 1991).

Finally we must not rule out luck. It was extremely fortunate that H.M. turned up in Montreal and underwent investigation by Brenda Milner and the many other excellent researchers at her laboratory. This has ensured, to the current day, that investigations of H.M. have taken full account of recent developments in neuropsychology. One can only heave a huge sigh of relief that H.M. did not end up elsewhere in 1953 because, without him, one can argue that the progress of human memory research might have been slower and the outcome different.

NOTES

1. While it is true that H.M. presents an outstandingly pure amnesia he is not free from other deficits. He has a well-established olfactory deficit (Eichenbaum, Morton, Potter, & Corkin, 1983) and is also known to have difficulty interpreting and reporting internal states (Hebben, Corkin, Eichenbaum, & Shedlack, 1985).
2. To say that H.M.'s data have merely confirmed existing ideas about memory is perhaps misleading. There is at least one finding, that obtained by Sagar, Gabrieli, Sullivan, & Corkin (1990), that causes problems for current theories of memory. Briefly, these authors showed that although H.M. could correctly make temporal order judgements for pairs of stimuli he could not, under comparable exposure conditions, show any evidence of recognising. Similarly, he also made accurate frequency of presentation judgements about items he appeared incapable of recognising!

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