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LA THÈSE A ÉTÉ
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A Psychometric Evaluation of the Wechsler Memory Scale and its Relation to Damage of the Brain.

Arthur G.A. Blouin

Thesis presented to the School of Graduate Studies, University of Ottawa, in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

ACKNOWLEDGEMENTS

Special thanks are extended to Dr. R.L. Trites who has provided considerable guidance, supervision and support throughout my studies at the University of Ottawa (including the preparation of this thesis) and who made available the clinical files upon which this research was based. Gratitude is also expressed to Maggie Entebbe who diligently assisted in the review of the files and coding of the data.

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ABSTRACT

Clinical files of 497 consecutive referrals to the Neuropsychology Laboratory at the Royal Ottawa Hospital who had been administered the Wechsler Memory Scale (WMS) as part of a standard battery of neuropsychological tests were reviewed. Clinical ratings of recent memory, remote memory, overall memory functions, memory for events prior to onset of pathology and memory for events subsequent to onset were carried out. The clinical ratings were based on information included in the file including a summary of presenting symptoms, clinical history, physician referral letters and behavioral description of the patient carried out at the time of the examination by a trained neuropsychological technician. Each of the 126 items comprising the WMS were coded pass or fail. In addition information concerning the lateralized location, extent and severity of cerebral pathology was recorded. The data were combined on computer with the original neuropsychological test results.

An item analysis indicated that items comprising the WMS ranged in difficulty from very easy to very hard. The easy and hard items added little to the discriminative power of the Memory Quotient indicating that the Memory Quotient discriminates primarily among patients of intermediate ability levels. Many items were found to be related to the clinical ratings of memory functioning. These items were recombined into revised memory scales. Other items were found to be related to attention and some to level of impairment.

The revised scales were found to predict clinical memory disorders for both recent and remote events with greater accuracy than the WMS. Also when intelligence and level of impairment were statistically controlled only Orientation and MQ were significantly related to the memory ratings. Orientation was reduced among patients with bilateral cerebral dysfunction with severe problems with day to day memories and among patients with left hemisphere dysfunction with severe problems with memory for remote events. The MQ was also reduced among left hemisphere patients with severe problems for remote events. On the other hand, the revised scales, although significantly related to the covariates intelligence and level of impairment were significantly related to clinical memory ratings, once the covariates were adjusted for. These findings indicated that the WMS as currently used is sensitive primarily to level of impairment and general intellectual abilities except among certain cases with severe memory problems. On the other hand the revised scales were consistently significantly related to the clinical ratings after the variance accounted for by the covariates (intelligence and impairment) were extracted. The relationship between the revised scales and the clinical ratings was not dependent upon lateralization of cerebral pathology. These findings indicate that the WMS as presently used is mainly a measure of intelligence and level of impairment and discriminates primarily among patients of intermediate ability level. Those with severe memory disorders however appear to be low on certain subtests. A revision of the test indicates that memory can be measured by items comprising the test although the control of intelligence and impairment is essential.

The superior discriminative ability of the revised scales was cross-validated in a subsample of the original group seen after a follow-up period. Reliability coefficients and related norms for the WMS and revision were presented with conversion tables from raw scores to standard scores and percentile scores in order to facilitate clinical use.

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INTRODUCTION

The aim of this dissertation was to evaluate the validity of the most widely employed clinical test of memory, the Wechsler Memory Scale (WMS). The WMS was originally published in 1945 (Wechsler, 1945). The construction of the WMS (item selection) was based on antiquated concepts of the psychology of memory as well as outdated notions of the effects of brain lesions on psychological processes. The scoring of the test simply involved summing items into subscales, summing the subscales and after correcting for age, arriving at a single index, the Memory Quotient (MQ).

Attempts to validate the WMS against external criteria have sought to evaluate the effectiveness of identifying organic vs non-organic patients, ignoring any appreciation of regional localization of function within the human brain. Factor analytic studies have attempted to establish the construct validity of the WMS, however the subscales used in factor analysis have not been validated. An analysis of the items comprising the WMS has never been reported. In spite of the apparent inadequacy of the research which has attempted to evaluate the WMS, an examination of the items suggests that there may be useful information included in the test, which probably accounts for its widespread use.

The WMS includes questions concerning the remote past as well as requiring the patient to learn new material. Some sections involve non-verbal material while others employ primarily verbal material. A test of immediate memory (digit span) is also included. The WMS is widely used, is apparently resistant to replacement by more modern memory tests (Cronholm & Molander, 1957; Cronholm & Ottoson, 1963; Cronholm & Schalling, 1963, 1968; Ottoson, 1960) and appears to include items useful in a clinical memory examination. For these reasons, the present research was aimed at identifying items that are related to external criteria. The criteria of primary interest for the purposes of the test were clinical ratings of memory and confirmed lateralized cerebral dysfunction. It was hypothesized that certain items could be selected from the WMS and used to form a set of sub-scales which would be effective for identifying memory disorders in patients referred for neuropsychological assessment.

Literature Review

Memory

Memory has been defined as the "effects of earlier perceptual experience upon present behavior" (Milner, 1968). Young (1966) has stated that memory is a "physical system by which there is made a record or representation of certain past events. It is in the nature of records to be consulted when future action has to be decided on." These definitions provide a broad conceptual framework for our understanding of memory. The definition is refined however by excluding disorders which may affect these processes, but are not considered "memory". Thus, Milner (1968) states that it is important to distinguish between memory loss and an impairment of attention (vigilance), general dementia and perceptual disorders. Further, in considering a definition of memory, a number of temporal factors are relevant.

The terms recent and remote memory refer to the time scale in a person's life. Recent memory refers to events that have occurred recently in the life of the patient, while remote memories refer to events of the distant past, usually pre-operative or pre-trauma events

(Milner, 1968). With an anterograde amnesia a patient is unable to remember events since the time of the lesion or operation and might describe the loss as a loss of recent memory. With a retrograde amnesia, the patient has difficulty remembering events covering a period before the lesion or operation and the loss of memory for remote events can be contrasted with the recent memory loss seen with an anterograde amnesia. The terms recent and remote memory do not refer to underlying mechanisms. The term immediate memory is defined behaviorally as the amount of information that can be reproduced immediately after presentation (Milner, 1968).

The terms long and short term memory however, refer to hypothetical processes mediating retention not categories of behavior (Milner, 1968). Short term memorys is thought to decay rapidly in a matter of seconds when rehearsal is prevented. Memories recalled from the remote past are recalled from the long term store, which is thought to be related to structural change. (Milner, 1968; Waugh and Norman, 1965). The Waugh and Norman (1965) conception of the memory process involves transferring input from the sensory memory (duration of a few hundred milliseconds) to a primary memory system with a storage of several seconds and finally to a more permanent secondary memory system where information can be stored for minutes or years. This process is thought to be an orderly sequence of storage systems but according to Milner (1968) these systems must overlap in time and behavior may be jointly determined by them.

According to the Atkinson and Shiffrin (1971) model, the short term memory system is a working memory which controls rehearsal, coding, decisions and retrieval. The memory system is thought of in terms of information flow into and out of short term storage. The short term memory system is given a position of pivotal importance because "the processes carried out in the short term store are under the immediate control of the subject and govern the flow of information in the memory system; they can be called into play at the subject's discretion." According to Baddely (1976) however, the need for a distinction between short term and long term memory is questioned. Baddely cites the case presented by Warrington and Shallice (1969) of a partially aphasic patient (K.F.) who had a severely impaired short term store but whose long term memory was normal. He questions the need for a short term store (in contrast to Atkinson and Shiffrin) since severe impairment of the short term store does not necessarily disrupt the input of information into long term storage. Warrington and Shallice view the pattern of impairment in the case of K.F. as support for the distinction between a short term and long term store. The role of the short term store in controlling the entire memory system (according to the Atkinson, Shiffrin model) is weakened by the report of such a case. Other patients with impaired short term memory, such as the cases with parietal lobe lesions presented by Cermak et al. (1971) also have impaired long term stores. The impairment of long term store is thought to be a function of the initial short term memory deficit. Howe (1970) states that the most convincing evidence for a distinction between a short term memory store and a long term store comes from the pattern of deficits seen after bilateral hippocampal lesions. In these cases the short term store is intact while the capacity to transfer information from short term to long term storage is lost. Milner (1968) states that the lesion has disrupted the essential transition process from short term to long term memory. This process is known as consolidation.

Memory can also be thought of as a three stage process: registration, retention and recall or recognition. The terms consolidation, storage and retrieval are also used to illustrate these hypothetical stages. It is often difficult, if not impossible to determine at which of these stages a breakdown in memory has occured (Howe, 1970). The fact that Warrington and Weiskrantz (1970) claim that organic amnesia is a defect of retrieval but not of consolidation, while others such as Milner (1968) and Woods and Piercy (1974) dispute this claim, considering the basic effect to be one of consolidation, reflects the difficulty in sorting out these stages.

Brain Structure Involved in Memory

The brain structures most frequently implicated in human memory are the hippocampus, the mammillary bodies, and portions of the thalamus, the dorsal medial nucleus and the anterior nucleus, (Ojeman, 1968). The hippocampus is a phylogenetically old structure consisting of three layered archicortex. It sits in the medial aspect of the temporal lobe and forms the shape of a rams horn. Within the hippocampus is the dentate gyrus and the hippocampal gyrus. Axons from the pyramidal cells of the hippocampal gyrus gather together to form the major efferent group of fibers, the fimbria. The fimbria becomes continuous with the fornix which loops around the thalamus and the post commisural fornix reaches the mammillary bodies. Some of the fibers branch to reach the septal nucleus. There are also reciprocal connections between the septal nucleus and the hippocampus via the longitudinal stria (indusium griseum). (See Figure 1 from Netter, 1972). The post commisural fornix also sends fibers to the anterior nucleus of the thalamus.

The hippocampus receives afferents from the cingulate gyrus, widespread areas of the cortex, the prepyriform cortex, and the entorhinal cortex via the perforant pathway and the alvear pathway (see Figure 2 from Carpenter, 1975). The hippocampus also receives noradrenergic connections from the locus coereleus and seretonergic projections from the raphé nucleii.

The hippocampus can be considered the major anatomical structure in a circuit important for human memory. This circuit involves the projections from the hippocampus via the fornix to the mammillary bodies, from the mammillary bodies via the mamillothalamic tract to the dorsal medial nucleus of the thalamus, from the thalamus to the cingulate gyrus and from the cingulate gyrus back to the hippocampus (Ojeman, 1966).

The Effects of Brain Lesions on Memory in Man

A variety of disorders of cerebral brain function are accompanied by disorders of memory (amnesia). In some cases the memory disorder is accompanied by disorders

Fig. 1 The location of the hippocampus in the brain and the major efferent projections (from Netter, 1972).

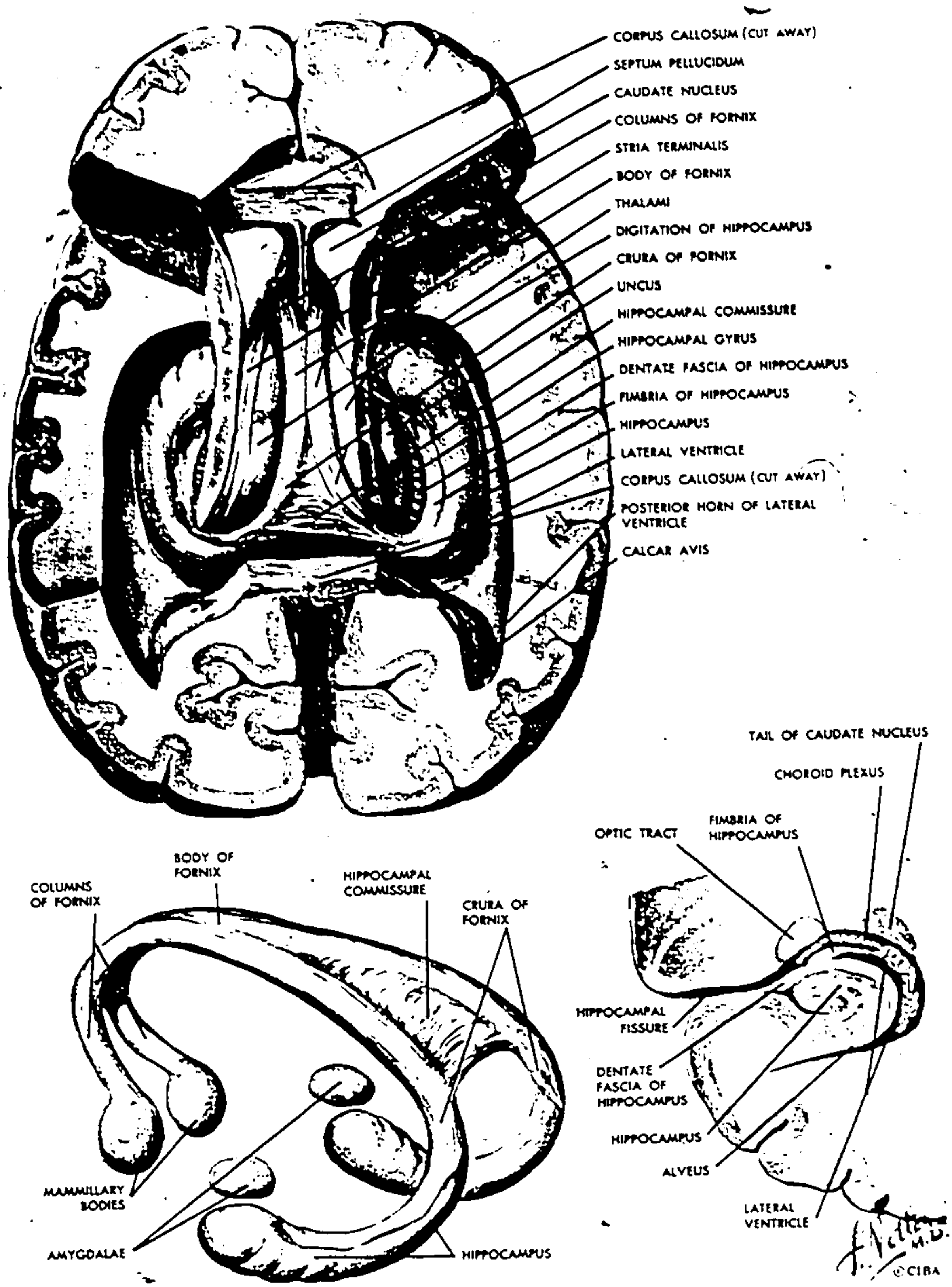
CORPUS CALLOSUM (CUT AWAY)
SEPTUM PELLUCIDUM
CAUDATE NUCLEUS
COLUMNS OF FORNIX
STRIA TERMINALIS
BODY OF FORNIX
THALAMI
DIGITATION OF HIPPOCAMPUS
CRURA OF FORNIX
UNCUS
HIPPOCAMPAL COMMISSURE
HIPPOCAMPAL GYRUS
DENTATE FASCIA OF HIPPOCAMPUS
FIMBRIA OF HIPPOCAMPUS
HIPPOCAMPUS
LATERAL VENTRICLE
CORPUS CALLOSUM (CUT AWAY)
POSTERIOR HORN OF LATERAL VENTRICLE
CALCAR AVIS
TAIL OF CAUDATE NUCLEUS
CHOROID PLEXUS
FIMBRIA OF HIPPOCAMPUS
OPTIC TRACT
BODY OF FORNIX
COLUMNS OF FORNIX
HIPPOCAMPAL COMMISSURE
CRURA OF FORNIX
HIPPOCAMPAL FISSURE
DENTATE FASCIA OF HIPPOCAMPUS
HIPPOCAMPUS
ALVEUS
MAMMILLARY BODIES
AMYGDALAE
HIPPOCAMPUS
LATERAL VENTRICLE
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Figure 1.

Fig. 2 Major afferent projections to the hippocampus (from Carpenter, 1975).

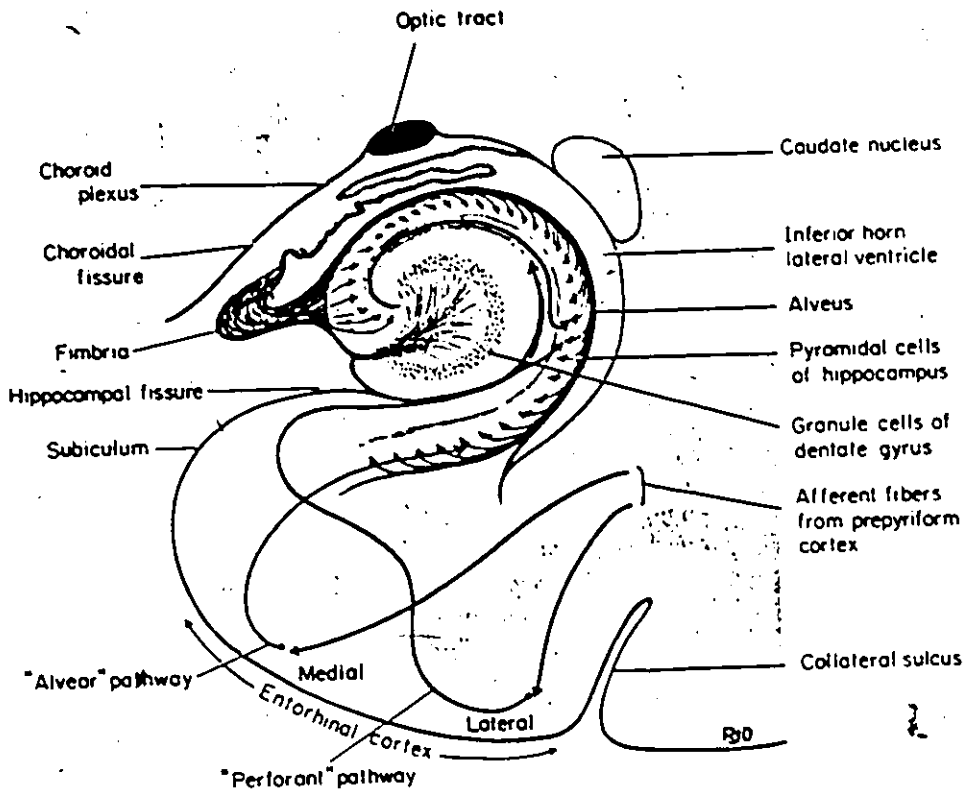

Optic tract
Choroid plexus
Choroidal fissure
Fimbria
Hippocampal fissure
Subiculum
Caudate nucleus
Inferior horn lateral ventricle
Alveus
Pyramidal cells of hippocampus
Granule cells of dentate gyrus
Afferent fibers from prepyriform cortex
Collateral sulcus
"Alvear" pathway
Medial
Entorhinal cortex
Lateral
"Perforant" pathway

Figure 2.

of other psychological processes, including general intellectual decline, impaired perceptual processes or attentional deficits. When establishing the relationship between a particular brain structure and memory functioning, it is essential to sample behavior widely in order to demonstrate that the memory disorder is relatively specific and that the perceptual, attentional or intellectual deficits do not account for the poor performance on memory tests. Patients with bilateral lesions of the hippocampus have been studied intensively and the relationship between the hippocampus and memory functioning is now widely recognized.

Scoville and Milner in 1957 reported the results of bilateral surgical removal of the medial aspect of the temporal lobe in 30 psychotic patients in an effort to improve personality functioning. The surgeon approached the medial aspect by inserting a suction tube into the anterior tip of the temporal lobe. In five cases the anygdala and uncus only were removed. In all the others some portion of the hippocampus was included either extending posteriorly 5 cm (in most of the cases) or 8 cm (in one case). Additionally, a radical bilateral hippocampal removal was carried out in one epileptic patient (H.M.). Psychological test results were reported for 10 of these patients, 9 of whom were psychotic, the other being epileptic. Most of the subsequent psychological testing illustrating the deficit after surgical removal of the hippocampus bilaterally have been carried out on H.M. since his normal personality functioning made him most amenable to study.

This patient fell off of a bicycle at the age of 9 years and was rendered unconscious. At the age of 16 years, he began having seizures which became so severe that the radical bilateral medial temporal lobe resection was carried out when he was 27 years of age. The operation reduced the number of seizures in H.M. but had no effect on the personality functioning of the psychotics.

The most dramatic effect of the operation was on memory functioning. Those with the most extensive removal of the hippocampus bilaterally (H.M. and one psychotic with 8 cm removed posteriorly and one psychotic with 5 cm removed) were left with a severe anterograde amnesia. They could not store new information in long term memory although they could retrieve memories from the remote past. Immediate memory (measured by span tests) was intact. These patients have been described as not being able to remember current events such as a recent death in the family or what they had for lunch a half an hour earlier. The deficit did not appear to reflect a general intellectual decline since performance on intelligence tests was within the normal range. Pre-operatively, H.M. had an I.Q. score of 104 and post-operatively it was 112. One of the psychotic patients with a severe anterograde amnesia (a physician) had a post operative I.Q. score of 122, while another patient had an I.Q. of 78. In contrast the patients scored 67, 70 and 60 respectively on the Wechsler Memory Scale.

Another group of 5 patients had a moderately severe memory disorder after removal of 5 or 6 cm posterior from the tip of the temporal lobe. A third group of 2 patients had no memory impairment after surgery. One had unilateral temporal lobe removal while the other had bilateral removal of the amygdala and uncus, sparing the hippocampus. The authors concluded that removal of the hippocampus results in a loss of the ability to store new information. Bilateral removal was thought to be necessary to produce the amnesia. The severity of the memory impairment was thought to be related to the amount of hippocampus removed. (Scoville & Milner, 1957).

Since this report, surgeons have avoided bilateral medial temporal lobe removal and the number of cases for study has been limited. Penfield and Milner (1958) reported that in a series of 90 patients who had undergone unilateral temporal lobe removal, 2 had shown the severe anterograde amnesia seen after bilateral removal. It was presumed that the unoperated side had atrophied prior to the operation and that these cases represented examples of bilateral hippocampal dysfunction. In 1974, Penfield and Mathieson published autopsy findings confirming this hypothesis.

A number of papers have reported intensive investigation of H.M., the two patients of Penfield and at times other similar patients, and have defined the pattern of symptoms which result, illustrating both the nature of the deficit and the psychological functions retained.

Milner, Corkin and Teuber (1968) reported that H.M. and two other hippocampal patients were able to perform the Wisconsin Card Sorting Task normally but failed on a delayed face recognition task. Frontal patients made a great many perseverative errors on the Wisconsin Card Sorting Task but were successful on the delayed face recognition task. A double dissociation of the symptoms resulting from hippocampal and frontal lesions was thus obtained. It was further demonstrated that failure by the hippocampectomized patients on the delayed face recognition task was not a result of a perceptual disorder since hippocampectomized patients are able to perform the Mooney face perception task at least as well as normals (Milner, Corkin & Teuber, 1968).

Drachman and Arbit (1966) have illustrated the nature of the memory disorder by administering span tests of verbal and nonverbal material. Patients with bilateral lesions of the hippocampus were found to have normal digit span but were unable to benefit from repeated trials in an attempt to memorize lists of digits that exceeded their immediate span (supra-span lists). A similar finding was reported for a nonverbal task. Additionally Sidman, Stoddard and Mohr (1968) found that while immediate memory for a circle elipse matching to sample task was normal, H.M. was impaired when a delay was introduced. His immediate and apparently short term memory for consonant trigrams was also found to be normal. Wickelgren (1968) also found normal short term recognition memory for single digit numbers, three digit numbers and pitch of pure tones in H.M. Further, H.M. was lacking in ability to form long term memory but showed a normal rate of decay in short term memory. These findings indicate that immediate memory is intact. The findings also suggest that attentional factors or perceptual deficits cannot account for failure of recall after a delay. It would appear that the ability to consolidate information into long term memory was impaired (Milner, 1968; Wickelgren, 1968). Since the impairment has been demonstrated for both verbal and nonverbal material, it is considered a global amnesia which can be demonstrated by either free recall or recognition tasks.

It was also demonstrated that the amnesia is not restricted to material presented in a particular sensory modality. H.M. and other hippocampectomized patients showed no improvement over repeated trials on either a tactile maze or on a visual maze (Corkin, 1965; Milner, Corkin & Teuber, 1968). When the visual maze was shortened there continued to be little evidence of learning after 125 trials, (Milner, Corkin & Teuber, 1968). H.M. was, however, able to learn a very short maze in which the number of choice points came within the span of his immediate memory. Further he showed savings on subsequent recall tests 1, 5, 8 and 14 days later. These findings suggested that there may be some sparing of memory for motor skills (Milner, Corkin & Teuber, 1968).

Corkin, (1968) postulated that there may be separate memory systems for motor skills and other input. H.M. was able to improve his performance on 3 motor tests, Rotary Pursuit, Bimanual Tracking and Tapping. When retested several days after the end of training on Rotary Pursuit, he showed complete retention. Corkin

(1968) suggests that the residual capacity for some motor memory may indicate that there is more than one set of neural structures concerned with memory and that those which mediate motor learning are not dependent on the medial portion of the temporal lobe. It was pointed out elsewhere however, (Milner, Corkin & Teuber, 1968) that a more complete hippocampectomy may have abolished the simple motor learning demonstrated.

While the severity of the amnesia is stressed, some residual memory functions were evident. H.M. showed some isolated ability to remember certain events (President Kennedy's assassination). This finding suggests that the hippocampectomy is not complete with H.M. and tends to favor the argument that a more complete hippocampectomy would abolish the motor learning demonstrated by Corkin (1968).

Warrington and Weiskrantz (1970) suggested that the memory deficit in the amnesic syndrome is best characterized as a failure of retrieval rather than a failure to consolidate. They found that amnesics, while impaired on free recall and yes-no recognition tasks of verbal material, demonstrated improved performance with cued recall (Warrington & Weiskrantz, 1970). This finding suggested that the information was stored but the retrieval process was disrupted. Woods and Piercy (1974) however found that normals if tested after a one week delay show the same improvement with cued recall that the amnesics show after a one minute delay. They argue that the results of Warrington and Weiskrantz (1970) cannot be used to support the failure of retrieval hypothesis. It may be that the strength of the memory trace is reduced in the amnesics, a likely alternative explanation.

The most convincing findings that indicate that the consolidation from short term memory to long term memory is impaired in amnesics are the results of a study by Marslen-Wilson and Teuber (1975). They found that when presented with photographs of faces of people famous in the news during the decades prior to the onset of amnesia, H.M. and other amnesics were able to correctly recognize at a high rate. Recognition of photographs of faces of people who became famous subsequent to the onset of amnesia was however severely impaired. These findings are consistent with the clinical descriptions of amnesics. They can retrieve information from the remote past (indicating that retrieval is intact) but are unable to store new information.

Bilateral hippocampal lesions then result in a permanent anterograde amnesia. It is a global amnesia which is evident with both verbal and nonverbal material and has been demonstrated in the visual, tactile and auditory modalities. Immediate memory is intact and perceptual abilities and general intellectual functions remain relatively well preserved. The patients are able to retrieve information from the remote past, indicating that the hippocampus is not the storage site for memory but seems to play a critical role in the consolidation of information from short term memory to long term memory. The pattern has been seen in patients in which fairly well defined surgical lesions have been carried out in epileptic and psychotic patients (Scoville and Milner, 1957). The pattern has also been seen in patients with epilepsy in which one side was removed while the contralateral side had atrophied prior to operation (confirmed by autopsy results, Penfield and Mathieson, 1974). While epileptic patients have been those most extensively studied with H.M. the most widely tested, the pattern of symptoms has also been seen in patients with bilateral infarction of the posterior cerebral arteries. Ojeman (1966) discusses a case in which a permanent anterograde amnesia followed bilateral occlusion of the posterior cerebral arteries. Autopsy findings indicated involvement of the hippocampus on both sides with amygdala, uncus and lateral temporal lobe remaining intact. There was also cortical damage to the occipital lobes.

The syndrome termed transient global amnesia is thought to result from transient vascular insufficiency of the temporal lobes due to ischemia of the posterior cerebral arteries. An episode of anterograde and retrograde amnesia usually lasts from between a few hours to a few days in an otherwise alert, insightful patient. Recovery is usually complete and there is usually no other impairment of neuropsychological activity (Hecaen and Albert, 1978). The memory impairment then appears to be dependent upon bilateral destruction of the hippocampus but is not restricted to a particular manner of destruction.

While bilateral destruction leads to a global amnesia, unilateral lesions lead to a specific memory disorder. After dominant temporal lobe lesions there is impairment of memory for verbal material while after non-dominant temporal lobe lesions memory for verbal material remains intact. Tasks designed to test memory for verbal material were presented by Milner (1967) in the visual and auditory modality. Short passages were read to the patients while different passages were presented visually and read by the patient at a controlled rate. Similarly paired associates were either read to the patient or read by the patient at a controlled rate. Recall scores were combined to yield one verbal memory score in the visual mode and one in the auditory mode. There was a significant post operative drop for the dominant temporal group in the visual and auditory task but no comparable impairment in the non-dominant temporal group. The impairment persisted for several years (Milner, 1967).

With non-dominant temporal lobe lesions however, it was found that recognition of faces after a delay was selectively impaired. After dominant temporal lobe lesions only a mild impairment resulted (Milner, 1968). Kimura further analyzed the non-dominant temporal lobe memory deficit using the recurring figure task in which figures were presented in succession and the patient was required to identify those that had been previously presented. When nonsense figures (not subject to verbal coding) were presented in the visual modality, patients with non-dominant temporal lobe lesions were impaired while patients with lesions of the dominant temporal lobe performed the task well. On the other hand when verbal material was presented, the dominant temporal group was impaired while the non-dominant lesioned group was not.

These findings demonstrate a double dissociation of symptoms following non-dominant and dominant temporal lesions.

Corsi (1972) established that the specific memory disorder seen with unilateral temporal lobe lesions depended on the amount of hippocampus extracted. He had four groups with lesions in each hemisphere: 1) with hippocampus intact; 2) with excision of the pes hippocampi; 3) with excision of the pes hippocampi and about 1 cm of the body of the hippocampus and 4) with radical ablation of the entire hippocampal region. They were presented two verbal tasks and two nonverbal tasks. On the verbal tasks the dominant temporal groups were selectively impaired and the greater the hippocampal involvement, the greater the verbal memory deficit. Similar results were obtained with the non-dominant temporal group. Performance on the nonverbal tests was impaired while performance on verbal tests was normal. The degree of impairment was a function of the extent of hippocampal involvement.

Thus, the hippocampus is a structure that is critically involved in human memory functioning. Bilateral lesions lead to a global amnesia in which the memory disorder is independent of the sensory modality or the nature of the material to be recalled (verbal or nonverbal).

Lateralized hippocampal lesions however give rise to material specific memory disorders in which lesions of the hippocampus of the non-dominant hemisphere lead to memory deficit for nonverbal material (faces, nonsense figures, possibly also bird songs) while lesions of the dominant hippocampus leads to a memory impairment for verbal material.

Barbizet (1975) pointed out that a global amnesia is also seen when other structures close to the neuraxis are damaged. Thus he distinguishes an "axial amnesia" from a "cortical amnesia". With an axial amnesia the inability to recall is independent of sensory modality or verbal or nonverbal nature of the material (Barbizet, 1975). With cortical amnesias the capacity for immediate memory can be reduced. The cortical amnesia is thought to be specific and probably related to either gnoxic, praxic or language deficits if there is not a specific sensory or motor deficit (Barbizet, 1975).

Further evidence for an involvement of axial structures in memory functions comes from autopsy study of pathological changes in the brains of patients who have had Korsakoff's psychosis. Korsakoff's psychosis is a disorder characterized by a syndrome of amnesia, disorientation and confabulation. The amnesia is similar to that seen after bilateral hippocampal removal since the ability to record ongoing events is severely impaired. According to Ojeman (1966) "amnesia for some events preceding the illness is noted, and at times even remote memory is defective". Korsakoff's disease is usually associated with chronic alcoholism but may be seen in a variety of disorders. The neuropathological changes may result from chronic thiamine chloride deficiency (Ojeman, 1966).

Collins, Victor and Adams (1961) have reported neuropathological changes associated with Korsakoff's disease. It was found that in addition to degeneration of the mamillary bodies, lesions of the medial thalamus (dorsal medial and medial pulvinar nuclei) were consistently encountered. Also lesions of the medial hypothalamus, periacquaductal grey of the midbrain and floor of the fourth ventricle were at times encountered. The hippocampi were generally intact. It is generally considered that the axial amnesia results from the degeneration of mamillary bodies and/or dorsal medial nuclei of the thalamus. Ojeman (1966) reports that bilateral damage to the mamillary bodies as a result of hemorrhage can result in a permanent anterograde amnesia. Memory disorders have also been found after stereotoxic lesions of the dorsal medial nucleus of the thalamus (Ojeman, 1966).

Other structures closely related to the hippocampus anatomically are the fornix, amygdala, uncus and cingulate gyrus. Ojeman (1966) reported that while some cases of bilateral lesions of the fornix have resulted in memory deficits, others have survived with no impairment. When a memory disorder is found after lesions of the fornix, it appears to be less severe than with other axial amnesias since patients are able to compensate for the loss (Ojeman, 1966). Among the cases reported by Scoville and Milner (1957) some had amygdala uncus and hippocampus removed while others had only amygdala and uncus removed. Only those with removal of the hippocampus exhibited the anterograde amnesia. Lesions of amygdala and uncus had no apparent effect on memory functioning.

In summary, memory and various memory processes have been defined. Memory ("the effects of earlier perceptual experiences upon present behavior", Milner, 1968) involves both short term and long term processes. The transfer of information from short term to long term storage (consolidation) is thought to be dependent upon axial structures of the brain (hippocampus, thalamic nuclei and mamillary bodies). Bilateral damage to axial brain structures (particularly the hippocampi) has been shown to lead to an anterograde amnesia in which there is an impairment of consolidation. Other psychological functions such as attention and perception have been shown to be relatively spared. Additionally performance on intelligence tests remains relatively intact.

Specific memory disorders can occur as a result of unilateral damage to the hippocampus in either the dominant or non-dominant temporal lobe. With hippocampal lesions of dominant temporal lobe the memory impairment is specific to verbal material while memory for nonverbal material is impaired with lesions of the non-dominant temporal lobe (Milner, 1968).

With a retrograde amnesia, there is a failure to recall events that occured prior to the onset of the disorder (Barbizet, 1975). Among patients with closed head injury, two classes of retrograde amnesia have been documented. A temporary retrograde amnesia can occur which can cover weeks, months or years prior to trauma. This amnesic period usually shrinks during the recovery period. Also a permanent amnesia covering a few seconds prior to the trauma is often seen (Schacter, D.L. and Grovitz, H.F., 1977).

When conducting clinical assessment of memory functions that occur in association with cerebral dysfunction, a number of important points must be distinguished. It is important to distinguish a memory disorder from a disorder of attention, perception or general intellectual decline (Milner, 1968). Thus overall level of impairment, attention and perception must be controlled in the assessment of a test of memory. Additionally, a memory test must include both verbal and nonverbal material in order to identify specific memory disorders that result as a consequence of lateralized damage of the brain. To be used clinically, a memory test must also test the ability to store new information (recent memory) as well as provide for a test of memory for events of the remote past. It was with respect to these well documented complex relationships between cerebral function and memory processes that the external criteria used to evaluate the items included in the WMS were selected. Additionally, these points must be considered when evaluating the research that has sought to evaluate the WMS as a useful clinical test of memory in patients with dysfunction of the brain.

The Wechsler Memory Scale (WMS)

David Wechsler published the Wechsler Memory Scale in 1945. It was designed to be a "standardized memory scale for clinical use" to detect memory defects associated with organic brain conditions (Wechsler, 1945). At the time when Wechsler developed the test, the only memory test available for clinical use was described in Wells' book, Mental Tests in Clinical Practice (1927). Wechsler thought that the test developed by Wells and Martin (1923) was overly long, involved too many materials and wasn't sufficiently standardized. Wechsler experimented with a number of items (some coming from Wells and Martin's test) and developed a test which could be administered in 15 minutes and incorporated the Memory Quotient that had been introduced in the Wells and Martin Test (1923).

The Wechsler Memory Scale (1945) consists of seven subtests. The first, consists of six simple questions of personal and current information (INFORM) such as "How old are you?" and "Who is the Prime Minister of Canada?". The second test consists of five questions testing immediate orientation (ORIENT) such as "What year is this?". For each of the first two subtests, one point is given for each correct answer and zero is given if incorrect. The third subtest is called mental control (CONTROL). The patient is required to count backwards from 20 to 1, to repeat the alphabet and to count by 3's beginning at one. Credit is given for speed and accuracy. The fourth test, logical memory (PASSAGES) consists of two passages which are read to the subject and the subject is then required to immediately recall as much of the story as he can. One point is given for each correct item recalled and half points are given for partially correct items. Test five is the memory span for digits (DIGITS) forwards and backwards. The maximum number of digits are 8 forward and 7 backward. The sixth test is primarily figural rather than verbal in nature and is called visual reproduction (VISUAL R). The subject must draw from memory four geometric figures that have been exposed for 10 seconds. Scoring is based on accuracy of reproduction. The seventh test, associate learning (ASSOC L) consists of 10 paired word associates (6 relatively easy like: "up-down" and 4 relatively hard like: "cabbage-pen"). The subject is given 3 presentations and 3 recall trials in which the order of the pairs is changed. Scoring is based on the number of correct items for all three recall tests. The scores for each of the subscales are summed to yield the total raw score.

Wechsler standardized the test with subjects aged 25 to 50, including both men and women, (Wechsler, 1945). For 100 of his subjects the test results of the Wechsler-Bellevue Adult Intelligence Scale were also available. Wechsler used a trial and error method for arriving at a constant which when added to the total raw score provided a Memory Quotient comparable to the Intelligence Quotient. A constant was provided for age groups of 5 or 10 year intervals between 25 and 50 so that the Memory Quotient was, like the Intelligence Quotient, age adjusted.

Wechsler (1945) did not discuss his theoretical position regarding memory processes, or cerebral dysfunction. However, at the time certain assumptions were prevalent that are currently recognized as false. At the time it was widely assumed that memory was an "ability of the intellect". One of the basic assumptions of this model is that abilities are unidimensional or unitary traits (Kelley, 1964). Wechsler included questions referring to remote events as well as tests for retention of recent material. He also included figural material as well as verbal material. However, selective testing of immediate (or short term memory) versus memory for the remote past or verbal versus nonverbal memory was lost in the calculation of a single score, the Memory Quotient (MQ). Thus, reliance on a single score, the MQ as a measure of memory does not do justice to our current knowledge of the complexity of memory processes and their relation to cerebral function as discussed above.

In spite of the complex relationship between general psychological processes and cerebral function (as discussed in detail in Reitan and Davison, 1974) many researchers have attempted to evaluate the validity of the Wechsler Memory Scale as a test for "organicity". The assumption that organicity is a unitary concept that can be measured by a single best test is common among clinical psychologists. It is however a faulty assumption (Davison, 1974).

Validity Studies

The research studies that have attempted to establish the validity of the Wechsler Memory Scale fall into a number of classes. Those that have related to WMS to external criteria have focussed on demonstrating the ability of the WMS to separate those with confirmed cerebral dysfunction from those without evidence of cerebral dysfunction. Others have shown the effects of certain diseases or medical interventions on the test. The internal consistency of the test has been examined by factor analytic studies and the degree to which the test overlaps with intelligence measures has been studied by correlation techniques and factor analysis.

Wechsler's intent was to detect memory deficits in cases with organic impairment. Cohen (1950) compared neurotic, psychotic and organic patients on the Wechsler Memory Scale and found no significant differences. Age and intelligence were controlled. Howard (1950) compared paretic and psychotic patients and found that they could be differentiated while psychotics, encephalitics and epileptics could not. He concluded that the Wechsler Memory Scale was useful for detecting brain damage of a gross nature however his groups also differed in terms of level of general intellectual functioning. In a later study the scale failed to differentiate psychotic organic and psychotic non organic groups. This led to the conclusion that the scale should be used with caution, (Howard, 1954). He subsequently found that another variable to be controlled when investigating the test was length of institutionalization since protracted institutionalization depressed performance both with organics and controls.

Walton (1958) also found that long periods of institutionalization depressed scores on the test but that repeated administration on four occasions improved the accuracy of prediction of organic patients in comparison to functional patients. Initial administration of the test led to a high number of misclassifications. Parker (1957) in comparing a number of tests designed to detect organicity included the Wechsler Memory Scale. The only test that discriminated the 30 male organic patients from the 30 non organic male patients was the block design subtest of the Wechsler-Bellevue.

Russell (1975) developed a method for readministering sections of the WMS in order to measure "long term memory". After a half an hour delay, the subjects were required to recall the Logical Memory and Visual Reproduction subtests. It was found that the semantic short term and half an hour subtests were selectively reduced among those with cerebral dysfunction of the left hemisphere. Similarly, the figural short term and long term measures were lower among those with right hemisphere damage. The new measures correlated with the Impairment Index of the Halstead Reitan Battery. The additional requirement of recall after a half hour delay may be a useful modification of the WMS.

Bachrach and Mintz (1974) employed the subtests in a discriminant analysis and found that four subtests (Information, Story Recall, Designs and Associates) were able to significantly differentiate the groups (those with cerebral impairment from those without). They also found however that when Designs alone was used the discriminate power was just as effective. They found that a cut off score of 10 on Designs was effective at classifying 89% of the cases correctly. When the subtests were factor analyzed, Designs was as effective a discriminator as the combination of tests arrived at after factor analysis.

Kljajic (1975) compared the effectiveness of two experimental forms of subtest analysis as screening devices for subjects with organic brain pathology. Evidence of cerebral pathology came from electroencephalogram and pneumoencephalogram results. Both methods of combining subtest scores were about 70% accurate at discriminating the "organics" from those with no evidence of cerebral pathology. However, Prigatano (1977) in attempting to cross-validate the results of Kljajic (1975) and Bachrach and Mintz (1974) failed to support their findings. When using the cut off score of 10 on Designs recommended by Bachrach and Mintz (1974), Prigatano (1977) found that a high percentage were correctly classified into the groups with or without cerebral pathology. However, when matched for age, intelligence, Memory Quotient and sex, a high number of misclassifications were made. Similarly the findings of Kljajic (1975) were not supported when age, intelligence and sex were controlled. Prigatano also employed the three factors arrived at by Kear Colwell (1973 in a factor analytic study of the test) and found that only one, representing orientation, separated the matched groups.

The research that has attempted to validate the Wechsler Memory Scale (summarized in Table 1) as a sensitive test of cerebral pathology, has met with limited success. Those findings in which differences between various groups have been reported, have apparently capitalized on differences in intelligence among the groups. The major criticism of these studies however is in the choice of the external criteria used to assess the predictive accuracy of the test. Since clinical neuropsychological test batteries are now accepted as accurate means of inferring cerebral dysfunction from behavior (Reitan, 1974) the aim of identifying a single test for this purpose is outdated.

Factor analytic studies have attempted to determine the internal consistency of the test. Davis and Swenson (1970) factor analyzed the subtest scores of 622 patients

TABLE 1

Validity studies of the WMS

AUTHOR	METHOD	CONTROLLED	DIFFERENCES
Cohen (1950)	Neurotics vs Psychotics vs Organics	Age, Intell.	None
Howard (1954)	Psychotic organic vs Psychotic	Length of institutionalization	None
Parker (1957)	Organic vs Non Organic	Sex hospitalization	None
Prigatano (1977)	Organic vs Non Organic	Age, Intelligence, Sex	None
	Organic vs Non Organic (using factor scores, Kear-Colwell, 1973)	"	Organic vs Non Organic
Howard (1950)	Paretics vs psychotics vs encephalitics vs epileptics	None	Paretics vs Psychotics
Walton (1958)	Organic vs functional (repeated administrations)	# administrations institutionalization	Organic vs Functional
Bachrach and Hintz (1974)	Organic vs Non Organic	None	Organic vs Non Organic
Kjlajic (1975)	Organic vs Non Organic	None	Organic vs Non Organic
Prigatano (1977)	Organic vs Non Organic	None	Organic vs Non Organic
Russell (1975)	Controls vs Brain Damaged vs Right vs Left Hemisphere Damage	Age, Education	Controls vs right vs left vs brain damage

with a variety of neurological and psychiatric problems. Two factors emerged. The first was interpreted as a general "memory" factor representing both long and short term storage and retrieval while the second appeared related to powers of concentration and attention. Dujovne and Levy (1971) eliminated the orientation and information subscales, based on an unpublished analysis of the discriminative power of these scales. They then factor analyzed the remaining scales in both a normal and a patient population (which consisted of both organic and non organic patients). For the normal group, three factors labelled general retentiveness, simple learning and associative flexibility were determined among the patients. The three factors were labelled mental control, associational flexibility and cognitive dysfunction. Bachrach and Mintz (1974) factor analyzed the subtests in a group of psychiatric patients, some of whom had cerebral impairment. Three factors were arrived at. The first loaded on Designs, Story Recall and Associates. The second included information and orientation while the third was composed of Mental Control and Digit Span.

Kear-Colwell (1973) factor analyzed the subtests separately in a group of patients with confirmed cerebral pathology and in a not confirmed group. The analysis with the two groups yielded almost identical factors. Three factors were obtained. The first loaded on Logical Memory, Visual Reproduction and Associate Learning and was thought to be related to learning and immediate recall of fairly complex novel information in visual and auditory modalities. The second loaded on Mental Control, Digit Span and to a lesser extent on Information. It was thought to be related to verbal non-semantic information processing. The third was concerned with orientation in place and time and the ability to recall simple long established verbal information. It loaded on Orientation and Information. When these factor scores were included in a factor analysis with Wechsler intelligence scores, age and sex, three factors again emerged, Intellectual ability, verbal-performance discrepancy and age. Kear-Colwell (1977) subsequently replicated the factor analysis of the Wechsler Memory Scale subtests and found nearly identical factors in a separate population.

The results of the factor analytic studies are fairly consistent and indicate that the test is not unidimensional. In fact, 3 factors emerge fairly consistently (Bachrach & Mintz, 1974; Kear-Colwell, 1973, 1977). The three factors appear to be involved with retention of new material (Logical Memory, Visual Reproduction and Associates), attention and concentration (Mental Control, Digit Span), and orientation and recall of remote events (Information and Orientation). The subscales thus appear to measure a number of different aspects of psychological functions. The fact that Visual Reproduction uses figural material, suggests that this subscale may include items that would be useful for identifying specific memory disorders for non-verbal material. Portions of this test may be verbally coded however since Kear-Colwell (1973) found a high correlation between Visual Reproduction and Verbal I.Q. The Memory Quotient does not appear to be measuring a single ability "memory". Some items included in the test may be useful for measuring different aspects of memory.

Another common criticism of the test (Erickson and Scott, 1977) is that since the Memory Quotient is highly correlated with scores on intelligence tests ($r = .83$, Fields, 1971, $r = .75$, Hall and Toal, 1957) it may be simply a redundant measure of intelligence. Ivinskis, Allen and Shaw (1971) included the subtests of the Wechsler Memory Scale with the subtests of the WAIS in a factor analysis. They found that of the six factors that emerged, only one could be considered a memory factor. Only Digit Span and Mental Control loaded on this factor. Thus, the authors question whether the test can be considered a test of memory.

Eysenck and Halstead (1945) analyzed 15 memory tests similar to the ones included by Wechsler (1945). They also included measures of intelligence as measured by the Ravens Progressive Matrices Test. They found that one factor could account for 74% of the variance and this factor could be interpreted as representing intelligence.

Erickson and Scott (1977) in an excellent review of clinical memory testing acknowledge the difficulty in interpreting such findings. They state clearly:

> "The problem is not a simple one. Although one would hope that a test of memory and a test of intelligence would not be so highly correlated as to be redundant, one cannot assume that the two would not be significantly correlated. Guilford (1967) viewed memory as a hierarchical structure. Memory is one of the major hierarchical factors and one of the major operations... One can say one is dealing with general intelligence rather than memory or one can conclude that memory functioning is important in successfully performing on an intelligence test... Given this impasse, the

> question becomes somewhat different. It is no longer whether the WMS is tapping an undifferentiated construct called memory but whether it is addressing the questions we have about memory in useful and differentiated ways" (Erickson and Scott, 1977).

Thus, a high correlation with intelligence test scores does not necessarily invalidate the test as a specific test of memory. If the test does measure memory in a way that is different from intelligence, then one would expect that the Wechsler Memory Scale would be low among cases in which the apparent memory deficit is disproportionate to the general intellectual function. Milner and Scoville (1957) reported that Wechsler-Bellevue Intelligence Score results of three patients who had severe memory disorders as a consequence of bilateral hippocampal removal. They scored 112, 122 and 76 on the I.Q. test and 67, 70 and 60 respectively on the Wechsler Memory Scale. Findings such as these, although quite rare suggest that there are items included in the test which measure memory functions in a way that is different from what is being measured in a test of general intelligence. These findings tend to validate (on a small scale) the test as a test of memory.

Reliability of the Wechsler Memory Scale

There have been few reliability studies of the Wechsler Memory Scale. An alternative form is available (Stone, Girdner & Albrecht, 1946) and has been used to attempt to establish reliability. Stone et al. (1946) administered the two forms within a two week interval to three groups of intellectually superior college-age subjects. Although no statistical differences between the two forms were found, a coefficient of equivalence was not calculated. Bloom (1959) administered the two forms to male and female psychotic patients and examined individual subtests. Four subtests were administered and the correlations ranged from between .58 to .77. Ivinskis, Allen and Shaw (1971) reported a split-half reliability coefficient of +.75 (uncorrected for length). Thus the research on equivalent forms reliability and split-half reliability have been reported. Reliability data for this widely used test is lacking.

The Use of Wechsler Memory Scale in Various Pathological Conditions

A number of studies have reported the Wechsler Memory results in various patient populations. The Memory Quotient has been found to be reduced in various conditions generally acknowledged to be accompanied by memory disorders.

Korsakoff patients have reduced Memory Quotients in relation to their Intelligence Quotients (Victor, Talland and Adams, 1959). Electroconvulsive shock had a greater effect on the Memory Quotient if administered to the dominant hemisphere than if administered to the non-dominant hemisphere (Zamora & Kaebling, 1965). As mentioned previously, patients with neurosurgical lesions of the temporal lobes (involving the hippocampus) have been found to have reduced Memory Quotients relative to their Intelligence Quotients (Scoville & Milner, 1957; Milner & Penfield, 1955). Advancing age reduced performance on the test in a group of college graduates (Strother, Schaie & Horst, 1957). The test has also been employed in a variety of other studies which have aimed to measure the effects of certain diseases or medical interventions. These types of studies add little to our understanding of the test (Erickson & Scott, 1977), however, since the effects of overall level of impairment and intelligence are generally not controlled in these studies.

Rationale for this Research

The nature of memory disorders that accompany cerebral insult have been defined. After removal of the hippocampus bilaterally there is a permanent anterograde amnesia, for both verbal and nonverbal material. After loss of the hippocampus in the dominant temporal lobe there is a specific memory disorder for verbal material while after hippocampal loss in the non-dominant temporal lobe the memory disorder is specific to nonverbal material. Subcortical axial amnesias such as those commonly seen with Korsakoff's psychosis lead to a global memory disorder. Cortical amnesias are generally considered specific types of amnesias (Barbizet, 1975) and are thought to be related to apraxic agnosic or aphasic disturbances. After trauma there can be a retrograde amnesia as well as an anterograde amnesia. In many disorders, encephalopathies, dementia, etc. there is diffuse neuronal loss and the memory disorder is accompanied by impairment of a variety of psychological functions. In these disorders the memory impairment is considered just one of the constellation of psychological functions impaired.

The WMS (Wechsler, 1945) was constructed with the purpose of evaluating memory ability in patients with impaired cerebral functions. Research efforts attempting to validate the test have been lacking in a number of ways. Validity studies have assessed the test primarily as a test of organicity. The ability of the test to discriminate various brain damaged patients appears to be due to differences in intelligence or general level of impairment among the groups. The WMS has not been validated against external measures of memory ability.

The aim of the present research was to evaluate the predictive validity (or concurrent validity) of the Wechsler Memory Scale. An additional important consideration was to institute revisions which would provide an effective test of memory clinically useful among patients referred to neuropsychology. When conducting research aimed at establishing concurrent validity it is essential to employ adequate validating criteria. The present research included clinical ratings of different types of amnesia as the external criteria.

The literature that has defined the anterograde amnesia associated with specific cerebral damage has relied on experimental tests. Clinical descriptions of the syndrome have also been documented clearly and comprehensively (Milner, 1966; Milner, Corkin, and Teuber, 1968). While extensive experimental testing is required to specify the nature and limits of the cognitive deficit, a salient picture of the syndrome is provided by the clinical description (Milner, 1968). Patients with severe anterograde amnesia may appear relatively normal in conversation if not called upon to store new information. If questions requiring memory for recent events are presented however, the amnesia becomes readily apparent. These patients may not recall what they had for breakfast; that a close friend had recently died, or if an examiner walks out of the room and returns after a short period of time, the patient may not remember the examiner or the previous conversation. The clinical descriptions and the impressions obtained have been confirmed by detailed experimental tests.

Retrograde amnesia is usually described in terms of the clinical symptoms. The reason for this is that the memories from the remote past that are lost are usually specific to the patient. Some attempts to devise tests of remote memory by focusing on public events or television content of the past have been used (Marslin, Wilson, and Teuber, 1972). These, however, have not attained widespread use and have not been used to define retrograde amnesia. The clinical syndromes defining both anterograde and retrograde amnesia have been clearly described and validated by experimental tests. Barbizet (1970) has outlined the importance of clinical descriptions of memory functions. The present research employed clinical descriptions of the psychological symptoms of patients referred for neuropsychological assessment in order to rate the severity of different types of memory disorder.

Among patients where there was no clear, rapid onset of cerebral pathology (Alzheimer's patients, dementing patients, alcoholics, etc.) memory for recent events (anterograde amnesia) was rated separately from memory for remote events (retrograde amnesia). Similar ratings were conducted among patients where there was a clear onset of cerebral pathology (head injuries, cerebral vascular accident, neurosurgery, etc.). In this case, the ratings of recent memory were clearly separated in time from the ratings of remote memory. Recent memory referred to events subsequent to onset of pathology, while remote memory referred to events prior to onset. An overall rating was conducted, disregarding the retrograde or anterograde components.

It was also considered important to include as external criteria, measures of memory function that are not entirely of a verbal nature, since hippocampal lesions of the right hemisphere may lead to memory deficits for non-verbal material. Thus, each item was related to the memory component of the Tactual Performance Test from the Neuropsychological Test Battery. On the T.P.T., each patient is required to place ten different shaped blocks into the appropriately shaped spaces on a form board. Three trials are given: one with the left hand; one with the right hand, and one with both hands. After completing the task, there was a recall test where the patient was required to recall as many of the forms as possible in any order. The patient was required to draw each form recalled on a piece of paper, so that verbal abilities were not required to perform this task.

Another non-verbal memory test used as an external criterion was subtest 7 of the Halstead Category Test. The first six subtests of the Category Test represent six separate principles. In each subtest, positive or negative feedback is employed to arrive at the correct principle. Subtest 7 is essentially a review in which trials are presented randomly from each of the previous subtests and the patient must identify the trial and remember the correct principle in order to respond correctly. Thus, two tests considered to measure memory functions of a non-verbal nature were also employed as external criteria.

This research, then, consisted of an analysis of each item of the W.M.S. The criteria for selecting a good item was that it discriminated patients according to the severity of the memory disorder. Consistent with the multi-trait approach described by Cronbach (1970) and Allen and Yen (1979) each item was also related to measures of ability not defined as memory but considered important to control when conducting a memory examination. Thus, each item was related to measures of attention (Knox Cube Test), general neuro-psychological impairment (Impairment Index), and psycho-metric intelligence (Wechsler Adult Intelligence Scale). Information concerning lateralized cerebral dysfunction was included in order to determine if performance on any particular scale reflected a memory disorder associated with lateralized cerebral pathology.

METHOD

Subjects

Four hundred and ninety-seven consecutive patients, 15 years of age and over, that had been referred to the neuropsychology laboratory at the Royal Ottawa Hospital and had been administered the WMS between the years 1969 and 1977 were employed as subjects. Ninety-three subjects were employed in a cross validation study. Of these, 77 had returned for at least one follow-up assessment, 12 had been assessed three times and 4 had been assessed 4 times. All had received the Wechsler Memory Scale. The referrals to the neuropsychology laboratory were from a number of sources including psychiatry, neurology, neurosurgery, family practice, rehabilitation medicine and psychology. Thirty-two subjects were seen both at first testing and on a second follow-up occasion. These subjects were used in the study of test-retest reliability.

Procedures

At the time of initial assessment, each subject was administered a well standardized neuropsychological test battery (Kløve, 1974; Stuss and Trites, 1977; Trites, 1977). For a list of tests included in the battery see Appendix E. All tests were administered by a trained technician.

The administration of the tests was conducted prior to the formulation of the purpose and design of the current research. All of the neuropsychological test results were coded, keypunched and stored on computer tape at the time of clinical assessment. The scores on the seven subtests, the total raw score, the corrected score and the Memory Quotient of the Wechsler Memory Scale were also stored on computer at this time. The accuracy was checked by comparing a computer printout of the data with the test result summary in the file.

A clinical file was constructed for each case. Included in the file were copies of referral letters, discharge summaries, medical history reviews, medical chart reviews, and reports of special investigations (EEG, Pneumoencephalogram, angiogram, brain scan, X-ray, C.A.T. scans, neurosurgery reports, etc.) when available. Additionally, a detailed history was taken for each case outlining previous illnesses, head injuries, episodes of unconsciousness, epilepsy, fainting spells, injuries to the limbs, previous psychiatric illness, chemical or electrical shock therapy and eating, sleeping and self-care habits. A one to three page summary of the history was included outlining in detail the reason for the referral and the presenting psychological and medical symptoms. In addition, a one to two page report of comments by the technician on the response of the patient to testing and any unusual behavioral patterns (including difficulty remembering test instructions, etc.) was included.

For the explicit purposes of the present research, each file was systematically reviewed in the following order. The history summary, technicians comments, chart review, referral letters and medical reports were read and the clinical rating of memory functioning was carried out. The medical reports and referral letters were reviewed in detail and the neurological status was recorded. The files were organized so that this information could be coded before the rater saw the Wechsler Memory Scale results. Once this information was recorded, the 126 items from the Wechsler Memory Scale were coded wither 0 (fail) or 1 (pass). In addition, partial answers were given a score of .5 on the Logical Memory Section. The Wechsler Memory Scale had been scored by the technician at the time of initial assessment according to the procedures outlined by Wechsler (1945). The Wechsler Memory Scale results, clinical ratings of memory function and neurological status were all coded by a student enrolled in the master's degree in psychology at the University of Ottawa trained for this purpose by the author. Each file was subsequently reviewed by the author and the validity and accuracy of coding was checked.

The following information concerning memory functioning was included. Subjects were considered to have no memory problems if it was clear that nowhere in the file was there a reference to a difficulty with memory. Complaints of impaired memory function (from the patient, technician or others) were rated as being mild, moderate or severe under one or more of the following categories:

1) memory for ongoing day to day events (DDMEM)
2) memory for events from the remote past (REMMEM)
3) memory for events prior to the onset pathology (retrograde amnesia in cases where there was a cerebral insult clearly defined in time, PRIOTR)
4) memory for events subsequent to the onset (SUBSTR), and
5) a rating of overall memory functioning. This category included a rating of the memory disorder irrespective of the previously defined categories (OVERMEM).

The protocol employed for rating these categories of memory functions was based on the descriptions of amnesia reported by Milner (1966) and Barbizet (1970) and is presented in Appendix F.

Regarding neurological status, the following information was recorded:

1) neurological diagnosis (NDIAG), either no lesion right hemisphere, left hemisphere, bilateral or equivocal.

2) duration of neurological symptoms (DURSYM), either recently acquired or long standing (more than one year).

3) nature of the lesion (NATUREL) either chronic-static, slowly progressive, rapidly progressive or equivocal.

4) nature of neurodiagnostics (NATUREND) either EEG, pneumoencephalogram, angiogram, brain scan, echoencephalogram, C.A.T. scan, neuro-surgery report, more than one of the above or other neurodiagnostic.

5) etiology (ETIOL), either tumour, cerebral vascular disease, trauma (closed), trauma (penetrating) infectious disease of the brain, epilepsy, degenerative disease, presenile dementing disease, senility, toxic, anoxia, psychopathology, depression or other.

6) extent of lesion (EXTENT), either localized small, localized moderate or large.

7) severity (SEVER) either no neurological illness, mild, moderate or severe.

8) the duration (DURSYM) between the onset of pathology and testing (in months).

The data were coded onto coding forms designed for the purposes of this research. Data were then transferred to standard coding sheets which were sent to a commercial keypunch company. The computer cards were keypunched and verified. The data were then transferred to computer disk storage and a printout was obtained. Based on this printout, the accuracy of the data was checked and errors corrected. The two separate computer files for each subject (1. the clinical neuropsychological test results, and 2. the clinical memory results, neurological information and WMS items) were then merged creating a single file for each subject.

Design

Only those subjects that showed no signs of aphasia on the Wisconsin Aphasia Screening Test were included in the analysis of the psychometric properties of the WMS. This restriction excluded approximately 3% or 18 subjects. Test data of the patient's first testing were included in the initial analysis. Cross-validation was carried out on subjects with test data obtained on subsequent follow up tests.

Data Analysis

Indices of difficulty were calculated for each item (the proportion of subjects passing the item). Indices of discrimination were also calculated. Each item was related to the following external criteria. Memory Quotient, WAIS Full Scale I.Q., Impairment Index, Knox Cube Test, Tactual Performance Test Memory and subtest 7 of the Category Test, by comparing those who scored in the top 27% on the test with those who scored below the 28th percentile (Brown, 1970). The discrimination index for these measures was the proportion of subjects passing the item in the low group subtracted from the proportion passing in the high group. For the relationship between the following criteria: DDMEM, REMMEM, PRIOTR, SUBSTR, OVERMEM the measure of association was Gamma. The statistic gamma was employed since it can be applied if the two variables are dichotomous, if one is dichotomous and the other is not or if neither is dichotomous. In each case it will represent a measure of association that can take on values from -1 to +1. It is calculated as the number of discordant pairs divided by the total number of united pairs, (Mueller, Schuenter, Cortner, 1970).

$$\text{Gamma} = \frac{P - Q}{P + Q}$$

Items with indices of discrimination greater than .30 were selected and a number of scales were constructed, each scale representing items maximally related to a specific criterion measure. Validation of these scales was carried out by correlating each scale with the criteria. Comparisons were made with the correlations between the new scales and the seven standard scales generally included in the Wechsler Memory Scale. Analysis of covariance was carried out and the relationship between both the old and the new scales and each of the criterion measures was determined while intelligence (WAIS Full Scale I.Q.) and impairment (Impairment Index) were controlled. Stepwise discriminant function analyses were carried out in order to determine the percentage of subjects that could be classified according to each criterion group on the basis of the new subscales as well as the old subscales. These analyses were cross-validated by performing stepwise discriminant function analyses among subjects that had been clinically seen on more than one occasion. The test results for their subsequent testing was used to predict group membership.

PESULTS

Description of Sample

The age, intelligence quotients, sex and hand dominance of the validation and cross validation samples are presented in table 2.

The number and percentage of subjects with different clinical memory problems are presented in Table 2a. Inter-rater reliability coefficients were calculated for recent, remote and overall memory ratings. There was overlap for 98% of the cases yielding coefficients of .96, .97 and .96 respectively.

For memory for ongoing day to day events, the majority either had no difficulty (57.0%) or moderate difficulty (23.8%). Very few (2.2%) had severe difficulty while 16.9% had mild difficulty. The majority of the subjects had no difficulty with memory for events of the remote past (70.6%) and only 1.2% had severe difficulty remembering remote events.

For those subjects in which the memory disorder could be related to a specific onset, there were a greater number of subjects with anterograde amnesia (87.2%) than those with a retrograde amnesia (67.2%). Only 1.6% of the patients with memory complaints, regardless of the nature of the complaint, could be classified as having a severe memory disorder. The majority of memory problems were rated as mild or moderate.

TABLE 2

Age, intelligence quotients, sex and hand dominance of validation and cross-validation samples.

	Validation Sample			Cross-validation sample		
	Mean	Std. dev.	Range	Mean	Std. dev.	Range
Age	30.9	16.6	15.0- 83.0	17.8	3.2	15.0- 27.0
Full Scale	95.6	14.9	46.0-136.0	105.4	10.2	84.0-126.0
Verbal	97.4	15.2	54.0-145.0	105.6	10.9	80.0-128.0
Perform.	93.8	15.2	49.0-132.0	104.5	9.5	82.0-125.0
		N	%	N	%	
Sex						
Males		327	66.0	71	76.0	
Females		169	34.0	22	22.0	
Hand domin.						
Right		448	90.4	85	91.3	
Left		48	9.6	8	8.7	
Total		496				

TABLE 2a

Clinical rating of Memory Function.

	No difficulty		Mild		Moderate		Severe		Not Classified
	n	%	n	%	n	%	n	%	n
Day to day events	280	57.0	83	16.9	117	23.8	11	2.2	6
Events of the remote past	346	70.6	74	15.1	64	13.1	6	1.2	7
Events prior to onset	21	43.8	10	20.8	14	29.2	3	6.3	449
Events subsequent to onset	15	23.8	11	17.5	35	55.6	2	3.2	434
Overall memory	272	55.4	96	18.6	115	23.4	8	1.6	6

The localization of neuropathology according to cerebral hemisphere is presented in Table 3 for those subjects in which neurodiagnostics were available.

TABLE 3

Neurological rating of location of lesion.

	N	%
No diagnosis made	115	
No lesion	164	42.9
Right hemisphere	42	11.0
Left hemisphere	83	21.7
Bilateral	83	21.7
Equivocal	10	2.6

Of those in which a lesion was detected, there were a greater number of left hemisphere cases (21.7%) or bilaterally dysfunctional (21.7%) patients than right hemisphere cases (11.0%).

In Table 4 the numbers and percentages of cases with either recently acquired or longstanding (more than one year) neurological symptoms is presented. For the majority (70.9%) of cases, symptoms had begun more than

TABLE 4

Duration of neurological symptoms

Duration	Right hemisphere		Left hemisphere		Bilateral		Equivocal		Total	
	N	%	N	%	N	%	N	%	N	%
Recently acquired	18	56.3	14	31.8	11	23.9	1	20.0	55	29.1
Long standing	14	43.8	30	68.2	35	76.1	4	80.0	134	70.9

one year prior to testing. A greater proportion (56.3%) of those with dysfunction of the right hemisphere had recently acquired symptoms in comparison to left hemisphere (31.8%) or bilateral (23.9%) cases.

The nature of the lesion, either chronic static, slowly progressive or equivocal is presented in Table 5. Here it can be seen that there were an equal number of chronic static and slowly progressive cases. The majority of the symptoms were acute (60.3%). Left hemisphere cases tended to be slowly progressive more frequently than those with right hemisphere damage. The patients with bilateral cerebral dysfunction tended to be chronic static or slowly progressive most frequently.

The type of neurodiagnostics used in the neurological ratings are presented in Table 6.

Most of the subjects had been given either an EEG (64.2%) or more than one neurodiagnostic investigation (21.9%). Neurosurgeons reports (6.8%) and angiograms (4.8%) were among the most frequent of the other investigations.

The etiology of neurological symptoms is presented in Table 7. The most frequently occurring etiology was closed head injury (20.4%). Cerebral vascular accident was also relatively frequent (11.0%). The other category (40.9%) refers to a variety of disorders in which cerebral

TABLE 5

Nature of lesion

Nature	Right hemisphere		Left hemisphere		Bilateral		Equivocal		Total	
	N	%	N	%	N	%	N	%	N	%
Chronic static	4	12.5	8	15.4	14	29.8	1	20.0	27	19.9
Slowly progressive	2	6.3	10	19.2	14	29.8	1	20.0	27	19.9
Acute onset	26	81.3	34	65.4	19	40.4	3	60.0	82	60.3

TABLE 6

Nature of neurodiagnostics

Neurodiagnostics	N	%
EEG	199	64.2
Pneumoencephalogram	5	1.6
Amgiogram	15	4.8
Brain Scan	-	-
Echoencephalogram	1	.3
C.A.T. Scan	-	-
Neurosurgeons report	21	6.8
More than one of the above	68	21.9
Other	1	.3

TABLE 7

Etiology

Etiology	N	%
Tumour	8	2.5
Cerebral Vascular Accident	35	11.0
Trauma (closed)	65	20.4
Trauma (penetrating)	6	1.9
Infectious disease of brain	3	.9
Epilepsy	7	2.2
Degenerative disease	6	1.9
Presenile dementing disease	11	3.5
Senility	1	.3
Toxic	20	6.3
Anoxia	–	–
Psychopathology	25	7.9
Other	130	40.9

dysfunction was suspected but no etiology was confirmed. These included cases whose reason for referral was headache or difficulty in school or a variety of complaints for which a diagnosis as to etiology was not arrived at.

Table 8 presents an estimate of the severity of the neurological illness. The majority had either mild (41.2%) or moderate (39.8%) illness.

Item Analysis

The list of items, corresponding item number and proportion of patients passing the item is presented in Table 9.

The items ranged in difficulty from very easy, "What city is it?"; difficulty index of .986, to very difficult; difficulty index of .052 "darkness".

Items were plotted according to their relationship to the external criteria (ordinate) and the difficulty index (abscissa). Figure 3 presents the relationship (Gamma) between the level of difficulty and measure of association between each item and the clinical rating of day to day memory.

It can be seen in Figure 3 that there are a number of items that are strongly related to day to day memory functions. There are items related to memory

TABLE 8

Estimated severity of neuropathology

Severity	Right hemisphere		Left hemisphere		Bilateral		Equivocal		Total	
	N	%	N	%	N	%	N	%	N	%
No Neurol. Disease									10	4.7
Mild	12	37.5	22	42.3	24	47.1	2	40.0	87	41.2
Moderate	16	50.0	22	42.3	20	39.2	3	60.0	84	39.8
Severe	4	12.5	8	15.4	7	13.7		0	30	14.2

TABLE 9

List of items, item numbers and indices of difficulty (Non aphasics).

Item	Number	Difficulty Index
WAGE (How old are you)	1	.947
BORN (When were you born)	2	.961
PM (Who is the Prime Minister)	3	.948
BEFOREHM (who was the Prime Minister before him)	4	.499
PREMIER (Who is the premier of this province)	5	.471
MAYOR (Who is the mayor of this city)	6	.497
YEAR (What year is it)	7	.952
MONTH (What month is it)	8	.933
DAY (What day is it)	9	.732
WHERENOW (What is the name of the place you are now in)	10	.840
CITYIN (In what city is it)	11	.986
CNTBKWIE (count backwards from 20 to 1)	12	.941
CNTBKWOE (no errors)	13	.870
CNTBKWIO (No errors in 10 seconds)	14	.512
ALPHIE (say alphabet)	15	.774
ALPHOE (say alphabet no errors)	16	.712
ALPHIO (say alphabet no errors in 10 sec)	17	.641
CNT3IE (count by 3's)	18	.561
CNT3OE (count by 3's no errors)	19	.508
CNT3IO (count by 3's, within time	20	.355
AT Anna Thompson	21	.570
STH of South	22	.249
BOST Boston	23	.481
EMPL employed	24	.259
SCRUB as a scrub woman	25	.518

TABLE 9 (continued)

Item	Number	Difficulty Index
OFF in an office building	26	.137
REP reported	27	.295
CITYHILL at the City Hall	28	.087
STN Station	29	.203
HELDUP that she had been held up	30	.310
STATEST on State Street	31	.224
NIGHTB4 the night before	32	.124
ROBBED and robbed	33	.659
$15.00 of $15.00	34	.497
FOUR She had four	35	.512
CHILDREN little children	36	.434
RENT the rent	37	.312
DUE was due	38	.266
NOTEAT and they had not eaten	39	.343
TWODAYS for two days	40	.302
OFFICER the officers	41	.456
TOUCHED touched by the woman's story	42	.283
PURSE made up a purse	43	.566
HER for her	44	.446
AMERIC The American	45	.392
LINER liner	46	.662
NY New York	47	.404
STRK struck a mine	48	.404
LIVERP near Liverpool	49	.302
MON Monday	50	.138
EVE evening	51	.085
BLNDNG In spite of a blinding	52	.111
SNOSTRM snowstorm	53	.301
DKNESS and darkness	54	.052
SIXTY the sixty	55	.410
PASS passengers, including 18	56	.455
WOMEN women	57	.540
RESC were all rescued	58	.473
BOATS though the boats	59	.213

TABLE 9 (continued)

Item		Number	Difficulty Index
TOSSED	were tossed about	60	.276
CORKS	like corks	61	.233
HEAVY	in the heavy sea	62	.153
PORT	they were brought into port	63	.326
NXTDAY	the next day	64	.216
BRITISH	by a British	65	.289
STEAMER	steamer	66	.298
DIG1	Digits, 1	67	.993
DIG2	Digits, 2	68	.993
DIG3	Digits, 3	69	.993
DIG4	Digits, 4	70	.982
DIG5	Digits, 5	71	.892
DIG6	Digits, 6	72	.654
DIG7	Digits, 7	73	.385
DIG8	Digits, 8	74	.165
DIGB1	Digits Backwards 1	75	.988
DIGB2	Digits Backwards 2	76	.988
DIGB3	Digits Backwards 3	77	.961
DIGB4	Digits Backwards 4	78	.728
DIGB5	Digits Backwards 5	79	.439
DIGB6	Digits Backwards 6	80	.210
DIGB7	Digits Backwards 7	81	.098
TWOLNS	Two lines crossed, four flags	82	.941
FACING	facing one another	83	.589
ACCUR	accurate	84	.162
LGESQ	Large square two diameter	85	.895
FOURSMILL	Four small squares within a large square	86	.740
DIAM	Two diameters, in each small square	87	.585
DOTS	Sixteen dots	88	.559
ACCURA	Accuracy	89	.066
LGEREC	Large rectangle, small rectangle inside	90	.722

TABLE 9 (continued)

Item		Number	Difficulty Index
VERTCON	Vertices connected	91	.617
SHIFTRT	small rectangle shifted	92	.431
OPENREC	open rectangle with loop at each end	93	.472
CENTSIDE	Centers and one side correct	94	.416
FIGCOR	One loop incorrect	95	.367
FIGPROP	Proportional	96	.224
NORTHA		97	.895
FRUITA		98	.629
OBEYA		99	.226
ROSEA		100	.698
BABYA		101	.513
UPA		102	.933
CABBAGEA		103	.160
METALA		104	.730
SCHOOLA		105	.254
CRUSHA		106	.187
CABBAGEB		107	.542
BABYB		108	.904
METALB		109	.893
SCHOOLB		110	.547
UPB		111	.972
ROSEB		112	.826
OBEYB		113	.462
FRUITB		114	.780
CRUSHB		115	.522
NORTHB		116	.954
OBEYC		117	.611
FRUITC		118	.915
BABYC		119	.911
METALC		120	.927
CRUSHC		121	.661
SCHOOLC		122	.707
ROSEC		123	.917
NORTHC		124	.982
CABBAGEC		125	.638
UPC		126	.968

Fig. 3 The relationship between each item and the clinical rating of day to day memory plotted as a function of index of difficulty.

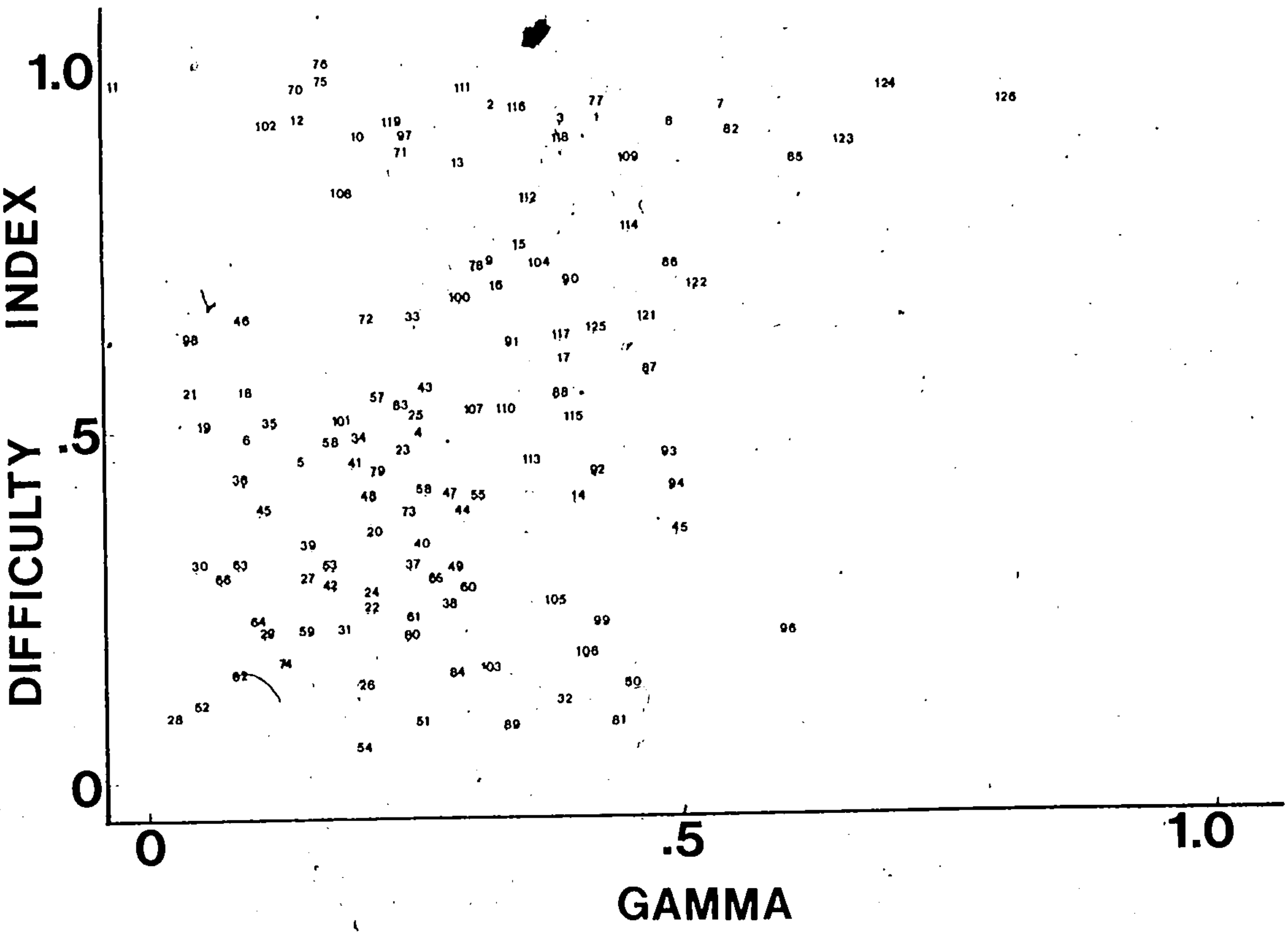


Figure 3.

functioning at every level of difficulty. Similarly there are items that can be excluded as a measure memory for day to day events. Based on the criterion of a Gamma of .3 or greater the following 52 items were included in a revised scale labelled DAYDAY-REV:

UPB	ALPHIE	CRUSHB	DIGB7
NORTHC	DIGB4	OBEYB	
BORN	DAY	OPENREC	
NORTHB	METALA	SHIFTRT	
DIGB3	FOURSMLL	CENTSIDE	
YEAR	ALPHOE	SIXTY	
UPC	LGEREC	CNTBKWOE	
PM	SCHOOLC	FIGCOR	
WAGE	CRUSHC	TOSSED	
MONTH	OBEYC	SCHOOLA	
TWOLNS	CABBAGEC	OBEYA	
ROSEC	VERTCON	FIGPROP	
FRUITC	ALPHIO	CRUSHA	
METALB	DIAM	CABBAGEA	
LGESQ	DOTS	MON	
ROSEB	CABBAGEB	NIGHTB4	
FRUITB	SCHOOLB	ACCURA	

Figure 4 presents the measure of association (Gamma) of each item with the rating of remote memory, plotted as a function of difficulty index. Again it can be seen that there are items related to the clinical assessment of remote memory functioning at a wide range of difficulty

Fig. 4 The relationship between each item and clinical ratings of remote memory plotted as a function of index of difficulty.

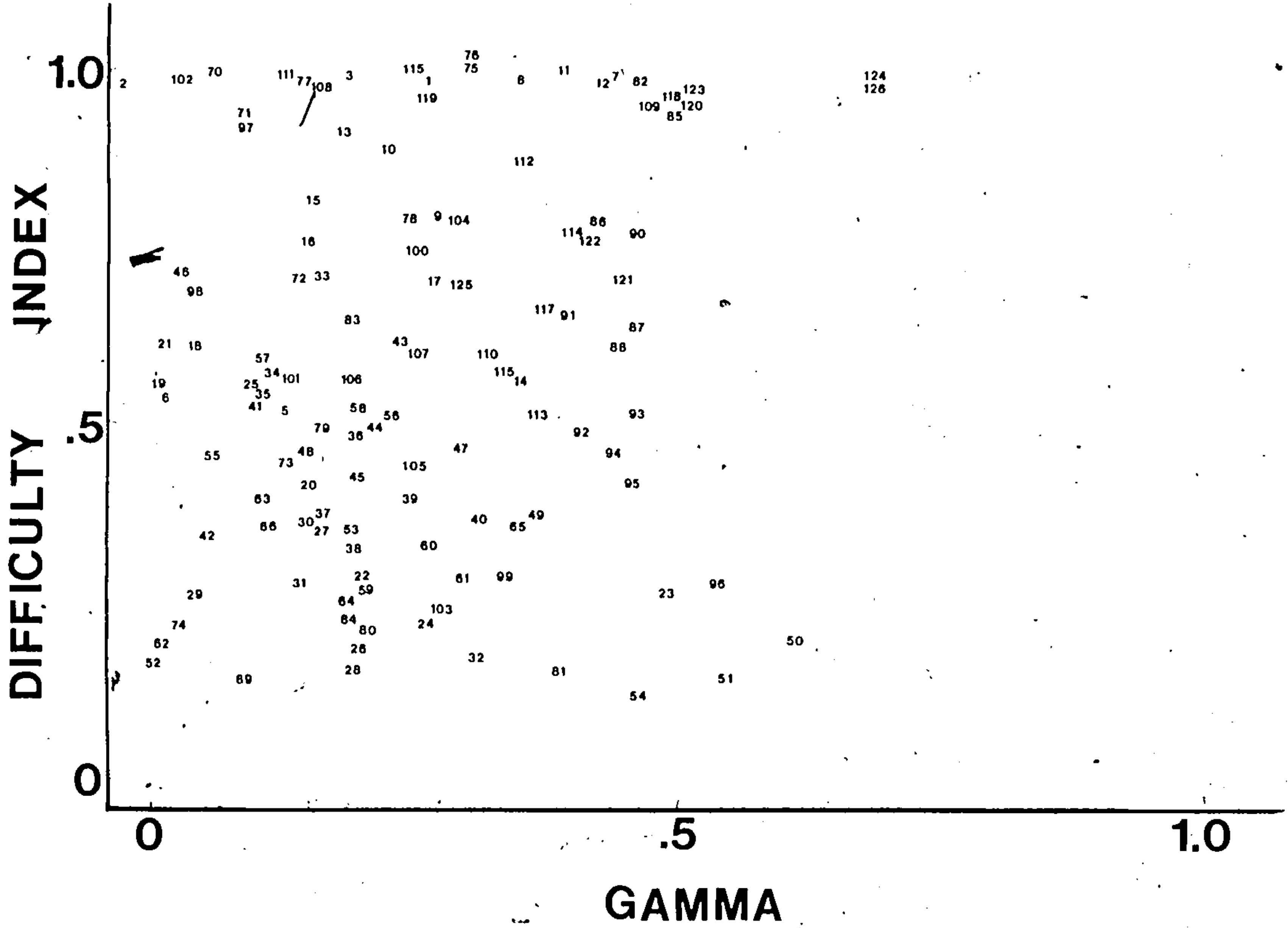


Figure 4.

levels. The following 35 items were included as a scale of memory for remote events (REMOTE-REV):

DIGB2	TWOLNS	FOURSMLL	SHIFTRT
DIGB1	ROSEC	LGEREC	CENTSIDE
NORTHC	FRUITC	FRUITB	FIGCOR
CITYIN	METALC	SCHOOLC	TWODAYS
YEAR	METALB	CRUSHC	LIVERP
MONTH	LGESQ	OBEYC	BRITISH,
CNTBKWIE	ROSEB	OPENREC	OBEYA
FIGPROP	ACCUPA		
CRUSHA	DIGB7		
CABBAGEA			
MON			
NIGHTB4			

In Figure 5 the association between the items and events prior to the onset pathology are presented. Those 31 items with a Gamma greater than .30 were included in the following scale: PRIOR-REV:

WAGE	METALA	SNOSTRM	EVE
TWOLNS	CRUSHC	SCHOOLA	
CNTBKWIE	SCHOOLB	DUE	
YEAR	STRK	NEXTDAY	
UPA	NY	CRUSHA	
MONTH	SIXTY	BOATS	
ROSEC	FIGCOR	OFF	
LGESQ	NOTEAT	MON	
ROSEB	TWODAYS	BLNDNG	
SCHOOLC	RENT	NIGHTB4	

Fig. 5. The relationship between each item and clinical ratings of memory for events prior to onset plotted as a function of index of difficulty.

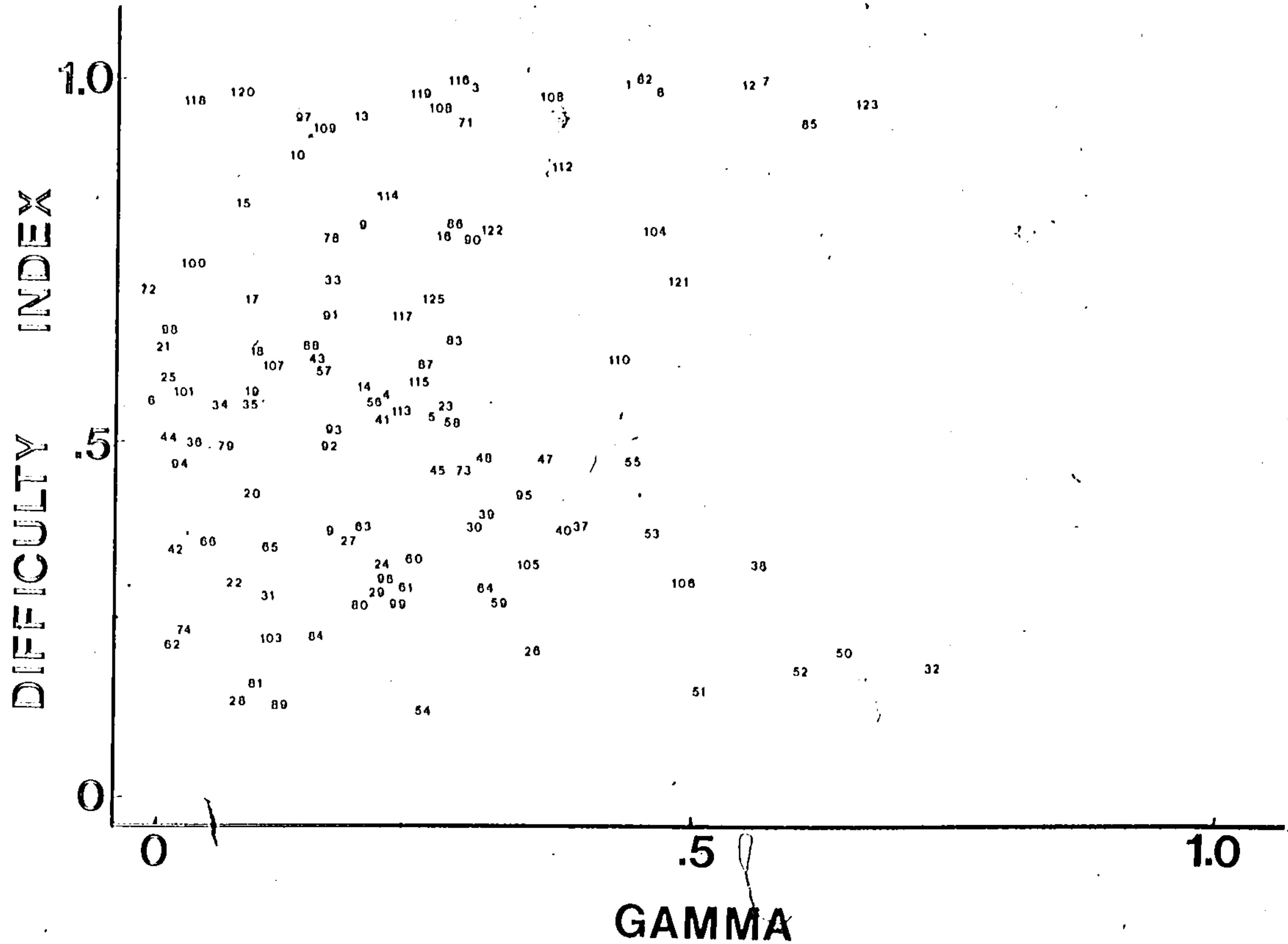


Figure 5.

Fig. 6. The relationship between each item and clinical ratings of memory for events subsequent to onset plotted as a function of index of difficulty.

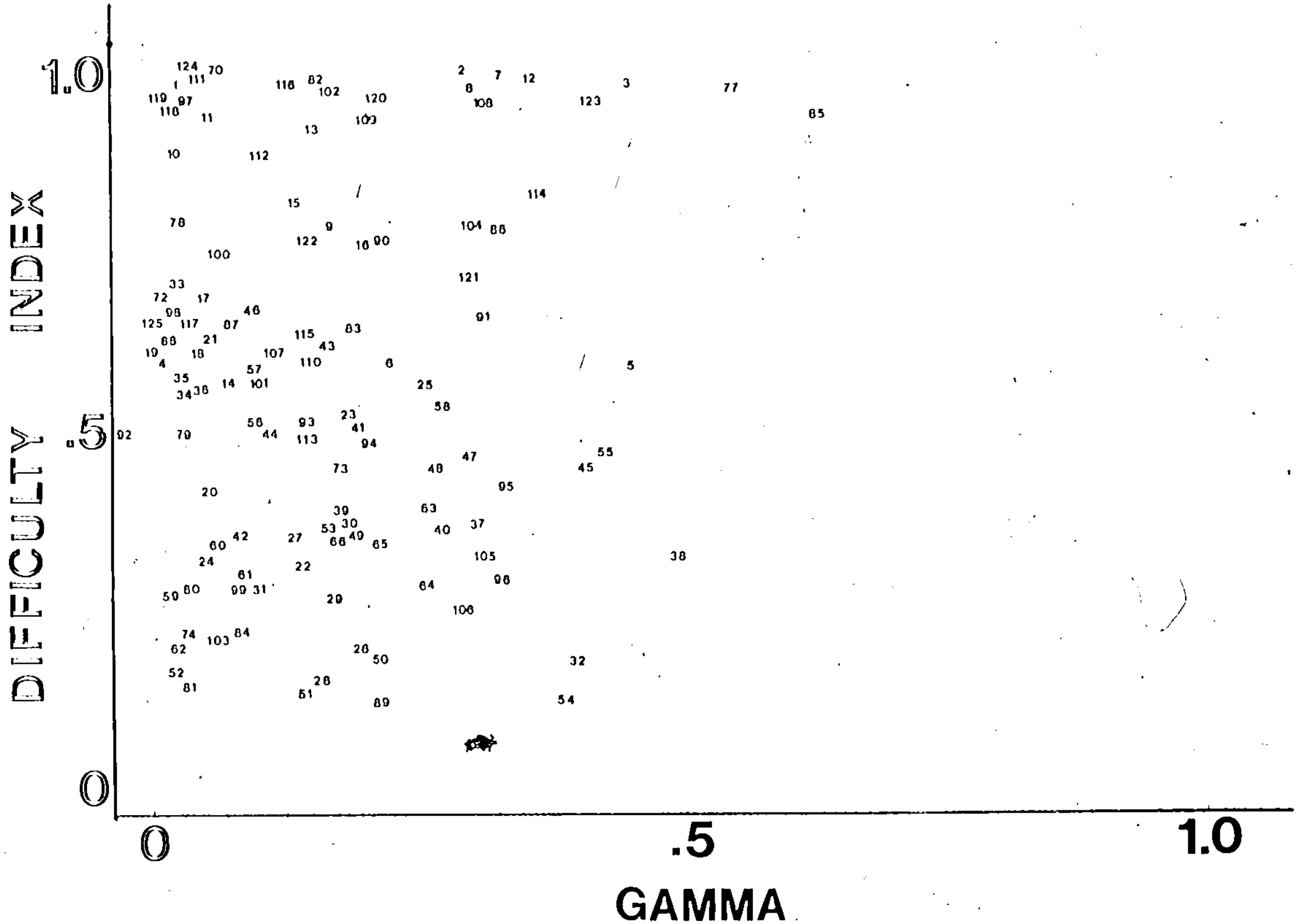


Figure 6.

Figure 6 presents the measure of association for each item and the rating of memory functioning for events subsequent to trauma plotted as a function of level of difficulty. The 29 items with a Gamma of greater than .30 were included in the following scale SUBSEQ-REV:

YEAR	PREMIER
PM	SIXTY
DIGB3	AMERIC
CNTBKWIE	FIGCOR
BABYB	RENT
ROSEC	SCHOOLA
LGESQ	DUE
FRUITB	FIGPROP
FOURSMLL	NIGHTB4
VERTCON	DKNESS

The association between the overall memory rating and each item is plotted as a function of the index of difficulty for each item in Figure 7. Those 55 items with a discrimination index of .30 or greater were selected for inclusion in the scale OVERMEM-REV:

Fig. 7. The relationship between each item and clinical ratings of overall memory functioning plotted as a function of index of difficulty.

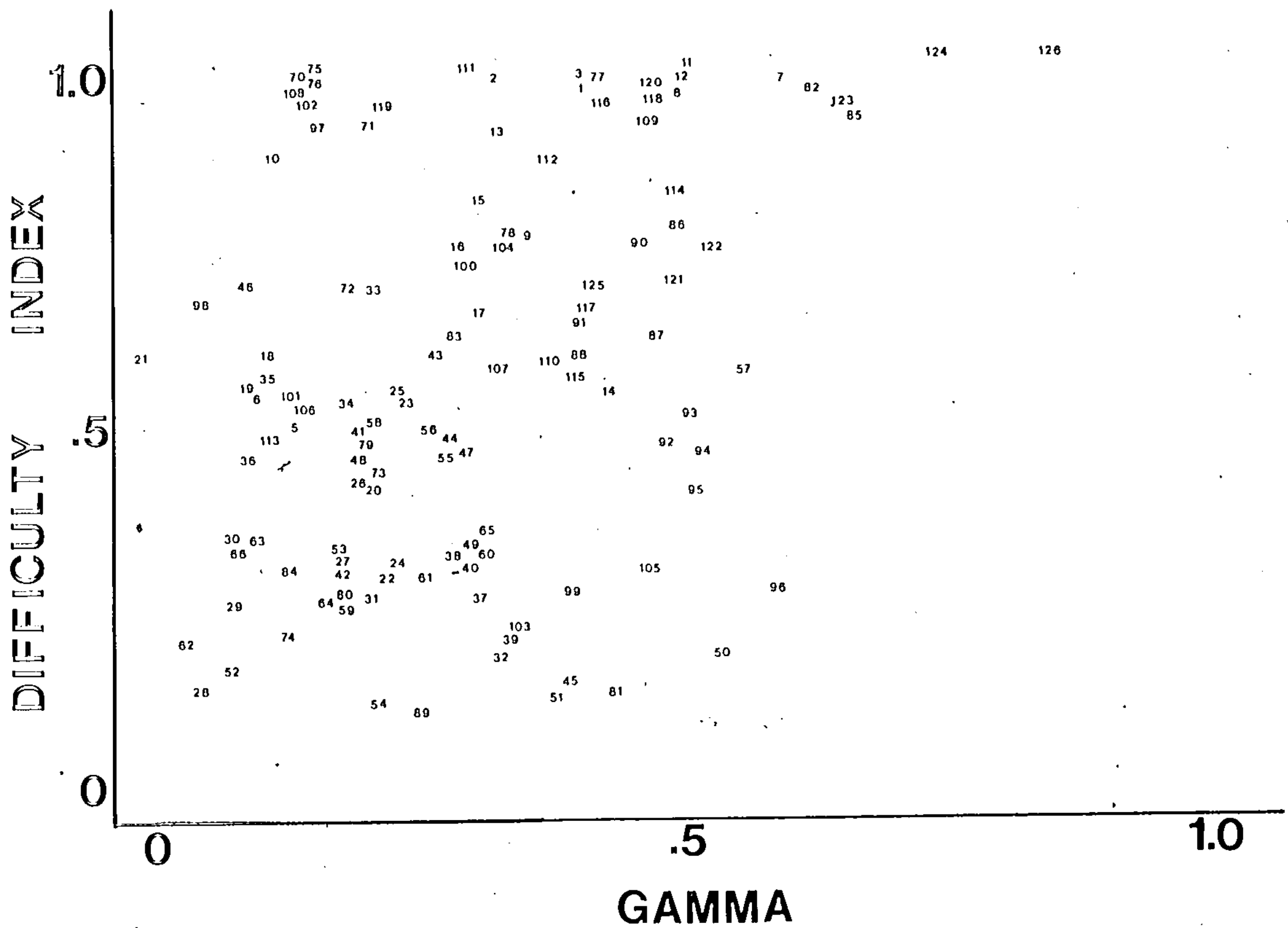


Figure 7.

CITYIN	FOURSMLL	FIGCOR	ALPHIO
NORTHC	LGEREC	SCHOOLA	FACING
UPC	SCHOOLC	FIGPROP	CABBAGEB
CNTBKWIE	OBEYC	MON	UPB
YEAR	VERTCON	DIGB7	NY
METALC	DIAM	UPB	BRITISH
MONTH	DOTS	BORN	LIVERP
TWOLNS	CRUSHB	CNTBKWOE	TOSSED
FRUITC	WOMEN	ROSEB	TWODAYS
ROSEC	CNTBKWIO	CRUSHB	RENT
METALB	OPENREC	DIGB4	OBEYA
LGESQ	SHIFTRT	DAY	CABBAGEA
FRUITB	CENTSIDE	METALA	NOTEAT
NIGHTB4			
AMERIC			
EVE			

The discrimination index which related each item to the Memory Quotient, WAIS Full Scale I.Q., Impairment Index, Knox Cube Test, Category Test (subtest 7) and TPT Memory, was calculated by subtracting the proportion of subjects passing the item in the high group (upper 27%) from the proportion passing in the low group (lower 27%). The discrimination index obtained from the high and low groups on the Memory Quotient is plotted as a function of the difficulty index in Figure 8. Here it can be seen that the very easy items (discrimination index of

Fig. 8. The relationship between each item and the MQ plotted as a function of index of difficulty.

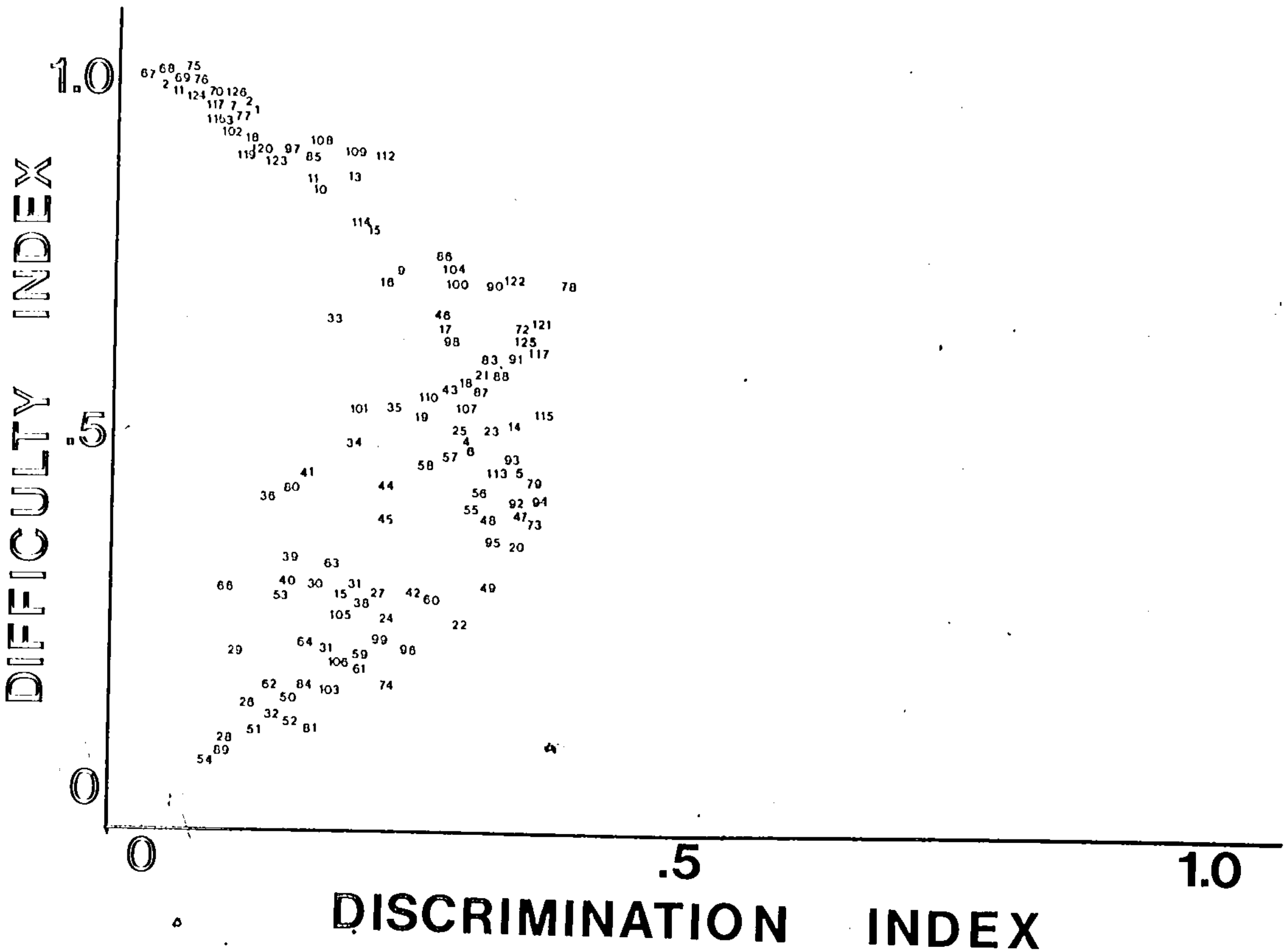


Figure 8.

.80 or greater) and the very difficult items (discrimination index of .20 or less) add very little to the discrimination between the high and low groups. The 64 items with a discrimination index of greater than .30 were included in a scale labelled WMSQUOT-REV:

DAY	ALPHOE	DIGB4	LINER
FOURSMLL	LGEREC	ROSEA	DIG6
METALA	SCHOOLC	CRUSHC	ALPHIO
FRUITA	CABBAGEB	MAYOR	NY
CABBAGEC	BABYA	OPENREC	CENTSIDE
VERTCON	FOURSMLL	RESC	DIG7
OBEYC	CNT30E	OBEYB	AMERIC
FACING	SCRUB	PREMIER	FIGCOR
DOTS	BEFOREHM	HER	CNT31O
PURSE	BOST	PASS	RENT
CNT31E	CNTBKWIO	SHIFTRT	REP
AT	CRUSHB	DIGB5	TOUCHED
DIAM	FIFTEEN	SIXTY	TOSSED
SCHOOLB	WOMEN	STRK	LIVERP
DUE	FIGPROP		
EMPL	SIXTY		
STH	CORKS		
OBEYA	DIG8		

The relationship of each item to WAIS Full Scale I.Q. is plotted as a function of the discrimination indices in Figure 9. While many of the items are highly related to I.Q. many fall below the .30 discrimination index

Fig. 9 The relationship between each item and the WAIS I.Q. plotted as a function of difficulty index.

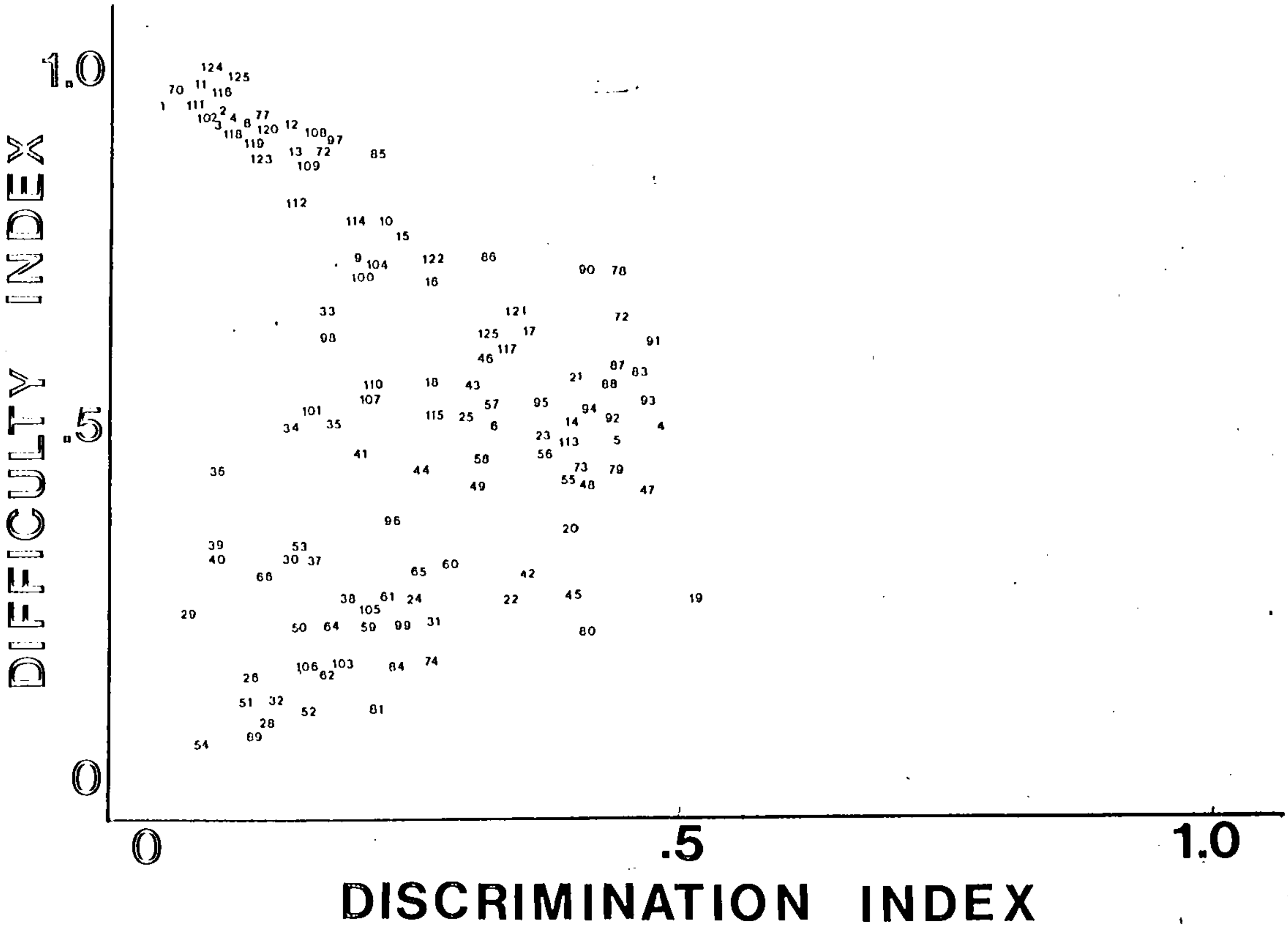


Figure 9.

Fig. 10   The relationship between each item and the impairment index plotted as a function of difficulty index.

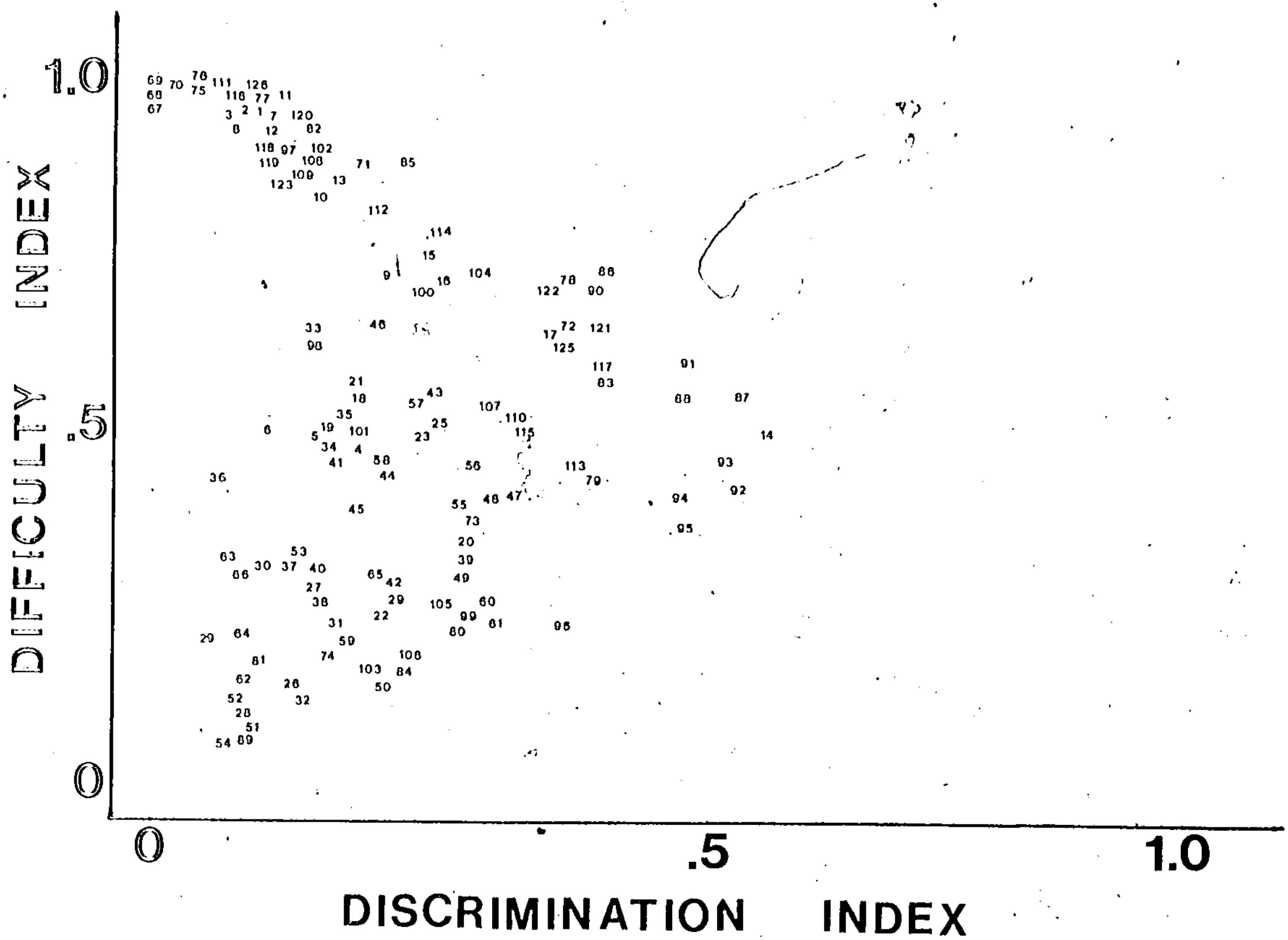


Figure 10.

criterion. Those 38 items with discrimination indices above .30 were included in the scale INTELL-REV:

FOURSMLL	WOMEN	LIVERP
LGEREC	FIGCOR	SIXTY
DIGB4	CENTSIDE	STRK
CABBAGEC	OPENREC	NY
CRUSHC	MAYOR	CNT310
ALPHIO	CNTBKWIO	STN
DIG6	SHIFTRT	AMERIC
LINER	BEFOREHM	CNT30E
OBEYC	BOST	DIGB6
VERTCON	OBEYB	
DIAM	PREMIER	
FACING	RESC	
PURSE	PASS	
AT	DIG7	
DOTS	DIGB5	

Those items maximally related to the impairment index were included in a scale labelled IMPINDEX-REV. The relationship between the 28 items and impairment are plotted as a function of index of difficulty in Figure 10

IMPINDEX-REV:

DIBG4	CABBAGEB	CORKS
FOURSMLL	SCHOOLB	FIGPROP
SCHOOLC	CRUSHB	
LGEREC	CNTBKW10	
DIG6	OBEYB	
CRUSHC	OPENREC	
ALPHIO	DIGB5	
CABBAGEC	STRK	
OBEYC	NY	
VERTCON	CENTSIDE	
FACING	SHIFTRT	
DOTS	FIGCOR	
DIAM	TOSSED	

The indices of discrimination for the Knox Cube Test, Category subtest 7 and TPT Memory t st are plotted as a function of the index of difficulty in Figures 11, 12 and 13 respectively. The 21 items included in the subscale ATTENT-REV were:

SCHOOLC	DIAM	CNT310
FOURSMLL	CENTBKWIO	DIGB6
LGEREC	OPENREC	FIGPROP
DIGB4	SHIFTRT	
DIG6	DIGB5	
VERTCON	CENTSIDE	
OBEYC	FIGCOR	
FACING	BOST	
DOTS	DIG7	

Fig. 11 The relationship between each item and visual attention (Knox Cube Test) plotted as a function of index of difficulty.

Figure 11.

Fig. 12 The relationship between each item and a measure of memory for nonverbal concepts (subtest 7 of Category) plotted as a function of index of difficulty.

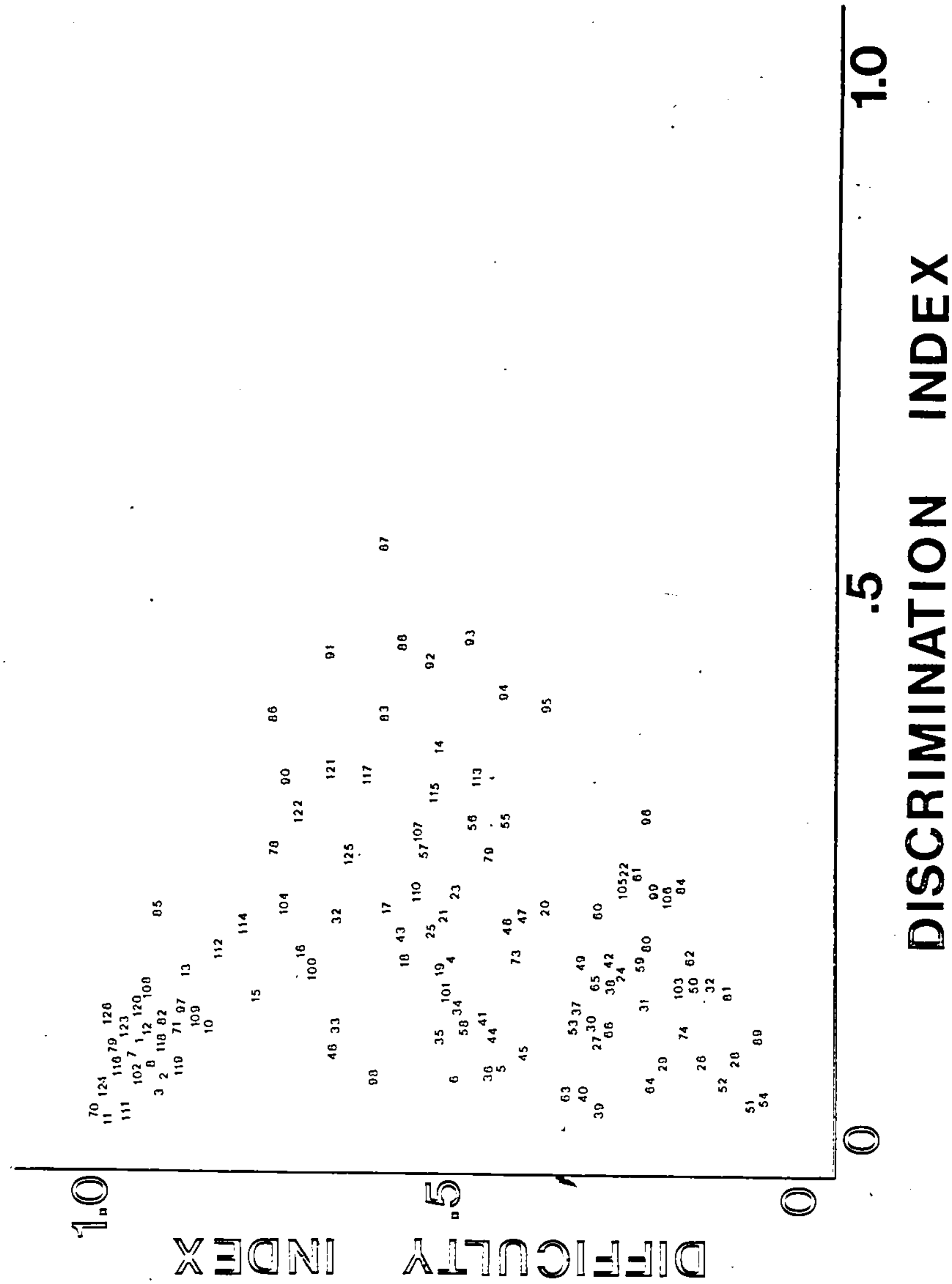


Figure 12.

Fig. 13 The relationship between each item and a test of memory for forms (Tactual Performance Test, Memory) plotted as a function of index of difficulty.

Figure 13.

Those 15 items included in the subscale CAT7-REV were:

FOURSMLL	CRUSHB
LGEREC	CNTBKW10
CRUSHC	SHIFTRT
VERTCON	OBEYB
OBEYC	OPENREC
OPENREC	CENTSIDE
DIAM	FIGCOR
DOTS	

The 13 items included in the subscale TPT-REV were:

DIAM	FIGCOR
DOTS	BOSTON
CNTBKW10	DIGB7
OPENREC	CNT310
SHIFTRT	DIGB6
DIGB5	FIGPROP
CENTSIDE	

The 10 items included in the scales CAT7 and TPT which were considered primarily nonverbal were included in a scale labelled NONVERB-REV:

FOURSMLL	OPENREC
LGEREC	CENTSIDE
VERTCON	FIGCOR
OPENREC	FIGPROP
DIAM	
DOTS	
SHIFTRT	

The list of items and the criterion variables to which they are related sufficiently to be included in a scale is summarized in Table 10. Here it can be seen that some items are clearly related to the memory functions that were rated clinically. These include YEAR, MONTH, NIGHTB4, TWOLNS, LGESQ, SCHOOLA, ROSEB, FRUITB, ROSEC but are relatively unrelated to I.Q. and the Memory Quotient. Other items are related to the WAIS I.Q. and the Memory Quotient, but not to the clinical ratings of memory functions. These include BEFOREHM, PREMIER, MAYOR, CNT30E.

Summary of Item Analysis Results

The item analysis indicated that the Wechsler Memory Scale consists of items ranging from very easy to extremely difficult. Those items that are very easy and those that are very difficult add little to the discriminative power of the test (see Fig. 8). When items were related

TABLE 10

The criterion measures and the items associated with each.

Item	No.	I.Q.	WMS MEM	REMOTE	PRIOR	DAY/ DAY	OVER ALL	SUBS	NDIAG	II	TPT	CAT	KNOX
WAGE	1				✓	✓							
BORN	2					✓	✓						
PM	3					✓		✓					
BEFOREMM	4	✓	✓										
PREMIER	5	✓	✓					✓					
MAYOR	6	✓	✓										
YEAR	7			✓	✓	✓	✓	✓	✓				
MONTH	8			✓	✓	✓	✓						
DAY	9		✓			✓	✓						
WHERENOW	10								✓				
CITYIN	11			✓			✓		✓				
CNTBKWIE	12			✓	✓		✓	✓	✓				
CNTBKWOE	13						✓						
CNTBKWIO	14	✓	✓	✓		✓	✓			✓	✓	✓	✓
ALPHIE	15					✓							
ALPHOE	16		✓			✓							
ALPHIO	17	✓	✓			✓	✓			✓			
CNT31E	18		✓										
CNT30E	19	✓	✓										
CNT310	20	✓	✓										✓

Item	No.	I.Q.	WIS MEM	REMOTE	PRIOR	DAY/ DAY	OVER ALL	SUBS	NDIAG	II	TPT	CAT	KNOX
AT	21	✓	✓										
STH	22	✓	✓										
BOST	23	✓	✓	✓									✓
EMPL	24		✓										
SCRUB	25		✓										
OFF	26				✓								
REP	27		✓										
CITYHLL	28												
STR	29												
HELDUP	30												
STATEST	31												
NIGHTB4	32			✓	✓	✓	✓	✓					
ROBBED	33												
$15.00	34		✓										
FOUR	35		✓										
CHILDREN	36												
RENT	37		✓		✓	✓		✓					
DUE	38		✓		✓			✓					
NOTEAT	39				✓	✓							
TWODAYS	40			✓	✓	✓							
OFFICER	41												
TOUCHED	42		✓										
PURSE	43	✓	✓										
HER	44		✓										
AMERIC	45	✓	✓				✓	✓					
LINER	46	✓	✓										
NY	47	✓	✓		✓		✓			✓			

Item	No.	I.Q.	WMS MEM	REMOTE	PRIOR	DAY/ DAY	OVER ALL	SUBS	NDIAG	II	TPT	CAT	KNOX
STRK	48	✓	✓		✓					✓			
LIVERP	49	✓	✓	✓			✓						
MON	50			✓	✓	✓	✓						
EVE	51			✓	✓	?	✓						
BLNDNG	52				✓								
SNOSTRM	53				✓								
DKNESS	54			✓				✓					
SIXTY	55	✓	✓		✓	✓		✓					
PASS	56	✓	✓										
WOMEN	57	✓	✓				✓						
RESC	58	✓	✓										
BOATS	59				✓								
TOSSED	60		✓			✓	✓			✓			
CORKS	61		✓										
HEAVY	62												
PORT	63												
NXTDAY	64				✓								
BRITISH	65			✓			✓						
STEAMER	66												
DIG1	67												
DIG2	68												
DIG3	69												
DIG4	70								✓				
DIG5	71								✓				
DIG6	72	✓	✓							✓			✓
DIG7	73	✓	✓						✓				✓
DIG8	74		✓						✓				

Item	No.	I.Q.	WMS MEM	REMOTE	PRIOR	DAY/ DAY	OVER ALL	SUBS	HDIAG	II	TPT	CAT	KNOX
DIGB1	75			✓									
DIGB2	76			✓									
DIGB3	77					✓		✓					
DIGB4	78	✓	✓			✓	✓			✓			✓
DIGB5	79	✓	✓							✓			✓
DIGB6	80	✓											✓
DIGB7	81			✓		✓	✓						
TWOLNS	82			✓	✓	✓	✓		✓				
FACING	83	✓	✓				✓			✓		✓	✓
ACCUR	84												
LGESQ	85			✓	✓	✓	✓	✓					
FOURSHLL	86	✓	✓	✓		✓	✓	✓		✓		✓	✓
DIAM	87	✓	✓	✓		✓	✓			✓	✓	✓	✓
DOTS	88	✓	✓	✓		✓	✓			✓	✓	✓	✓
ACCURA	89					✓							
LGEREC	90	✓	✓	✓		✓	✓			✓		✓	✓
VERTCON	91	✓	✓	✓		✓	✓	✓		✓		✓	✓
SHIFTRT	92		✓	✓		✓	✓			✓	✓	✓	✓
OPENREC	93	✓	✓	✓		✓	✓			✓	✓	✓	✓
CENTSIDE	94	✓	✓	✓		✓	✓			✓	✓	✓	✓
FIGCOR	95	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓
FIGPROP	96		✓	✓		✓	✓	✓		✓	✓	✓	✓
NORTHA	97												
FRUITA	98		✓										
OBEYA	99		✓	✓		✓	✓						
ROSEA	100		✓										
BABYA	101		✓										

Item	No.	I.Q.	WMS MEM	REMOTE	PRIOR	DAY/ DAY	OVER ALL	SUBS	HDIAG	II	TPT	CAT	KNOX
UPA	102				✓								
CABBAGEA	103					✓	✓						
METALA	104		✓		✓	✓	✓						
SCHOOLA	105				✓	✓	✓	✓					
CRUSHA	106				✓	✓							
CABBAGEB	107		✓			✓	✓			✓			
BABYB	108							✓					
METALB	109		✓	✓		✓	✓						
SCHOOLB	110		✓	✓	✓	✓				✓			
UPB	111					✓	✓		✓				
ROSEB	112			✓	✓	✓	✓						
OBEYB	113	✓	✓	✓		✓				✓		✓	
FRUITB	114			✓		✓	✓	✓					
CRUSHB	115		✓	✓		✓	✓			✓		✓	
NORTHB	116					✓			✓				
OBEYC	117	✓	✓	✓		✓	✓			✓		✓	✓
FRUITC	118			✓		✓	✓						
BABYC	119												
METALC	120			✓			✓						
CRUSHC	121	✓	✓	✓	✓	✓	✓		✓	✓		✓	
SCHOOLC	122		✓	✓	✓	✓	✓		✓	✓			✓
ROSEC	123			✓	✓	✓	✓	✓					
NORTHC	124					✓	✓						
CABBAGEC	125	✓				✓	✓			✓			
UPC	126					✓	✓		✓				

to external criterion measures, it was found that many were related to the clinical assessment of a number of aspects of memory functioning. Others were maximally related to intelligence measures, attention and level of impairment. Some items were found to be related to other tests of memory which were primarily of a nonverbal nature. Items with discriminative indices greater than .30 were grouped together to form twelve new scales.

Scale Validation

Correlations

Each of the scales of the WMS and each clinical rating were correlated (see Table 11). From Table 11 it can be seen that Information and Digits are generally not highly correlated with clinical memory ratings. Information was midly related to memory for events prior to and subsequent to the onset of pathology. Orientation, Control and Passages on the other hand were mildly related to memory for day to day events and to memory for remote events. Visual Reproduction and Associate Learning were found to be moderately related to overall memory problems, memory problems for day to day and remote events. The Memory Quotient was found to be moderately related to memory for events prior to the onset of patho-

TABLE 11

Correlations of WMS subscales with criterion variables (Non Aphasics).

	CRITERION VARIABLES					
WMS SCALES	DAY/DAY	REMOTE	PRIOR	SUBS	OVERALL	NDIAG
INFORM	.13	.09	.21	.24	.14	.03
ORIENT	.21	.21	.17	.02	.22	.13
CONTROL	.25	.15	.04	.14	.25	.09
PASSAGES	.26	.23	.41	.19	.27	.08
DIGITS	.18	.11	.04	.03	.18	.16
VISUAL REP	.36	.31	.27	.04	.41	.12
ASSOC LEARN	.38	.26	.20	.09	.35	.05
TOTAL RAW	.40	.31	.36	.05	.41	.13
MEMORY QUOT	.26	.44	.44	.26	.26	.09

logy but not highly correlated with the other ratings of memory function. None of the scales were found to be correlated with neurological status.

The correlation coefficients between each of the revised scales and the clinical memory ratings are shown in Table 12 and can be summarized as follows. In general, the correlations are higher than those in Table 11, which represent the correlations with the WMS scales. Four subscales (DAYDAY-REV, REMOTE-REV, IMPINDEX-REV, CAT7-REV) are more highly related to day to day memory problems than any of the WMS subscales. Nine of the 12 revised scales yield higher correlation coefficients with remote memory problems than the highest of the correlations between remote memory problems and the WMS subscales. In addition both PRIOR-REV and SUBSEQ-REV correlated more highly with memory for events prior to the onset than any of the WMS subscales. SUBSEQ-REV was more highly correlated with ratings of memory for events subsequent to onset than any WMS old scale. The scales DAYDAY-REV, REMOTE-REV, PRIOR-REV, SUBSEQ-REV, IMPINDEX-REV, CAT7-REV, ATTENT-REV and OVERMEM-REV all showed higher correlations with ratings of overall memory problems than any of the WMS subscales. The relation between the revised scales and neurological status was mild for the scale NEURO-REV.

TABLE 12

Correlation of revised subscale with criterion variables (Non Aphasics).

	CRITERION VARIABLES					
REVISED SCALES	DAY/DAY	REMOTE	PRIOR	SUBS	OVERALL	NDIAG
WMSQUOT-REV	.39	.30	.37	.06	.41	.14
DAY TO DAY-REV	.47*	.38*	.38	.03	.49*	.13
REMOTE-REV	.46*	.41*	.40	.11	.49*	.13
PRIOR-REV	.40	.34*	.59*	.22	.43*	.12
SUBS-REV	.40	.33*	.49*	.30*	.43*	.13
NEURO-REV	.35	.28	.29	.05	.35	.25*
INTELL-REV	.38	.30	.36	.10	.39	.13
IMPINDEX-REV	.42*	.35*	.34	.00	.45*	.13
NONVERBAL-REV	.37	.33*	.26	.03	.40	.09
CAT7-REV	.42*	.36*	.30	.03	.44*	.12
TPT-REV	.38	.33*	.25	.01	.41	.07
ATTENT-REV	.40	.33*	.29	.03	.42*	.13
OVERMEM1-REV	.46*	.40*	.43	.16	.48*	.16

* Signifies correlation coefficients whose value exceeds that of the highest correlation between traditional subscales and memory quotient and criterion value.

In general, the scales that had been constructed from the item analysis results were more highly and consistently related to the clinical memory ratings than the WMS subscales.

Discriminant Function Analysis

Discriminant function analysis was used to compare the predictive accuracy of the revised set of scales to the WMS subscales. The stepwise procedure which enters variables with the smallest Wilk's Lambda was used throughout. The minimum F to enter into the analysis was 1.0.

Separate discriminant analyses were carried out for the WMS subscales and the revised scales. In the first set of analyses the WMS scales and revised scales were each required to classify cases into either the no difficulty, mild, moderate or severe memory problem categories for each of the clinical ratings. For each analysis the chance hit rate was 25%. A summary of the discriminant results is presented in Table 13. Here it can be seen that when the scales are required to classify into one of the four groups, the WMS subscales correctly classify between 32.43% and 50.00% of the subjects. The classification rates were statistically significant

TABLE 13

Discriminant results: WMS subscales and revised scales, prediction of memory problem (no difficulty, mild, moderate or severe) and neurological diagnosis (no lesion, right, left or bilateral), the four group classification.

Criterion	WMS Subscales			Revised Scales		
	% Class	Wilk's	P	% Class	Wilk's	P
OVERALL	49.30	.7173	.0000	50.21	.5281	.0000
DAY TO DAY	48.03	.7441	.0000	50.95	.6970	.0000
REMOTE	50.00	.8341	.0000	58.90	.7829	.0000
PRIOR TO ONSET	30.95	.5038	.0983	78.57	.0314	.0000
SUBSEQUENT TO ONSET	32.43	.8054	.3080	49.12	.4369	.0372
NEUROLOGICAL DIAG.	37.71	.8543	.0003	44.33	.3008	.0000

for overall memory difficulties (Wilk's Lambda = .7173, p < .0000), day to day memory problems (Wilk's Lambda = .7441, p < .0000), memory for remote events (Wilk's Lambda = .8341, p < .0000), and neurological diagnosis (Wilk's Lambda = .8543, p < .0003). When the revised scales were used to make the same classification, the classification rates were higher for each criterion ranging from 44.33% to 78.57%. Each of the classification rates for the revised scales were statistically significant. These included prediction of overall memory problems (Wilk's Lambda = .5281, p < .0000), day to day memory problems (Wilk's Lambda = .6970, p < .0000), memory for remote events (Wilk's Lambda = .7829, p < .0000), memory for events prior to onset (Wilk's Lambda = .0314, p < .0000) and neurological diagnosis (Wilk's Lambda = .3008, p < .0000). A comparison of the WMS subscale and revised scale prediction results indicated that for each criterion, the revised scales yielded higher percentages of correct classification.

A second set of discriminant analyses, similar to the first group were carried out. Here the requirement was to predict according to two groups of clinical memory ratings. The no difficulty and mild memory problem groups were distinguished from the moderate and severe memory groups. Also the tests were required to distinguish those without central neurological dysfunction from those with positive evidence of dysfunction. The results are presented in Table 14.

For the two group classifications, there was an improvement in the predictive accuracy using the WMS subscales in discriminant analysis. Between 57.43% and 73.81% of the cases were correctly classified. The old scales when combined in discriminant analysis significantly classified subjects according to group for those with overall memory problems (Wilk's Lambda = .8153, $p < .0000$), memory for day to day events (Wilk's Lambda = .8087, $p < .0000$), remote memory problems (Wilk's Lambda = .8872, $p < .0000$), memory for events prior to onset (Wilk's Lambda = .8117, $p < .0300$), memory for events subsequent to onset (Wilk's Lambda = .9780, $p < .0200$), and neurological diagnosis (Wilk's Lambda = .9472, $p < .0115$).

When the revised scales were used to make the two group classifications, again a higher hit rate was attained generally than for the old scales. Between 68.42% and 83.33% of the cases were classified correctly

TABLE 14

Discriminant results: WMS subscales and revised scales, prediction of memory problem (no difficulty and mild versus moderate and severe) and neurological diagnosis (no lesion versus right, left and bilateral), the two group classification.

Criterion	WMS Subscales			Revised Scales		
	% Class	Wilk's	P	% Class	Wilk's	P
OVERALL	69.72	.8153	.0000	69.58	.8012	.0000
DAY TO DAY	70.51	.8087	.0000	75.48	.7815	.0000
REMOTE	70.22	.8872	.0000	76.91	.8475	.0000
PRIOR TO ONSET	73.81	.8117	.0300	83.33	.8431	.0006
SUBSEQUENT TO ONSET	66.24	.9780	.0200	68.42	.7626	.0283
NEUROLOGICAL DIAG.	57.43	.9472	.0115	65.80	.8835	.0000

according to group. For each of the criterion measures significant differences among the groups were attained, including memory difficulty overall (Wilk's Lambda = .8012, $p < .0000$), memory for day to day events (Wilk's Lambda = .7815, $p < .0000$), memory for remote events (Wilk's Lambda = .8475, $p < .0000$), memory for events prior to onset (Wilk's Lambda = .8431, $p < .0006$), memory for events subsequent to onset (Wilk's Lambda = .7826, $p < .0283$), and neurological diagnosis (Wilk's Lambda = .8835, $p < .0000$).

In summary, the results of this series of discriminant function analyses indicated that both the scales presented by Wechsler (1945) and the new scales presented here are significantly related to the external ratings of memory. When the tests were required to classify cases into four groups, the revised scales were found to consistently predict group membership at a higher rate than the old scales. The average difference in predictive accuracy was 14.39%. When a two group classification was made, in general a greater number of cases were correctly classified than for the four group classification. For the two group case, the revised scales predicted, on the average 5.27% more of the cases than the old scales. Detailed results of these discriminant analyses including the variables included by the stepwise method are presented in Appendix B.

Day to Day Memory Problems

The WMS subscales and the revised scales were included in a stepwise linear regression with the criterion day to day memory problems as the predicted variable. The revised scales were entered as a group on step one and the WMS subscales entered on step two. The multiple R between the revised scales and day to day memory problems was .5152 (d.f. = 14,255, F = 6.58, $p < .01$) and 26.54% of the variance was accounted for. On entering the WMS subscales, the multiple R increased to .5699 (d.f. = 24,245, F = 4.91, $p < .01$) and 32.45% of the variance was accounted for. Thus the revised scales are significantly related to day to day memory problems and when the WMS subscales are added only 5.91% more of the variance is accounted for.

In Table 15, the means, standard deviations, univariate F ratios and significance levels for each of the WMS subscales are presented for the cases grouped according to the rating of day to day memory problems. It can be seen that each subscale and the Memory Quotient significantly differentiates the groups. Additionally,

TABLE 15

WMS subscales means and F ratios for cases
cases grouped according to problems with day to day memory.

Variable	No Diff.	Mild	Mod.	Severe	F	d.f.	P
N	274	80	104	11			
INFORM	4.44	4.31	4.17	3.09	4.34	3,465	.004
ORIENT	4.56	4.53	4.22	3.41	10.26	3,465	.0000
CONTROL	6.33	5.93	4.99	4.27	10.40	3,465	.0000
PASSAGES	8.44	7.30	6.46	4.64	11.47	3,465	.0000
DIGITS	10.85	10.46	9.94	9.27	5.13	3,465	.0017
VIS REP	8.42	7.10	5.45	3.82	22.98	3,465	.0000
ASSOC LEARN	13.64	12.10	10.45	7.14	20.40	3,465	.0000
TOTAL RAW	57.56	52.72	46.47	35.64	29.83	3,465	.0000
MEMORY QUOT	93.69	90.91	84.61	72.18	12.06	3,465	.0000

for each scale (including Memory Quotient) the scores drop as a function of severity of memory problem. Those with the highest F ratios are Visual Reproduction (F = 22.98), Associate Learning (F = 20.40) and the total raw score (F = 29.83). Additionally, Visual Reproduction and Associate Learning were the first two of the six variables included in the stepwise discriminant function analysis (see Appendix A). These findings indicate that Visual Reproduction and Associate Learning are the best two of the WMS subscales to identify cases complaining of memory problems for day to day events.

The means, standard deviations, F ratios and significance levels for each of the revised scales grouped according to day to day memory problems is presented in Table 16. Here again it can be seen that each scale significantly separates the groups and the scores on each scale drop as a function of severity of the memory problem. The highest F ratios are for the scales DAY/DAY-REV and REMOTE-REV. The first two variables included in the discriminant analysis were DAY/DAY-REV and NEURO-REV (see Appendix B). It would appear that the best discriminator of day to day memory problems is the scale DAY/DAY-REV.

TABLE 16

Revised scales, means and F ratios for cases grouped according to problems with day to day memory.

Variable	No Diff.	Mild	Mod.	Severe	F	d.f.	P
WMSQUOT-REV	35.33	30.60	24.79	15.64	29.31	3,469	.0000
DAY TO DAY-REV	35.72	31.90	26.46	19.27	46.27	3,469	.0000
REMOTE-REV	27.77	24.55	20.52	15.18	42.71	3,469	.0000
PRIOR-REV	16.94	15.19	13.10	9.14	30.79	3,469	.0000
SUBSEQ-REV	12.47	11.33	9.88	6.82	32.12	3,469	.0000
NEURO-REV	11.84	11.45	10.65	8.45	25.53	3,469	.0000
INTELL-REV	22.30	19.14	15.38	9.64	25.97	3,469	.0000
IMPINDEX-REV	21.32	17.61	13.26	7.50	34.51	3,469	.0000
NONVERBAL-REV	6.73	5.14	3.52	2.27	25.45	3,469	.0000
CAT7-REV	10.01	7.85	5.41	3.18	32.76	3,469	.0000
TPT-REV	4.43	3.21	1.94	1.45	27.27	3,469	.0000
ATTENT-REV	12.56	10.28	7.69	4.73	30.01	3,469	.0000

Memory for Remote Events

The revised scales were entered on the first step as a group into a stepwise linear regression predicting memory problems for remote events. The multiple R was .4526 ($F = 4.67$, d.f. = 14.254, $p < .01$) and 20.48% of the variance was accounted for. When the WMS subscales were entered on step two, the multiple R increased to .5677 ($F = 4.82$, d.f. = 24,244, $p < .01$) and 32.18% of the variance was accounted for. Thus the revised scales are significantly related in combination with memory problems for the remote past and when the WMS subscales are also included 11.70% more of the variance can be accounted for.

The means, standard deviations, F ratios and significance levels for each of the old scales are presented according to group in Table 17. The scales Information and Digits did not differ significantly among the groups. For each of the other scales however, the F ratio indicated significant differences among the groups. Each of these scales (including Memory Quotient) dropped significantly as a function of the severity of the memory difficulty. The largest F ratios were for Visual Reproduction (16.11) Total Raw Score (16.55) and Associate Learning (9.34). Visual Reproduction and Associate

TABLE 17

WMS subscale means and F ratios for cases grouped according to memory problems for the remote past.

Variable	No Diff.	Mild	Mod.	Severe	F	d.f.	P
	338	71	54	5			
INFORM	4.38	4.26	4.19	3.00	2.11	3,464	.10
ORIENT	4.54	4.37	4.07	3.50	7.36	3,463	.0001
CONTROL	6.09	5.81	5.11	4.00	3.83	3,463	.01
PASSAGES	8.21	6.79	6.16	4.40	8.80	3,464	.0000
DIGITS	10.65	10.57	9.96	9.00	2.12	3,464	.10
VISUAL REP	8.08	6.56	4.81	4.60	16.11	3,464	.0000
ASSOC LEARN	13.08	11.45	10.46	7.50	9.34	3,353	.0000
TOTAL RAW	56.05	50.54	45.39	35.90	16.55	3,464	.0000
MEMORY QUOT	92.57	88.89	82.98	75.600	6.661	3,464	.0002

Learning were the first two variables included in the stepwise discriminant analysis (see Appendix A). Thus, among the WMS subscales, the best scales to differentiate memory problems for the remote past are Visual Reproduction and Associate Learning.

The means, standard deviations and F ratios of the revised scales for the cases grouped according to memory for remote events are presented in Table 18. Each of the revised scales is significantly related to remote memory. For each scale, the scores drop as a function of severity of the memory problem.

The highest F ratios were for the variables REMOTE-REV ($F = 30.71$) and DAYDAY-REV ($F = 26.26$). REMOTE-REV was the first variable included in discriminant analysis (see Appendix B). Thus it would appear that the best variable for discriminating memory problems for remote events was REMOTE-REV.

Memory for Events Prior to Onset

The stepwise linear regression of the subscales with the rating of memory for events prior to the trauma was invalid due to the insufficient number of cases with a clearly defined onset of memory difficulty.

TABLE 18

Revised scale means and F ratios for cases grouped according to memory for remote events.

Variable	No Diff.	Mild	Mod.	Severe	F	d.f.	P
	340	71	56	5			
WMSQUOT-REV	33.84	28.72	23.97	16.30	15.64	3,468	.0000
DAY TO DAY-REV	34.52	30.30	25.19	20.20	26.26	3,468	.0000
REMOTE-REV	26.99	22.91	19.09	15.30	30.71	3,468	.0000
PRIOR-REV	16.50	14.25	12.46	9.40	20.45	3,468	.0000
SUBSEQ-REV	12.12	10.96	9.36	7.40	18.65	3,468	.0000
NEURO-REV	11.67	11.30	10.39	8.40	14.68	3,468	.0000
INTELL-REV	21.41	17.72	14.56	10.30	15.63	3,468	.0000
IMPINDEX-REV	20.33	16.24	11.78	8.90	22.30	3,468	.0000
NONVERBAL-REV	6.39	4.42	2.88	2.80	19.93	3,468	.0000
CAT7-REV	9.51	6.82	4.61	3.60	23.79	3,468	.0000
TPT-REV	4.16	2.85	1.68	1.00	19.67	3,468	.0000
ATTENT-REV	11.96	9.44	6.93	5.00	19.57	3,468	.0000

The means, standard deviations, F ratios and significance levels for each WMS subscale classified according to memory for events prior to onset are presented in Table 19. Here it can be seen that only the Memory Quotient and Passages significantly discriminate the groups. While the score on passages dropped as a function of severity of the memory disorder, only the moderate and severe group could be separated on Memory Quotient.

The means, standard deviations, F ratios and significance levels for each of the revised scales on cases grouped according to memory for events prior to onset are presented in Table 20. Here it can be seen that three subscales significantly discriminate the groups, REMOTE-REV, PRIOR-REV and SUBSEQ-REV, while there are no differences among the groups on the other scales. Both PRIOR-REV and SUBSEQ-REV dropped as a function of severity of the memory disorder while the moderate and severe groups were lower than the no difficulty and mild group on REMOTE-REV. Thus, for identifying memory problems prior to onset the best scales are PRIOR-REV and SUBSEQ-REV.

TABLE 19

WMS subscale means and F ratios for cases
grouped according to memory for events prior to onset.

Variable	No Diff.	Mild	Mod.	Severe	F	d.f.	P
	20	8	12	2			
INFORM	4.48	4.50	4.08	3.50	.76	3,38	.53
ORIENT	4.55	4.63	3.92	5.00	1.75	3,38	.18
CONTROL	5.20	5.13	5.00	5.00	.03	3,38	.99
PASSAGES	6.78	6.44	4.46	3.50	2.85	3,38	.05
DIGITS	11.00	11.25	11.75	11.00	.08	3,38	.97
VISUAL REP	7.20	7.88	5.67	3.00	1.65	3,38	.19
ASSOC LEARN	10.39	13.60	9.20	8.50	1.82	3,38	.17
TOTAL RAW	52.64	53.75	44.21	39.50	2.53	3,38	.07
MEMORY QUOT	89.55	90.63	76.42	64.50	3.99	3,38	.01

TABLE 20

Revised scale means and F ratios for cases grouped according to memory difficulty for events prior to onset.

Variable	No Diff.	Mild	Mod.	Severe	F	d.f.	P
	20	8	12	2			
WMSQUOT-REV	29.88	29.75	21.88	17.5	2.42	3,38	.08
DAY TO DAY-REV	32.05	32.50	25.08	22.50	2.65	3,38	.06
REMOTE-REV	25.35	25.56	19.00	17.00	3.03	3,38	.04
PRIOR-REV	15.83	13.75	10.29	9.00	7.02	3,38	.00
SUBSEQ-REV	11.40	11.13	7.75	9.50	6.01	3,38	.00
NEURO-REV	11.85	11.63	10.92	10.00	1.31	3,38	.29
INTELL-REV	19.23	18.69	14.00	10.00	2.08	3,38	.12
IMPINDEX-REV	18.20	19.06	13.13	6.50	2.36	3,38	.09
NONVERBAL-REV	5.10	5.38	3.83	.50	1.47	3,38	.24
CAT7-REV	8.10	7.75	5.67	2.00	1.54	3,38	.22
TPT-REV	3.25	2.75	2.25	.50	.96	3,38	.42
TEMPORAL-REV	5.03	5.31	5.08	5.25	.30	3,38	.82
ATTENT-REV	10.85	11.94	8.08	5.00	1.92	3,38	.14

Memory for Events Subsequent to Onset

The stepwise linear regression of the revised and WMS scales on the criterion memory for events subsequent to onset was invalid due to the insufficient number of cases. The means, standard deviations and F ratios for each group on the old scales are presented in Table 21.

The F ratio is based on the three groups no difficulty, mild and moderate since there was only one case in the severe group. None of the WMS scales significantly discriminated the cases grouped according to memory for events subsequent to onset.

In Table 22, the means, standard deviations and F ratios of revised scales for the cases grouped according to memory for events subsequent to onset are presented. Again the F ratios are based on three groups since there was only one case in the severe group. Here it can be seen that none of the new scales significantly discriminated the groups classified according to memory for events subsequent to onset.

Overall Memory Problems

When the revised scales were included in step one of a stepwise linear regression predicting overall memory functioning, the multiple R obtained was .5378

TABLE 21

WMS subscale means and F ratios for cases grouped according to memory for events subsequent to onset.

Variable	No Diff.	Mild	Mod.	Severe	F	d.f.	P
	14	11	31	1			
INFORM	4.68	4.82	4.23	3.00	1.73	2,53	.17
ORIENT	4.50	4.73	4.45	5.00	.38	2,53	.77
CONTROL	5.00	5.64	5.71	6.00	.40	2,53	.75
PASSAGES	7.13	7.48	6.19	3.00	1.11	2,53	.35
DIGITS	11.14	10.45	11.10	12.00	.31	2,53	.82
VIS REP	6.93	7.91	7.10	3.00	.65	2,53	.58
ASSOC LEARN	9.88	13.75	11.88	9.00	1.38	2,53	.27
TOTAL RAW	57.82	55.34	51.98	41.00	.61	2,53	.61
MEMORY QUOT	90.21	92.55	86.94	66.00	.977	2,53	.41

TABLE 22

Revised scale means and F ratios for cases grouped according to memory difficulty for events subsequent to onset.

Variable	No Diff.	Mild	Mod.	Severe	F	d.f.	P
	14	11	31	1			
WMSQUOT-REV	29.14	32.68	29.98	19.00	.66	2,53	.58
DAY TO DAY-REV	30.50	34.09	31.05	25.00	.65	2,53	.58
REMOTE-REV	24.93	26.41	24.05	17.00	.74	2,53	.53
PRIOR-REV	15.57	15.73	13.84	10.00	1.25	2,53	.30
SUBSEQ-REV	11.75	11.73	9.92	10.00	2.18	2,53	.10
NEURO-REV	11.71	11.73	11.58	11.00	.09	2,53	.96
INTELL-REV	19.25	20.68	18.29	12.00	.52	2,53	.67
IMPINDEX-REV	16.54	20.14	17.95	8.00	.87	2,53	.46
NONVERBAL-REV	4.86	5.82	5.10	1.00	.58	2,53	.63
CAT7-REV	7.50	8.91	7.81	3.00	.56	2,53	.65
TPT-REV	2.93	3.64	3.13	1.00	.38	2,53	.77
ATTENT-REV	10.64	11.41	10.74	7.00	.23	2,53	.88

(F = 9.88, d.f. = 14,340, p < .01) and 28.92% of the variance was accounted for. When the WMS subscales were included in the second step the multiple R increased to .5723 (F = 7.35, d.f. = 22,332, p < .01) and 32.76% of the variance was accounted for. Thus the revised scales are significantly related to the rating of overall memory function and when the WMS subscales are added to the regression equation, only 3.84% more of the variance can be accounted for.

The means, standard deviations and F ratios for the WMS subscales are presented for the cases grouped according to overall memory problems in Table 23. All of the scales yielded significant univariate F ratios. For each scale the scores dropped as a function of severity of the memory disorder.

The highest F ratios were for Visual Reproduction (31.03), Associate Learning (17.37) and Total Raw score (33.51). When selected for the stepwise discriminant analysis Visual Reproduction was the first variable selected (see Appendix A).

The means, standard deviations and F ratios of the revised scales for each of the overall memory function groups is presented in Table 24. In each case the scores drop as a function of severity of the memory dis-

TABLE 23

WMS subscale means, standard deviations, F ratios for cases grouped according to memory function overall.

Variable	No Diff.	Mild	Mod.	Severe	F	d.f.	P
INFORM	4.44	4.40	4.07	2.83	4.69	3,464	.0021
ORIENT	4.58	4.46	4.22	2.92	11.70	3,464	.0000
CONTROL	6.35	5.88	5.03	3.00	11.53	3,464	.0000
PASSAGES	8.46	7.49	6.27	3.38	13.00	3,464	.0000
DIGITS	10.84	10.54	9.92	8.50	5.55	3,464	.0009
VIS REP	8.60	7.00	5.11	2.67	31.03	3,464	.0000
ASSOC LEARN	13.63	12.04	10.47	6.67	17.37	3,464	.0000
TOTAL RAW	57.84	52.66	45.18	29.96	33.51	3,464	.0000
MEMORY QUOT	93.81	91.17	83.57	70.00	12.42	3,464	.0000

TABLE 24

Revised scale means, standard deviations, F ratios for cases grouped according to overall memory function.

Variable	No Diff.	Mild	Mod.	Severe	F	d.f.	P
WMSQUOT-REV	36.34	32.75	25.43	16.17	31.57	3,468	.0000
DAY TO DAY-REV	36.17	32.80	26.38	16.00	51.92	3,468	.0000
REMOTE-REV	28.13	25.42	20.29	13.50	49.97	3,468	.0000
PRIOR-REV	17.05	16.00	13.32	7.33	34.13	3,468	.0000
SUBSEQ-REV	12.60	11.62	9.91	5.67	35.66	3,468	.0000
NEURO-REV	11.84	11.76	10.57	7.33	28.15	3,468	.0000
INTELL-REV	23.08	20.55	15.67	10.00	29.24	3,468	.0000
IMPINDEX-REV	21.84	18.78	12.95	8.17	40.31	3,468	.0000
NONVERBAL-REV	7.06	5.33	3.29	2.00	33.17	3,468	.0000
CAT7-REV	10.33	8.22	5.19	3.33	39.08	3,468	.0000
TPT-REV	4.69	3.33	1.87	1.00	34.21	3,468	.0000
ATTENT-REV	13.02	10.88	7.67	4.67	36.46	3,468	.0000
OVERMEM2-REV	36.43	31.94	26.49	16.75	49.45	3,468	.0000

order. The highest F ratios were for the scales DAYDAY ($F = 51.92$), REMOTE-REV ($F = 49.97$) and OVERMEM-REV (49.45), although each of the scales was highly related to the rating of memory functioning overall. When selected for inclusion in the analysis by the stepwise discriminant function procedure, the scales DAYDAY-REV and NEURO-REV were the first variables included (see Appendix B).

<u>Neurological Diagnosis</u>

When the revised scales were used to predict neurological diagnosis in the first step of the stepwise linear regression, the multiple R obtained was .3160 ($F = 1.47$, d.f. = 14,186, N.S.) and 9.99% of the variance was accounted for. The WMS subscales were included in the equation in step two and the multiple R increased to .5461 ($F = 3.12$, d.f. = 24,176, $p < .05$) and 29.83% of the variance was accounted for. This indicates that 19.84% more of the variance was accounted for by including the WMS subscales in the equation.

The means, standard deviations and F ratios of WMS subscales for the cases grouped according to neurological diagnosis are presented in Table 25. ASSOC LEARN and INFORM were not significantly related to neurological diagnosis however each of the other scales yielded significant F ratios.

It was found that when the right hemisphere group was compared to the no lesion group, they attained lower scores on VISUALR (Scheffé's analysis, $p < .05$), ORIENT (Scheffé's analysis, $p < .05$) and CONTROL (Scheffé's analysis, $p < .05$). Additionally, the right hemisphere group attained lower scores on PASSAGES than the no lesion group (Scheffé's analysis, $p < .05$) and the bilateral group (Scheffé's analysis, $p < .05$). The right hemisphere group attained significantly lower scores on DIGITS than the no lesion group (Scheffé's analysis, $p < .05$). Additionally, the bilateral group was significantly lower than the no lesion group on DIGITS (Scheffé's analysis, $p < .05$). On the Memory Quotient, the right hemisphere group was significantly lower than the no lesion group (Scheffé's analysis, $p < .05$), the left hemisphere group and the bilateral group (Scheffé's analysis, $p < .05$). Other pairwise comparisons among the neurological diagnosis groups on the WMS subscales were not statiscally significant.

TABLE 25

WMS subscale means, standard deviations, F ratios for cases grouped according to neurological diagnosis.

Variable	Noles	RT	LT	Bil	Equiv	F	d.f.	P
	146	34	51	66	7			
INFORM	4.38	4.16	4.29	4.23	4.57	.32	4,299	.86
ORIENT	4.62	4.12	4.33	4.40	4.14	3.29	4,298	.01
CONTROL	6.21	4.76	5.82	5.91	4.29	3.43	4,298	.009
PASSAGES	8.34	5.64	7.55	7.83	6.54	4.33	4,299	.002
DIGITS	10.99	9.79	10.43	9.94	10.57	3.32	4,299	.011
VISUAL REP	7.97	5.29	6.84	6.82	7.29	4.18	4,299	.003
ASSOC LEARN	12.88	10.64	12.01	12.43	12.58	1.56	4,240	.186
TOTAL RAW	56.04	45.88	52.08	52.00	50.39	4.72	4,299	.001
MEMORY QUOT	93.69	79.00	91.02	90.05	84.00	5.64	4,299	.0002

The means, standard deviations and F ratios of revised scales for the neurological groups are presented in Table 26. Here it can be seen that each scale was significantly related to neurological diagnosis. The largest F ratios were attained by the scales NEURO-REV and SUBSEQ-REV. Selected for inclusion in the stepwise discriminant function analysis were NEURO-REV, PRIOR-REV and SUBSEQ-REV (see Appendix B).

The multiple pairwise comparisons indicated that the right hemisphere group was significantly lower than the no lesion group on the following scales WMSQUOT-REV, OVERMEM-REV, DAYDAY-REV, REMOTE-REV, PRIOR-REV, SUBSEQ-REV, NEURO-REV, INTELL-REV, IMPINDEX-REV, NONVERB-REV, CAT7-REV, TPT-REV and ATTENT-REV, (Scheffé's analysis, $p < .05$ in each case). In addition, the right hemisphere group was significantly lower than the left hemisphere group (Scheffé's analysis, $p < .05$) and the bilateral group (Scheffé's analysis, $p < .05$) on the scale NEURO-REV. Other pairwise comparisons were not significant among the revised scales.

Analysis of Covariance

The item analysis identified items that were related to several aspects of memory difficulty as measured by the clinical ratings and the other tests

TABLE 26

Revised scale means, standard deviations, F ratios for cases grouped according to neurological diagnosis.

Variable	Noles	RT	LT	Bil	Equiv	F	d.f.	P
	148	34	52	66	7			
WMSQUOT-REV	34.04	24.35	29.81	30.14	28.50	4.95	4,302	.0007
DAY TO DAY-REV	33.91	27.59	30.64	31.20	30.57	4.20	4,302	.0025
REMOTE-REV	26.36	21.32	23.50	24.40	24.07	4.21	4,302	.0025
PRIOR-REV	16.37	12.84	14.90	15.13	14.50	4.86	4,302	.0008
SUBSEQ-REV	12.12	9.56	11.13	11.11	11.21	5.40	4,302	.0003
NEURO-REV	11.99	10.79	11.00	10.85	11.29	7.31	4,302	.0000
INTELL-REV	21.46	14.46	18.37	18.99	18.36	5.22	4.302	.0004
IMPINDEX-REV	19.97	13.25	16.64	17.33	18.21	4.96	4,302	.0007
NONVERBAL-REV	5.97	3.62	4.96	5.12	5.43	3.00	4,302	.02
CAT7-REV	9.01	5.94	7.15	7.12	7.86	3.52	4,302	.008
TPT-REV	3.84	2.03	3.12	3.39	3.57	3.18	4,302	.01
ATTENT-REV	11.79	7.50	9.79	10.04	10.57	5.04	4,302	.0006

of memory. Additionally, a number of items were found to be primarily related to intelligence or level of impairment. The revised scales created by these results were found to predict memory classifications and neurological diagnosis more accurately than the WMS subscales when combined in discriminant analysis. Generally the revised scales accounted for a significant percentage of the variance and when the WMS subscales were added in the stepwise linear regression between 3 and 20% more of the variance could be accounted for generally. Examination of the univariate relationship between each scale and the criterion measures revealed that all of the revised scales were related to day to day memory problems, remote memory problems and overall memory difficulty. Even those scales that included items selected due to their relationship to intelligence (WAISFSIQ) and level of impairment (Impairment Index) were related to a number of clinical ratings of memory. It was therefore unclear whether the reported differences between the various groups of cases with memory problems was due to differences between the groups in memory function or was confounded by level of impairment and intelligence.

In order to address this question, a series of analyses of covariance were carried out. The covariate WAISFSIQ and IMPAIRM were adjusted for simultaneously as the relationship between each of the WMS subscales and each revised scale and the clinical ratings of memory function were examined. It was also of interest to determine if the relationship between the scales and memory functioning depended upon the neurological diagnosis. NDIAG was therefore used as an independent variable in the 4 x 4 factorial design with two covariates (WAISFSIQ and IMPAIRM).

Day to Day Memory

The analysis of covariance of each of the WMS subscales among cases grouped according to day to day memory problems is presented in Table 27. Here it can be seen that the covariates IMPAIRM and WAISFSIQ are both significantly related to INFORM, CONTROL, PASSAGES and VISUALR and that when the two significant covariates have been adjusted for, there is no significant effect for either day to day memory problems, neurological diagnosis or the interaction between day to day memory and neurological diagnosis. Thus the

TABLE 27

Analysis of covariance results for each of the WMS subscales with impairment and I.Q. as covariates and clinical ratings of day to day memory problems and neurological diagnosis as independent variables.

Variable	Covariate	Ind. Var.	F	df	SIG
INFORM	IMPAIRM		6.94	1	.009
	WAISFSIQ		56.99	1	.000
		DDMEM	.57	3	.637
		NDIAG	1.30	3	.274
		INTERACTION	.55	9	.840
ORIENT	IMPAIRM		.66	1	.420
	WAISFSIQ		5.27	1	.023
		DDMEM	3.07	3	.030
		NDIAG	2.00	3	.110
		INTERACTION	2.99	9	.000
CONTROL	IMPAIRM		13.76	1	.000
	WAISFSIQ		10.55	1	.001
		DDMEM	2.11	3	.100
		NDIAG	.38	3	.770
		INTERACTION	1.27	9	.260
PASSAGES	IMPAIRM		8.45	1	.004
	WAISFSIQ		35.97	1	.000
		DDMEM	.98	3	.407
		NDIAG	.97	3	.391
		INTERACTION	1.01	9	.178

Continued

Variable	Covariate	Ind. Var.	F	df	SIG
DIGITS	IMPAIRM		1.58	1	.211
	WAISFSIQ		30.79	1	.000
		DDMEM	.87	3	.460
		NDIAG	1.46	3	.227
		INTERACTION	1.63	9	.111
VISUALR	IMPAIRM		94.23	1	.000
	WAISFSIQ		5.00	1	.027
		DDMEM	.96	3	.412
		NDIAG	.84	3	.476
		INTERACTION	.72	9	.689
ASSOCL	IMPAIRM		20.85	1	.000
	WAISFSIQ		2.25	1	.135
		DDMEM	2.07	3	.106
		NDIAG	.59	3	.623
		INTERACTION	.79	9	.629
MEMQUOT	IMPAIRM		2.96	1	.087
	WAISFSIQ		130.89	1	.000
		DDMEM	1.29	3	.279
		NDIAG	1.59	3	.193
		INTERACTION	1.39	9	.194

significant differences between the groups with day to day memory problems on the variables INFORM, CONTROL, PASSAGES and VISUALR reported above, can be accounted for by the differences among the groups in level of impairment and intelligence. Also the scales DIGITS and the Memory Quotient are significantly related to the covariate WAISFSIQ. Once intelligence is controlled for, there is no significant relationship between these scales and memory problems for day to day events. The scale ASSOCL was significantly related to IMPAIRM but once this covariate was adjusted for there was no significant relationship between ASSOCL and day to day memory problems.

While ORIENT was significantly related to WAISFSIQ the main effect for day to day memory and the interaction between day to day memory and neurological diagnosis were significant after WAISFSIQ was controlled for.

The scores on ORIENT, are plotted as a function of neurological diagnosis for each of the groups rated as having difficulty with day to day memory problems in Fig. 14. It was found that the memory groups differed significantly among the bilaterally lesioned but not among the other groups. Multiple comparison tests indicated that the bilaterally lesioned group

Fig. 14 Orientation scores plotted for each of the groups rated as having difficulty with day to day memory as a function of neurological diagnosis. NEURO DIAG 0 – no lesion, 1 – Right hemisphere, 2 – Left hemisphere, 3 – Bilateral.

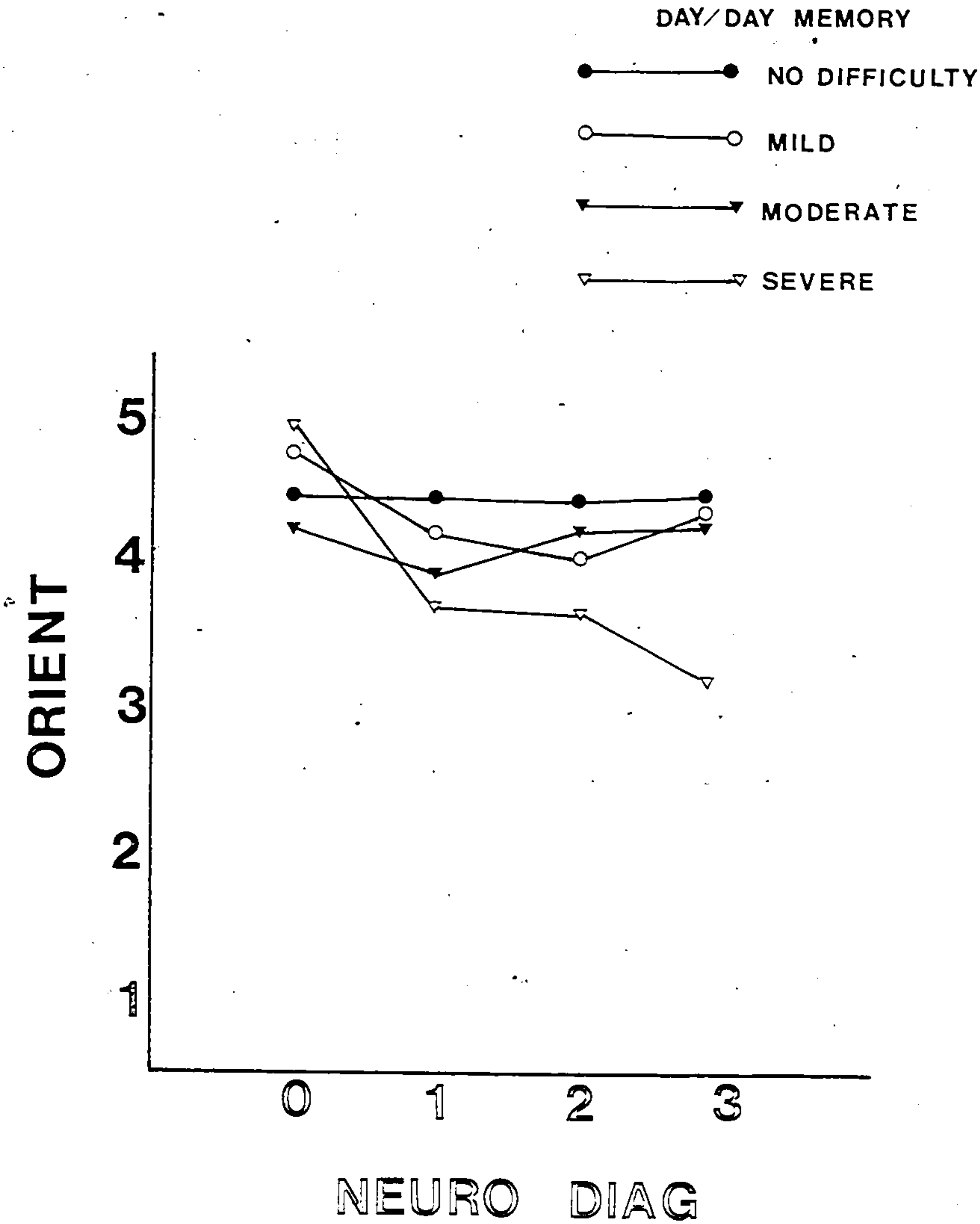

DAY/DAY MEMORY
NO DIFFICULTY
MILD
MODERATE
SEVERE
ORIENT
5
4
3
2
1
0
1
2
3
NEURO DIAG

Figure 14.

with severe memory problems scored significantly lower than the other groups with memory difficulties (Scheffé's analysis $p < .05$).

The analysis of covariance results for each of the revised scales as dependent variables, day to day memory problems as the independent variable and IMPAIRM and WAISFSIQ as covariates are presented in Table 28. It was found that among the cases grouped according to day to day memory problems, the variables IMPAIRM and WAISFSIQ both covaried significantly with each of the following scales: WMSQUOT-REV, OVERMEM-REV, DAYDAY-REV, REMOTE-REV, PRIOR-REV, SUBSEQ-REV, NEURO-REV, INTELL-REV, IMPINDEX-REV, NONVERB-REV, CAT7-REV, and ATTENT-REV. IMPAIRM covaried significantly with TPT-REV. Thus each of the new scales was significantly related to either impairment, full scale I.Q. or both. All but one of the scales was significantly related to both covariates.

With IMPAIRM and WAISFSIQ adjusted for, there was a significant relationship between the following scales and day to day memory problems, WMSQUOT-REV, OVERMEM-REV, DAYDAY-REV, REMOTE-REV, PRIOR-REV, SUBSEQ-REV, INTELL-REV, IMPINDEX-REV and ATTENT-REV. These scales were unrelated to neurological diagnosis and there was no significant interaction between neurological diagnosis and day to day

TABLE 28

Analysis of covariance results for each of the revised scales with impairment and I.Q. as covariates and clinical ratings of day to day memory and neurological diagnosis as independent variables.

Variable	Covariate	Ind. Var.	F	df	SIG
WMSQUOT-REV	IMPAIRM		57.12	1	.000
	WAISFSIQ		63.65	1	.000
		DDMEM	4.50	3	.004
		NDIAG	1.02	3	.383
		INTERACTION	1.28	9	.349
OVERMEM-REV	IMPAIRM		75.34	1	.000
	WAISFSIQ		21.72	1	.000
		DDMEM	7.45	3	.000
		NDIAG	1.16	3	.325
		INTERACTION	.86	9	.566
DAYDAY-REV	IMPAIRM		93.12	1	.000
	WAISFSIQ		12.00	1	.001
		DDMEM	6.99	3	.000
		NDIAG	.99	3	.396
		INTERACTION	.65	9	.753
REMOTE-REV	IMPAIRM		79.54	1	.000
	WAISFSIQ		12.95	1	.000
		DDMEM	6.83	3	.000
		NDIAG	.88	3	.453
		INTERACTION	.82	9	.602
PRIOR-REV	IMPAIRM		28.57	1	.000
	WAISFSIQ		9.40	1	.002
		DDMEM	5.34	3	.001
		NDIAG	2.25	3	.083
		INTERACTION	.89	9	.531

Continued

Variable	Covariate	Ind. Var.	F	df	SIG
SUBSEQ-REV	IMPAIRM		28.44	1	.000
	WAISFSIQ		35.83	1	.000
		DDMEM	7.70	3	.000
		NDIAG	1.66	3	.176
		INTERACTION	1.09	9	.374
NNEURO-REV	IMPAIRM		7.30	1	.007
	WAISFSIQ		12.45	1	.001
		DDMEM	8.72	3	.000
		NDIAG	4.31	3	.006
		INTERACTION	1.85	9	.060
INTELL-REV	IMPAIRM		63.79	1	.000
	WAISFSIQ		100.88	1	.000
		DDMEM	3.98	3	.009
		NDIAG	.67	3	.571
		INTERACTION	1.42	9	.179
IMPINDEX-REV	IMPAIRM		127.76	1	.000
	WAISFSIQ		13.32	1	.000
		DDMEM	3.96	3	.003
		NDIAG	.55	3	.647
		INTERACTION	.66	9	.742
NONVERB-REV	IMPAIRM		105.28	1	.000
	WAISFSIQ		5.21	1	.023
		DDMEM	.76	3	.517
		NDIAG	.37	3	.775
		INTERACTION	.65	9	.753
CAT7-REV	IMPAIRM		124.54	1	.000
	WAISFSIQ		5.97	1	.015
		DDMEM	1.51	3	.212
		NDIAG	.28	3	.843
		INTERACTION	.34	9	.962

Continued

Variable	Covariate	Ind. Var.	F	df	SIG
TPT-REV	IMPAIRM		126.49	1	.000
	WAISFSIQ		2.72	1	.101
		DDMEM	.69	3	.559
		NDIAG	.91	3	.439
		INTERACTION	.82	9	.599
ATTENT-REV	IMPAIRM		113.36	1	.000
	WAISFSIQ		39.77	1	.000
		DDMEM	3.41	3	.018
		NDIAG	.12	3	.948
		INTERACTION	.76	9	.651

memory for these scales. The scale NEURO-REV, was significantly related to both day to day memory problems and neurological diagnosis after the two covariates were adjusted for. The interaction between neurological diagnosis and day to day memory problems was of borderline significance for the scale NEURO-REV. The scales TPT-REV, CAT7-REV and NONVERB-REV were not related to day to day memory problems once impairment and intelligence were adjusted for. Thus in contrast to the WMS subscales, the new majority of the revised scales were significantly related to the ratings of day to day memory after impairment and intelligence were adjusted for. There was only one scale however (NEURO-REV) that was found to be related to neurological diagnosis.

Memory for Remote Events

The analysis of covariance results of each of the WMS subscales among cases grouped according to remote memory problems is presented in Table 29. Here it can be seen that the two covariates IMPAIRM and WAISFSIQ were both significantly related to INFORM, CONTROL, PASSAGES, DIGITS, VISUALR and MEMQUOT. Once the two covariates were accounted for in this analysis, none of the WMS subscales were found to be significantly

TABLE 29

Analysis of covariance results for each of the new scales with impairment and I.Q. as covariates and remote memory problems and neurological diagnosis as independent variables.

Variable	Covariate	Ind. Var.	F	df	SIG
INFORM	IMPAIRM		4.98	1	.027
	WAISFSIQ		53.61	1	.000
		REMMEM	.29	3	.831
		NDIAG	1.80	3	.148
		INTERACTION	1.05	8	.397
ORIENT	IMPAIRM		.66	1	.419
	WAISFSIQ		2.91	1	.018
		REMMEM	1.27	3	.285
		NDIAG	1.38	3	.047
		INTERACTION	1.93	8	.056
CONTROL	IMPAIRM		25.28	1	.000
	WAISFSIQ		6.77	1	.010
		REMMEM	1.24	3	.340
		NDIAG	.56	3	.639
		INTERACTION	1.29	8	.251
PASSAGES	IMPAIRM		8.23	1	.005
	WAISFSIQ		35.29	1	.000
		REMMEM	.95	3	.419
		NDIAG	1.23	3	.300
		INTERACTION	1.24	8	.278

Continued

Variable	Covariate	Ind. Var.	F	df	SIG
DIGITS	IMPAIRM		3.95	1	.048
	WAISFSIQ		23.60	1	.000
		REMMEM	2.31	3	.077
		NDIAG	.07	3	.977
		INTERACTION	.76	8	.642
VISUALR	IMPAIRM		94.92	1	.000
	WAISFSIQ		6.83	1	.010
		REMMEM	.89	3	.446
		NDIAG	1.28	3	.284
		INTERACTION	1.04	8	.409
ASSOCL	IMPAIRM		30.63	1	.000
	WAISFSIQ		1.98	1	.517
		REMMEM	.67	3	.574
		NDIAG	1.01	3	.390
		INTERACTION	.96	8	.466
MEMQUOT	IMPAIRM		5.88	1	.016
	WAISFSIQ		130.45	1	.000
		REMMEM	1.27	3	.064
		NDIAG	2.34	3	.288
		INTERACTION	2.01	8	.048

Fig. 15 Memory Quotient plotted for each of the groups with assessment of difficulty with memory for the remote past as a function of neurological diagnosis. NEURO DIAG: 0 - No lesion, 1 - Right hemisphere, 2 - Left hemisphere, 3 - Bilateral.

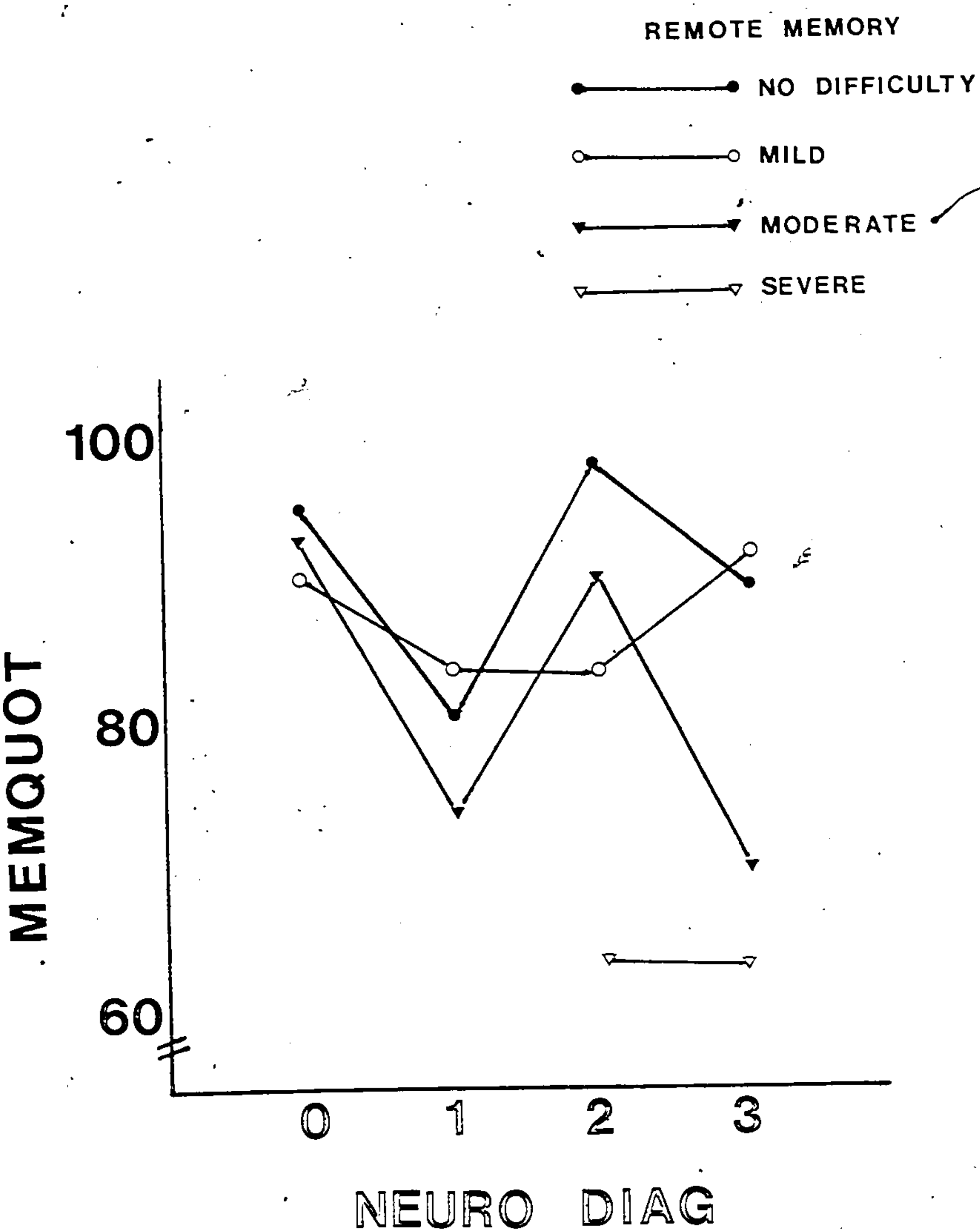

REMOTE MEMORY
NO DIFFICULTY
MILD
MODERATE
SEVERE
100
80
60
MEMQUOT
0
1
2
3
NEURO DIAG

Figure 15.

related to memory problems for the remote past, although there was a significant interaction between neurological diagnosis and memory for the remote past for the variable MEMQUOT.

In Fig. 15, MEMQUOT is plotted as a function of memory for the remote past, and neurological diagnosis. There were no cases without lesion or with right hemisphere lesion who had severe memory problems. The significant interaction was accounted for by the finding that the memory groups differed among the left hemisphere cases ($F = 3.75$, d.f. $= 3.47$, $p < .017$) but there were no differences among the other groups. It was found that among the left hemisphere group, the severe group attained significantly lower scores than the no difficulty group (Scheffé's analysis $p < .05$). The other pairwise comparisons were not found to be significant.

Intelligence (WAISFSIQ) covaried significantly with ORIENT in the comparison of groups with difficulties with remote memory, problems, however once intelligence was controlled for, ORIENT was still significantly related to neurological diagnosis although not to remote memory problems. The interaction between neurological diagnosis and remote memory problems was of borderline significance.

ORIENT is plotted as a function of neurological diagnosis for each of the groups rated on remote memory problems in Fig. 16. Here it can be seen that the interaction is due to the differences between the memory groups among the left hemisphere cases ($F = 7.56$, d.f. $= 3,47$, $p < .0003$). Multiple comparisons indicated that the severe group attained significantly lower scores than the no difficulty group (Scheffé's analysis $p < .05$), the mild group (Scheffé's analysis $p < .05$) and the moderate group (Scheffé's analysis $p < .05$). Other pair-wise comparisons were not significant. ASSOCL was associated with IMPAIRM but once IMPAIRM was accounted for, there were no significant differences among the remote memory groups or neurological groups on ASSOCL.

The analysis of covariance results of the revised scales with remote memory problems is presented in Table 30. The covariates IMPAIRM and WAISFSIQ covaried significantly with the following scales: WMSQUOT-REV, OVERMEM-REV, DAYDAY-REV, REMOTE-REV, PRIOR-REV, SUBSEQ-REV, NEURO-REV, INTELL-REV, IMPINDEX-REV, NONVERB-REV, CAT7-REV, and ATTENT-REV while IMPAIRM covaried significantly with TPT-REV. Once the covariates were adjusted for, there were still significant differences among the

Fig. 16 Orientation plotted as a function for each remote memory group as a function of neurological diagnosis. NEURO DIAG: 0 — No lesion, 1 — Right hemisphere, 2 — Left hemisphere, 3 — Bilateral.

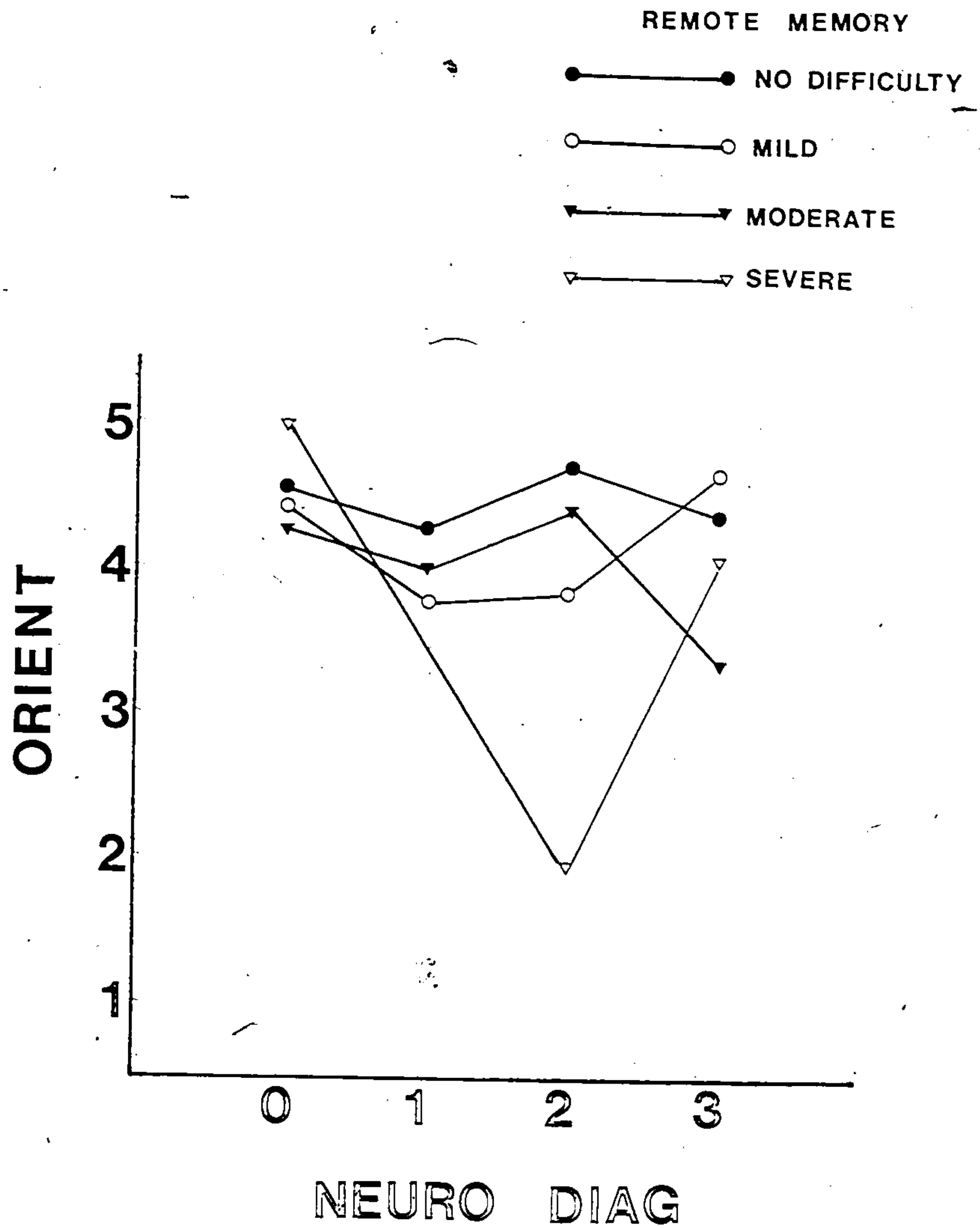

REMOTE MEMORY
NO DIFFICULTY
MILD
MODERATE
SEVERE
ORIENT
5
4
3
2
1
0
1
2
3
NEURO DIAG

Figure 16.

TABLE 30

Analysis of covariance results for each of the revised scales with impairment and I.Q. as covariates and remote memory problems and neurological diagnosis as independent variables.

Variable	Covariate	Ind. Var.	F	df	SIG
WMSQUOT-REV	IMPAIRM		71.13	1	.000
	WAISFSIQ		54.64	1	.000
		REMMEM	1.73	3	.162
		NDIAG	1.46	3	.227
		INTERACTION	1.67	8	.106
OVERMEM-REV	IMPAIRM		82.84	1	.000
	WAISFSIQ		21.03	1	.000
		REMMEM	4.43	3	.005
		NDIAG	.99	3	.399
		INTERACTION	.92	8	.503
DAYDAY-REV	IMPAIRM		108.60	1	.000
	WAISFSIQ		10.07	1	.002
		REMMEM	2.23	3	.086
		NDIAG	.76	3	.519
		INTERACTION	.74	8	.660
REMOTE-REV	IMPAIRM		84.24	1	.000
	WAISFSIQ		12.87	1	.000
		REMMEM	3.85	3	.010
		NDIAG	.95	3	.416
		INTERACTION	1.15	8	.333
PRIOR-REV	IMPAIRM		33.68	1	.000
	WAISFSIQ		9.02	1	.003
		REMMEM	1.98	3	.118
		NDIAG	2.37	3	.071
		INTERACTION	.85	8	.563

Continued

Variable	Covariate	Ind. Var.	F	df	SIG
SUBSEQ-REV	IMPAIRM		40.79	1	.000
	WAISFSIQ		29.87	1	.000
		REMMEM	2.36	3	.072
		NDIAG	2.07	3	.105
		INTERACTION	1.87	8	.065
NEURO-REV	IMPAIRM		12.94	1	.000
	WAISFSIQ		10.47	1	.001
		REMMEM	6.80	3	.000
		NDIAG	4.33	3	.005
		INTERACTION	1.61	8	.123
INTELL-REV	IMPAIRM		71.99		.000
	WAISFSIQ		94.25		.000
		REMMEM	1.36		.257
		NDIAG	.78		.508
		INTERACTION	1.81		.075
IMPINDEX-REV	IMPAIRM		141.51	1	.000
	WAISFSIQ		12.68	1	.000
		REMMEM	1.57	3	.198
		NDIAG	.58	3	.629
		INTERACTION	1.54	8	.146
NONVERB-REV	IMPAIRM		100.87	1	.000
	WAISFSIQ		6.00	1	.015
		REMMEM	1.34	3	.261
		NDIAG	.25	3	.862
		INTERACTION	.69	8	.702
CAT7-REV	IMPAIRM		126.87	1	.000
	WAISFSIQ		6.67	1	.010
		REMMEM	1.33	3	.267
		NDIAG	.09	3	.968
		INTERACTION	.88	8	.532

Continued.

Variable	Covariate	Ind. Var.	F	df	SIG
TPT-REV	IMPAIRM		125.16	1	.000
	WAISFSIQ		2.74	1	.099
		REMMEM	.59	3	.621
		NDIAG	.55	3	.650
		INTERACTION	.21	8	.989
ATTENT-REV	IMPAIRM		119.14	1	.000
	WAISFSIQ		39.72	1	.000
		REMMEM	1.96	3	.121
		NDIAG	.37	3	.776
		INTERACTION	1.12	8	.350

memory groups on the scales OVERMEM-REV, REMOTE-REV and NEURO-REV. For the scales OVERMEM-REV and REMOTE-REV there were no differences among the neurological diagnosis groups and there was no interaction between neurological diagnosis and remote memory problems. For the scale NEURO, the significant difference between the neurological groups was retained after impairment and intelligence was controlled. There was no interaction between neurological diagnosis and remote memory problem.

Overall Memory Problems

The results of the analysis of covariance for the WMS subscales among cases grouped according to overall memory difficulty is presented in Table 31. Both IMPAIRM and WAISFSIQ covaried significantly with the following scales: INFORM, CONTROL, PASSAGES and VISUALR. WAISFSIQ covaried significantly with DIGITS and MEM QUOT and IMPAIRM covaried significantly with ASSOCL. While IMPAIRM and WAISFSIQ were adjusted for these variables, there was no significant differences among either the overall memory groups or the neurological diagnosis groups. While WAISFSIQ covaried with ORIENT significantly, once WAISFSIQ was adjusted for there was

TABLE 31

Analysis of covariance results for WMS subscales as a function of overall memory problems with impairment and intelligence as covariates.

Variable	Covariate	Ind. Var.	F	df	SIG
INFORM	IMPAIRM		7.19	1	.008
	WAISFSIQ		58.29	1	.000
		OVERMEM	.45	3	.719
		NDIAG	.84	3	.474
		INTERACTION	.67	7	.696
ORIENT	IMPAIRM		.07	1	.794
	WAISFSIQ		6.05	1	.015
		OVERMEM	4.91	3	.003
		NDIAG	3.66	3	.013
		INTERACTION	3.94	7	.000
CONTROL	IMPAIRM		16.08	1	.000
	WAISFSIQ		10.48	1	.000
		OVERMEM	.85	3	.466
		NDIAG	.59	3	.620
		INTERACTION	1.71	7	.108
PASSAGES	IMPAIRM		8.02	1	.005
	WAISFSIQ		34.26	1	.000
		OVERMEM	.75	3	.522
		NDIAG	1.50	3	.215
		INTERACTION	.87	7	.532
DIGITS	IMPAIRM		2.94	1	.088
	WAISFSIQ		27.80	1	.000
		OVERMEM	.40	3	.756
		NDIAG	.45	3	.720
		INTERACTION	1.99	7	.059

Continued

Variable	Covariate	Ind. Var.	F	df	SIG
VISUALR	IMPAIRM		90.02	1	.000
	WAISFSIQ		5.87	1	.016
		OVERMEM	1.92	3	.129
		NDIAG	.81	3	.491
		INTERACTION	.99	7	.438
ASSOCL	IMPAIRM		24.43	1	.000
	WAISFSIQ		2.99	1	.085
		OVERMEM	.98	3	.406
		NDIAG	.64	3	.588
		INTERACTION	1.22	7	.295
MEMQUOT	IMPAIRM		3.87	1	.051
	WAISFSIQ		131.64	1	.000
		OVERMEM	.42	3	.183
		NDIAG	1.68	3	.736
		INTERACTION	1.67	7	.172

still a significant effect for OVERMEM and NDIAG. There was a significant interaction between OVERMEM and NDIAG.

ORIENT is plotted as a function of neurological diagnosis for each of the memory difficulty groups in Fig. 17. Here it can be seen that the interaction was accounted for by the significant difference among the memory groups for those with bilateral lesions ($F = 82.52$, d.f. = 3,47, $p < .0002$). Multiple comparisons indicated that the severe group attained significantly lower scores among the bilateral patients than any of the other memory groups (Scheffé's analysis $p < .05$).

The results of the analysis of covariance for the revised scales among cases grouped according to the rating of overall memory difficulty is presented in Table 32. Here it can be seen that both IMPAIRM and WAISFSIQ covary significantly with the following scales: WMSQUOT-REV, OVERMEM-REV, REMOTE-REV, PRIOR-REV, SUBSEQ-REV, NEURO-REV, INTELL-REV, IMPINDEX-REV, NONVERB-REV, CAT7-REV and ATTENT-REV. The covariate IMPAIRM covaried significantly with TPT-REV. Thus while the covariates accounted for a significant proportion of the variance among each of the revised scales there were still significant differences between the different groups classified with overall

Fig. 17 Orientation plotted for overall memory groups as a function of neurological diagnosis. NEURO DIAG: 0 - No lesion, 1 - Right hemisphere, 2 - Left hemisphere, 3 - Bilateral.

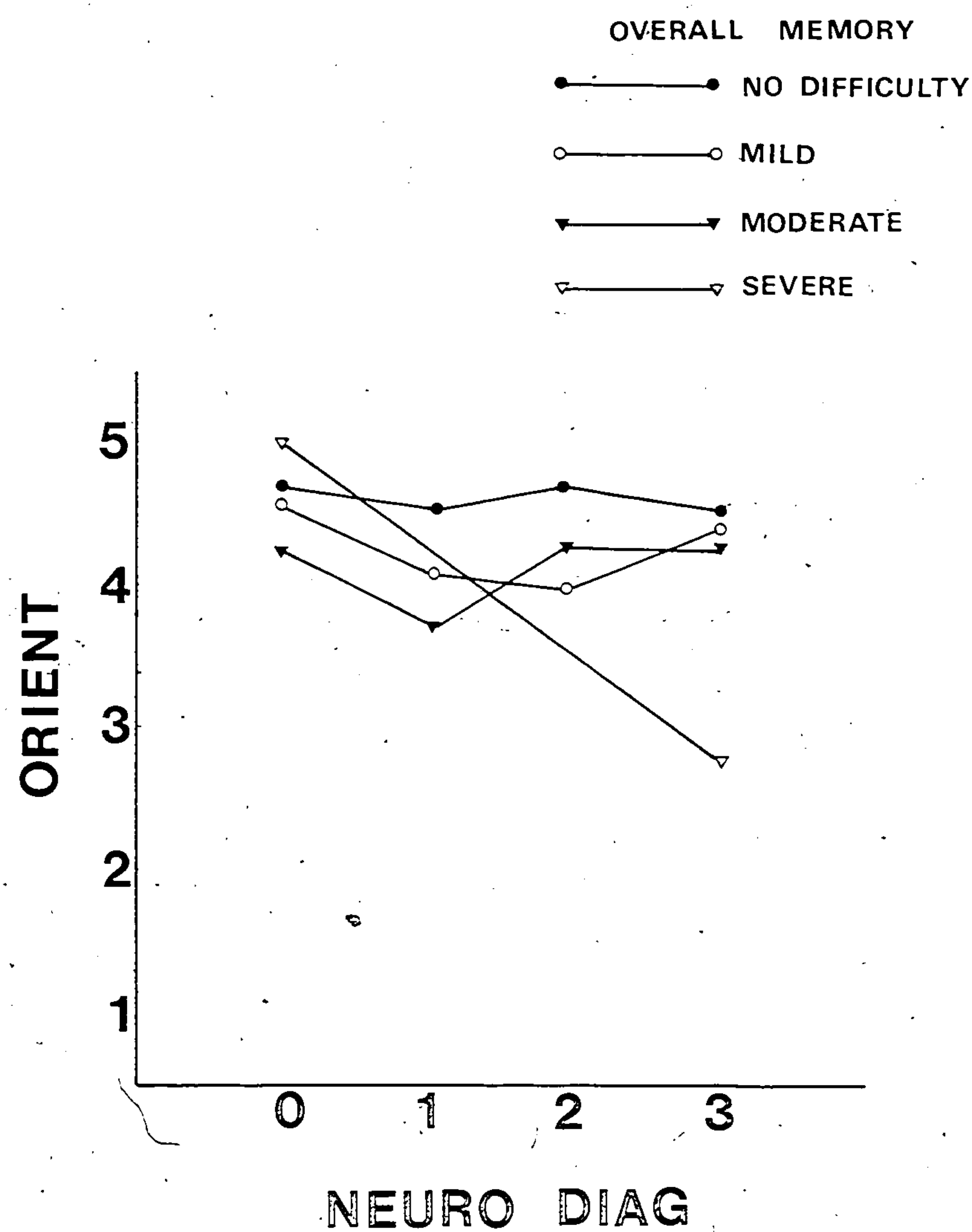

OVERALL MEMORY
NO DIFFICULTY
MILD
MODERATE
SEVERE
5
4
3
2
1
ORIENT
0
1
2
3
NEURO DIAG

Figure 17.

TABLE 32

Analysis of covariance results for the revised scales with IMPAIRM and WAISFSIQ as covariates and overall memory and neurological diagnosis as independent variables.

Variable	Covariate	Ind. Var.	F	df	SIG
WMSQUOT-REV	IMPAIRM		57.10	1	.000
	WAISFSIQ		63.94	1	.000
		OVERMEM	3.41	3	.018
		NDIAG	1.35	3	.258
		INTERACTION	1.51	7	.164
OVERMEM-REV	IMPAIRM		71.82	1	.000
	WAISFSIQ		23.07	1	.000
		OVERMEM	7.16	3	.000
		NDIAG	.90	3	.443
		INTERACTION	.81	7	.584
DAYDAY-REV	IMPAIRM		90.78	1	.000
	WAISFSIQ		12.45	1	.001
		OVERMEM	5.62	3	.001
		NDIAG	.54	3	.653
		INTERACTION	.87	7	.531
REMOTE-REV	IMPAIRM		75.79	1	.000
	WAISFSIQ		14.64	1	.000
		OVERMEM	6.41	3	.000
		NDIAG	.86	3	.462
		INTERACTION	.96	7	.459
PRIOR-REV	IMPAIRM		27.27	1	.000
	WAISFSIQ		10.24	1	.002
		OVERMEM	4.83	3	.003
		NDIAG	2.04	3	.109
		INTERACTION	.81	7	.580

Continued

Variable	Covariate	Ind. Var.	F	df	SIG
SUBSEQ-REV	IMPAIRM		26.81	1	.000
	WAISFSIQ		38.64	1	.000
		OVERMEM	6.95	3	.000
		NDIAG	2.55	3	.057
		INTERACTION	1.26	7	.270
NEURO-REV	IMPAIRM		8.57	1	.004
	WAISFSIQ		13.33	1	.000
		OVERMEM	6.81	3	.000
		NDIAG	6.08	3	.001
		INTERACTION	1.49	7	.170
INTELL-REV	IMPAIRM		63.60	1	.000
	WAISFSIQ		101.94	1	.000
		OVERMEM	2.93	3	.034
		NDIAG	1.31	3	.273
		INTERACTION	1.75	7	.10
IMPINDEX-REV	IMPAIRM		126.16	1	.000
	WAISFSIQ		14.81	1	.000
		OVERMEM	2.22	3	.087
		NDIAG	.68	3	.567
		INTERACTION	1.24	7	.279
NONVERB-REV	IMPAIRM		94.97		.000
	WAISFSIQ		6.07		.014
		OVERMEM	1.78		.152
		NDIAG	.17		.917
		INTERACTION	.75		.628
CAT7-REV	IMPAIRM		115.85		.000
	WAISFSIQ		7.01		.009
		OVERMEM	2.04		.109
		NDIAG	.32		.813
		INTERACTION	.51		.831

Continued

Variable	Covariate	Ind. Var.	F	df	SIG
TPT-REV	IMPAIRM		116.09		.000
	WAISFSIQ		3.00		.085
		OVERMEM	1.41		.240
		NDIAG	.70		.556
		INTERACTION	.68		.689
ATTENT-REV	IMPAIRM		113.60	1	.000
	WAISFSIQ		41.51	1	.000
		OVERMEM	3.43	3	.018
		NDIAG	.15	3	.932
		INTERACTION	1.36	7	.225

memory difficulties after the covariates had been adjusted for among the following variables: WMSQUOT-REV, OVERMEM-REV, DAYDAY-REV, REMOTE-REV, PRIOR-REV, SUBSEQ-REV, NEURO-REV, INTELL-REV and ATTENT-REV. Additionally, the neurological diagnosis groups were significantly different after IMPAIRM and WAISFSIQ were adjusted for on the variable NEURO-REV.

Memory Prior to Onset

The analysis of covariance results for the traditional scales among cases grouped according to memory function for events prior to onset are presented in Table 33. There were no significant differences among either the memory groups or the neurological groups on any of the WMS subscales. Additionally, neither IMPAIRM nor WAISFSIQ covaried significantly with any of the scales among the memory groups or among the neurological groups.

The results of the analysis of covariance for the revised scales among the cases grouped according to memory difficulty for events prior to onset are presented in Table 34. Here again none of the scales differed significantly among the memory group or the neurological diagnosis groups. Additionally, IMPAIRM and WAISFSIQ did not covary significantly with any of the scales.

TABLE 33

Analysis of covariance results for WMS subscales with impairment and I.Q. as covariates and memory prior to onset and neurological diagnosis as independent variables.

Variable	Covariate	Ind. Var.	F	df	SIG
INFORM	IMPAIRM		.50	1	.518
	WAISFSIQ		.03	1	.866
		PRIOTR	.37	3	.780
		NDIAG	.46	3	.723
		INTERACTION	.48	4	.753
ORIENT	IMPAIRM		6.82	1	.059
	WAISFSIQ		1.61	1	.273
		PRIOTR	1.95	1	.263
		NDIAG	1.74	3	.297
		INTERACTION	1.78	4	.295
CONTROL	IMPAIRM		.013	1	.914
	WAISFSIQ		.035	1	.860
		PRIOTR	.09	3	.962
		NDIAG	.84	3	.538
		INTERACTION	.47	4	.760
PASSAGES	IMPAIRM		.72	1	.443
	WAISFSIQ		1,45	1	.296
		PRIOTR	1.08	3	.454
		NDIAG	1.09	3	.451
		INTERACTION	1.27	4	.410
DIGITS	IMPAIRM		.148	1	.737
	WAISFSIQ		.261	1	.660
		PRIOTR	.179	3	.903
		NDIAG	.064	3	.974
		INTERACTION	.092	4	.958

Continued

Variable	Covariate	Ind. Var.	F	df	SIG
VISUALR	IMPAIRM		2.62	1	.247
	WAISFSIQ		.00	1	.999
		PRIOTR	.75	3	.616
		NDIAG	1.79	3	.378
		INTERACTION	.72	4	.627
ASSOCL	IMPAIRM		1.64	1	.329
	WAISFSIQ		.87	1	.449
		PRIOTR	.33	3	.813
		NDIAG	.29	3	.831
		INTERACTION	.63	4	.660
MEMQUOT	IMPAIRM		.45	1	.571
	WAISFSIQ		1.66	1	.326
		PRIOTR	1.51	3	.422
		NDIAG	.72	3	.626
		INTERACTION	.40	4	.771

TABLE 34

Analysis of covariance results for the revised scales with impairment and I.Q. as covariates and memory prior to onset and neurological diagnosis as independent variables.

Variable	Covariate	Ind. Var.	F	df	SIG
WMSQUOT-REV	IMPAIRM		1.19	1	.337
	WAISFSIQ		.13	1	.742
		PRIOTR	.49	3	.710
		NDIAG	.22	3	.879
		INTERACTION	.42	4	.789
OVERMEM-REV	IMPAIRM		5.41	1	.081
	WAISFSIQ		.23	1	.660
		PRIOTR	1.09	3	.448
		NDIAG	.27	3	.846
		INTERACTION	.40	4	.801
DAYDAY-REV	IMPAIRM		2.90	1	.164
	WAISFSIQ		.52	1	.513
		PRIOTR	.56	3	.669
		NDIAG	.13	3	.841
		INTERACTION	.22	4	.916
REMOTE-REV	IMPAIRM		2.80	1	.170
	WAISFSIQ		.02	1	.907
		PRIOTR	.90	3	.519
		NDIAG	.11	3	.951
		INTERACTION	.39	4	.810
PRIOR-REV	IMPAIRM		3.20	1	.148
	WAISFSIQ		.86	1	.406
		PRIOTR	2.10	3	.242
		NDIAG	.88	3	.523
		INTERACTION	.47	4	.756

Continued

Variable	Covariate	Ind. Var.	F	df	SIG
SUBSEQ-REV	IMPAIRM		4.18	1	.110
	WAISFSIQ		.01	1	.830
		PRIOTR	5.08	3	.075
		NDIAG	1.33	3	.381
		INTERACTION	.19	4	.932
NEURO-REV	IMPAIRM		5.54	1	.078
	WAISFSIQ		.86	1	.406
		PRIOTR	.56	3	.672
		NDIAG	.70	3	.600
		INTERACTION	.71	4	.626
INTELL-REV	IMPAIRM		1.85	1	.245
	WAISFSIQ		.11	1	.758
		PRIOTR	1.24	3	.405
		NDIAG	.36	3	.788
		INTERACTION	.32	4	.852
IMPINDEX-REV	IMPAIRM		1.77	1	.255
	WAISFSIQ		.02	1	.904
		PRIOTR	.45	3	.731
		NDIAG	.01	3	.997
		INTERACTION	.28	4	.877
NONVERB-REV	IMPAIRM		.67	1	.460
	WAISFSIQ		.64	1	.470
		PRIOTR	1.43	3	.358
		NDIAG	1.94	3	.265
		INTERACTION	2.32	4	.218
CAT7-REV	IMPAIRM		1.81	1	.250
	WAISFSIQ		.04	1	.854
		PRIOTR	.44	3	.735
		NDIAG	.25	3	.859
		INTERACTION	.42	4	.791

Variable	Covariate	Ind. Var.	F	df	SIG
TPT-REV	IMPAIRM		.40	1	.560
	WAISFSIQ		2.00	1	.230
		PRIOTR	.52	3	.690
		NDIAG	3.24	3	.143
		INTERACTION	3.44	4	.129
ATTENT-REV	IMPAIRM		2.19	1	.213
	WAISFSIQ		.38	1	.513
		PRIOTR	.84	3	.537
		NDIAG	.66	3	.619
		INTERACTION	.08	4	.984

Memory for Events Subsequent to Onset

The results of the analysis of covariance for the WMS subscales among the cases grouped according to memory for events subsequent to onset are presented in Table 35. Here it can be seen that none of the scales was significantly related to either the memory ratings for events subsequent to onset or neurological diagnosis. Additionally, neither IMPAIRM nor WAISFSIQ covaried significantly with any of the scales.

The results of the analysis of covariance for the new scales among cases grouped according to memory for events subsequent to onset and neurological diagnosis are presented in Table 36. It can be seen that there are no differences among the groups on any of the scales and neither IMPAIRM nor WAISFSIQ covary significantly with any of the scales.

Summary

The analysis of covariance indicated that either intelligence, impairment or both covary significantly with the relationship between each of the WMS subscales and the clinical ratings of day to day memory, remote memory and overall memory functions. Once these covariates were adjusted for, with the exception of

TABLE 35

Analysis of covariance results for the WMS subscales with impairment and I.Q. as covariates and memory subsequent to onset and neurological diagnosis as independent variables.

Variable	Covariate	Ind. Var.	F	df	SIG
INFORM	IMPAIRM		1.71	1	.212
	WAISFSIQ		.81	1	.384
		SUBSTR	2.06	3	.152
		NDIAG	.44	3	.727
		INTERACTION	.62	5	.690
ORIENT	IMPAIRM		.04	1	.836
	WAISFSIQ		.01	1	.915
		SUBSTR	.08	3	.871
		NDIAG	.89	3	.470
		INTERACTION	.19	5	.962
CONTROL	IMPAIRM		.72	1	.410
	WAISFSIQ		.00	1	.974
		SUBSTR	.33	3	.802
		NDIAG	.70	3	.570
		INTERACTION	1.71	5	.198
PASSAGES	IMPAIRM		.07	1	.792
	WAISFSIQ		9.32	1	.009
		SUBSTR	1.18	3	.354
		NDIAG	.69	3	.572
		INTERACTION	1.88	5	.162

Continued

Variable	Covariate	Ind. Var.	F	df	SIG
DIGITS	IMPAIRM		.06	1	.808
	WAISFSIQ		6.42	1	.030
		SUBSTR	.67	3	.589
		NDIAG	.37	3	.776
		INTERACTION	2.40	5	.119
VISUALR	IMPAIRM		1.41	1	.262
	WAISFSIQ		3.83	1	.079
		SUBSTR	.28	3	.838
		NDIAG	1.45	3	.286
		INTERACTION	.15	5	.957
ASSOCL	IMPAIRM		.55	1	.477
	WAISFSIQ		1.09	1	.321
		SUBSTR	.79	3	.529
		NDIAG	.82	3	.515
		INTERACTION	1.10	5	.409
MEMQUOT	IMPAIRM		.70	1	.423
	WAISFSIQ		30.88	1	.000
		SUBSTR	1.30	3	.329
		NDIAG	2.92	3	.087
		INTERACTION	3.09	5	.067

TABLE 36

Analysis of covariance results for the revised scales with impairment and I.Q. as covariates and memory for events subsequent to trauma and neurological diagnosis as independent variables.

Variable	Covariate	Ind. Var.	F	df	SIG
WMSQUOT-REV	IMPAIRM		2.70	1	.122
	WAISFSIQ		2.98	1	.106
		SUBSTR	.84	3	.496
		NDIAG	.15	3	.927
		INTERACTION	1.27	5	.329
OVERMEM-REV	IMPAIRM		4.64	1	.049
	WAISFSIQ		3.13	1	.099
		SUBSTR	.32	3	.811
		NDIAG	.17	3	.912
		INTERACTION	.45	5	.810
DAYDAY-REV	IMPAIRM		2.17	1	.163
	WAISFSIQ		1.35	1	.265
		SUBSTR	.54	3	.660
		NDIAG	.21	3	.889
		INTERACTION	.47	5	.792
REMOTE-REV	IMPAIRM		4.13	1	.050
	WAISFSIQ		3.09	1	.100
		SUBSTR	.41	3	.762
		NDIAG	.14	3	.925
		INTERACTION	.76	5	.658
PRIOR-REV	IMPAIRM		2.96	1	.107
	WAISFSIQ		1.08	1	.315
		SUBSTR	.33	3	.804
		NDIAG	.45	3	.724
		INTERACTION	1.13	5	.388

Continued

Variable	Covariate	Ind. Var.	F	df	SIG
SUBSEQ-REV	IMPAIRM		.02	1	.902
	WAISFSIQ		7.29	1	.017
		SUBSTR	.31	3	.821
		NDIAG	1.03	3	.408
		INTERACTION	.61	5	.693
NEURO-REV	IMPAIRM		1.62	1	.224
	WAISFSIQ		.02	1	.900
		SUBSTR	.21	3	.891
		NDIAG	.38	3	.773
		INTERACTION	.70	5	.632
INTELL-REV	IMPAIRM		4.20	1	.060
	WAISFSIQ		9.34	1	.009
		SUBSTR	.26	3	.854
		NDIAG	.18	3	.905
		INTERACTION	1.26	5	.336
IMPINDEX-REV	IMPAIRM		6.11	1	.027
	WAISFSIQ		1.16	1	.300
		SUBSTR	.62	3	.615
		NDIAG	.13	3	.941
		INTERACTION	.41	5	.835
NONVERB-REV	IMPAIRM		6.40	1	.024
	WAISFSIQ		3.70	1	.075
		SUBSTR	.37	3	.774
		NDIAG	1.09	3	.386
		INTERACTION	.41	5	.837
CAT7-REV	IMPAIRM		7.96	1	.014
	WAISFSIQ		.95	1	.345
		SUBSTR	.50	3	.691
		NDIAG	.24	3	.866
		INTERACTION	.26	5	.926

Continued

Variable	Covariate	Ind. Var.	F	df	SIG
TPT-REV	IMPAIRM		11.36	1	.005
	WAISFSIQ		.81	1	.383
		SUBSTR	.25	3	.863
		NDIAG	1.38	3	.269
		INTERACTION	.70	5	.632
ATTENT-REV	IMPAIRM		9.79	1	.007
	WAISFSIQ		7.19	1	.018
		SUBSTR	.38	3	.772
		NDIAG	.63	3	.609
		INTERACTION	1.20	5	.360

ORIENT, which is low among those bilateral patients with severe memory problems, the WMS subscales were unrelated to any of the clinical ratings. There was no interaction between the side of the lesion and clinical rating for the WMS subscales (other than ORIENT).

The revised scales however generally were related to clinical memory ratings after intelligence and impairment were controlled for. It had been seen previously that the new scales tend to drop as a function of the severity of the memory disorder. In general, the relationship between the new scales and clinical memory ratings did not depend on the neurological diagnosis. The only scale that was significantly related to neurological diagnosis was NEURO.

Cross Validation

Stepwise discriminant function analyses were carried out employing only those subjects that had been administered the WMS on more than one occasion. Only the test scores that had been obtained subsequent to the initial testing were employed to predict group membership. This then represented a cross validation employing 93 subjects that had received a follow-up from the initial referral. Sixty one of these subjects had not received the WMS at first referral. This then represents a sample of subjects which partially overlaps the validation sample (32 subjects) but tested at a different phase of the referral process (at follow-up). Subjects receiving a follow-up evaluation can be considered a subsample of first time referrals and are younger with higher levels of psychometric intelligence (see Table 2).

Separate discriminant analyses were conducted for the WMS subscales and the revised scales. In the first set of analyses the old and new scales were each required to classify cases into either the no difficulty, mild, moderate or severe memory problem categories for each of the clinical ratings. The results of these discriminant function analyses are presented in Table 37. The WMS subscales, when required to classify cases into one of four groups were able to classify between 39.58% and 62.50% of the cases. This range compares favourably to the 32.43% to 50.00% range obtained among the original sample. The classification rates were statistically significant for overall memory difficulty (Wilk's Lambda = .6660, $p < .0010$), day to day memory problems (Wilk's Lambda = .6259, $p < .0015$), remote memory problems (Wilk's Lambda = .6991, $p < .0100$), memory for events prior to onset (Wilk's Lambda = .5781, $p < .0216$), memory for events subsequent to onset (Wilk's Lambda = .5508, $p < .0097$) but not for neurological diagnosis.

TABLE 37

Discriminant results: cross validation results using WMS subscales and revised scales to predict memory problem (no difficulty, mild, moderate or severe) and neurological diagnosis (no lesion right, left and bilateral) the four group classification.

Criterion	WMS Subscales			Revised Scales		
	% Class	Wilk's	P	% Class	Wilk's	P
Overall	45.12	.6660	.0010	54.22	.5837	.0000
Day to Day	46.34	.6259	.0015	46.99	.6271	.0015
Remote	50.00	.6991	.0100	54.22	.7794	.0086
Prior to onset	62.50	.5781	.0216	69.39	.2666	.0000
Subsequent to onset	51.22	.5508	.0097	68.00	.3827	.0001
Neurological diagnosis	39.58	.7810	.2931	58.49	.6456	.0931

In the cross validation sample, the revised scales again predict memory group in the four group classification at a higher rate overall than the WMS subscales. The range is from 46.99% to 69.39% of the cases correctly classified. This also compares favourably to the 44.33% to 78.57% range reported among the original sample. The classification rates were statistically significant for overall memory (Wilk's Lambda = .5837, $p < .0000$), day to day memory (Wilk's Lambda = .6271, $p < .0015$), remote memory (Wilk's Lambda = .6456, $p < .0931$) and memory for events subsequent to onset (Wilk's Lambda = .3827, $p < .0001$). The prediction rates for neurological diagnosis were not statistically significant.

A second set of discriminant analyses were carried out on the WMS subscales and the revised scales requiring a prediction to only two groups, either no memory problem or a mild memory problem distinguished from a moderate or severe problem and no lesion distinguished from those with confirmed evidence of cerebral lesion. The results are presented in Table 38. Here it can be seen that the WMS subscales predicted between 60.00% and 77.11% of the variance. This again is a considerably higher prediction rate than in the four group classification rate.

TABLE 38

Discriminant results: cross validation results using WMS subscales and revised scales to predict memory problem (no difficulty and mild versus moderate and severe) and neurological diagnosis (no lesion versus those with right, left or bilateral lesions), the two group classification.

Criterion	WMS Subscales			Revised Scales		
	% Class	Wilk's	P	% Class	Wilk's	P
Overall	71.43	.7860	.0000	71.23	.7209	.0002
Day to Day	67.07	.7968	.0013	70.24	.7999	.0001
Remote	77.11	.7611	.0020	78.31	.7030	.0011
Prior to onset	65.31	.8180	.0600	91.84	.4717	.0030
Subsequent to onset	60.00	.8633	.0016	72.00	.6664	.0016
Neurological diagnosis	56.86	.9747	.0500	73.21	.8204	.0500

The prediction rates were statistically significant for the overall memory rating (Wilk's Lambda = .7860, $p < .0000$), day to day memory (Wilk's Lambda = .7968, $p < .0013$), remote memory (Wilk's Lambda = .7611, $p < .0020$), memory prior to onset (Wilk's Lambda = .8189, $p < .0600$), memory subsequent to onset (Wilk's Lambda = .8633, $p < .0016$) and neurological diagnosis (Wilk's Lambda = .9747, $p < .0500$). Thus in the cross validation sample, the WMS subscales were again significantly related to each of the criterion variables.

The classification rates for the revised scales presented in Table 38, indicate that between 70.24% and 91.84% of the cases were classified according to group correctly. Again this compares favourably with the prediction rates obtained in the initial sample (between 68.42% and 83.33%). The revised scales predicted significantly according to the two group classification rate for each criterion variable including overall memory problems (Wilk's Lambda = .7209, $p < .0002$), day to day memory problems (Wilk's Lambda = .7999, $p < .0001$), remote memory problems (Wilk's Lambda = .7939, $p < .0011$), memory for events prior to onset (Wilk's Lambda = .4717, $p < .0030$), memory for events subsequent to onset (Wilk's Lambda = .6664, $p < .0016$) and neurological diagnosis

(Wilk's Lambda = .8204, $p < .0500$). Thus in the cross validation sample, the new scales were significantly related to each of the criterion variables.

<u>Reliability</u>

Those cases that had been administered the WMS on first testing and then again on a second testing were selected in order that test-retest reliability coefficients could be calculated. The Pearson product moment correlation coefficients of the scores on first testing with the scores on second testing are presented in Table 39. Each WMS subscale and the Memory Quotient were found to yield statistically significant reliability coefficients. The most reliable of the WMS subscales were found to be DIGITS ($r = .8027$, $p < .000$), PASSAGES ($r = .7577$, $p < .000$) and MEMQUOT ($r = .7391$, $p < .000$). Among the new scales, those yielding the highest reliability coefficients were WMSQUOT-REV ($r = .7454$, $p < .000$), INTELL-REV ($r = .7514$, $p < .000$) and PRIOR-REV ($r = .7319$, $p < .000$). The scales found to be fairly unreliable were TPT-REV ($r = .4958$, $p < .002$), CAT7-REV ($r = .5307$, $p < .001$), ASSOCL-REV ($r = .4815$, $p < .007$) and ORIENT-REV ($r = .5357$, $p < .001$).

TABLE 39

Test-retest reliability coefficients
for WMS subscales and revised scales.

	r	n	p
INFORM	.6014	32	.000
ORIENT	.5357	32	.001
CONTROL	.6210	31	.000
PASSAGES	.7577	31	.000
DIGITS	.8027	32	.000
VISUALR	.5569	32	.000
ASSOCL	.4815	25	.007
MEMQUOT	.7391	32	.000
WMSQUOT-REV	.7454	32	.000
OVERMEM-REV	.7043	32	.000
DAYDAY-REV	.6779	32	.000
REMOTE-REV	.6634	32	.000
PRIOR-REV	.7319	32	.000
SUBSEQ-REV	.6614	32	.000
NEURO-REV	.6892	32	.000
INTELL-REV	.7514	32	.000
IMPINDEX-REV	.6216	32	.000
NONVERB-REV	.4273	32	.007
CAT7-REV	.5307	32	.001
TPT-REV	.4958	32	.002
ATTENT-REV	.0522	32	.000

Norms

The means and standard deviations for each of the WMS subscales are presented according to age in Table 40. The age groups included were from 15-30 years, 31-45 years, 46-60 years and 61-75 years. Tests of linear trend indicated that the following scales dropped significantly as a function of increased age: CONTROL ($F = 26.01$, d.f. = 1,469, $p < .0000$), PASSAGES ($F = 18.28$, d.f. = 1,469, $p < .0000$), DIGITS ($F = 4.79$, d.f. = 1,469, $p < .0292$), VISUALR ($F = 134.78$, d.f. = 1,469, $p < .0000$), and ASSOCL ($F = 47.95$, d.f. = 1,469, $p < .0000$). INFORM and ORIENT did not drop significantly with increased age.

Conversion tables from raw scores to percentile scores, standard scores (mean of 50, standard deviation of 10) and scale scores (mean of 10, standard deviation of 3) are presented in Table 41. The percentiles were arrived at from cumulative frequency distributions. Percentiles were converted to scale scores and standard scores according to the conversion tables presented by Jastak and Jastak (1976).

TABLE 40

Means, standard deviations and number of cases for each of the WMS subscales according to age (15-30 years, 31-45 years, 46-60 years, 61-75 years).

	AGE												Test of Linear Trend		
	15 - 30			31 - 45			46 - 60			61 - 75					
WMS Subscale	$\overline{X}$	σ	n	$\overline{X}$	σ	n	$\overline{X}$	σ	n	$\overline{X}$	σ	n	F	df	P
INFORM	4.29	1.26	301	4.35	1.22	52	4.47	1.50	82	4.46	1.46	37	2.11	1,469	.1467
ORIENTATION	4.53	.81	300	4.33	.94	52	4.32	.94	82	4.41	.83	37	3.08	1,469	.0800
MENTAL CONTROL	6.35	2.24	300	5.44	2.72	52	5.17	2.41	82	4.87	2.00	37	26.01	1,469	.0000
PASSAGES	8.36	3.71	301	7.23	3.13	52	6.38	3.35	82	6.93	3.47	37	18.28	1,469	.0000
DIGITS	10.75	2.35	301	10.31	2.40	52	10.38	2.24	82	9.92	2.14	37	4.79	1,469	.0292
VIS REP	8.74	3.21	301	6.71	3.90	52	4.99	3.09	82	3.84	3.05	37	134.78	1,469	.0000
ASSOC LEARN	13.60	4.00	218	11.61	4.36	52	10.68	3.76	71	9.53	3.76	34	47.95	1,469	.0000

TABLE 41

Raw score conversion tables of *WMS* subscales to percentiles, standard scores and scale scores.

WMS Subscales	Raw Score	AGE											
		15 - 30			30 - 45			45 - 60			60 - 75		
		%ile	Stand Score	Scale Score	%ile	Stand Score	Scale Score	%ile	Stand Score	Scale Score	%ile	Stand Score	Scale Score
INFORMATION	0							2	29	4			
	1	1	25	3				4	33	5	5	34	5
	2	6	35	6	8	36	6	11	38	6	11	38	6
	3	30	45	8	25	43	8	24	43	8	24	43	8
	4	58	52	11	54	51	10	42	48	9	43	48	9
	5	76	57	12	79	58	12	70	55	12	70	55	12
	6	100	80	19	100	80	19	100	80	19	100	80	19
ORIENTATION	0							1	26	3			
	1	1	25	3	2	29	4	2	29	4	< 5	34	< 5
	2	4	33	5	8	36	6	5	34	5	5	34	5
	3	11	38	6	12	38	6	11	38	6	11	38	6
	4	32	45	9	46	49	10	49	50	10	43	48	9
	5	100	80	19	100	80	19	100	80	19	100	80	19

Continued

		15 - 30			30 - 45			45 - 60			60 - 75		
MENTAL CONTROL	0				4	33	5	4	33	5			
	1	2	29	4	6	35	6	5	34	5	3	31	4
	2	3	31	4	19	41	7	18	41	7	11	38	6
	3	7	35	6	27	44	8	24	43	8	27	44	8
	4	11	38	6	39	47	9	37	47	9	46	49	10
	5	27	44	8	50	50	10	59	52	11	62	53	11
	6	58	52	11	60	53	11	66	54	11	81	59	13
	7	65	54	11	73	56	12	81	59	13	92	64	14
	8	73	56	12	79	58	12	90	63	14	100	80	19
	9	100	80	19	100	80	19	100	80	19			
DIGITS	0- 6.0	2	29	4	6	35	5	2	29	4	3	31	3
	7.0	5	34	5	12	38	6	7	35	6	11	38	6
	8.0	14	39	7	23	43	8	22	42	8	30	45	8
	9.0	31	45	8	37	47	9	37	47	9	49	50	10
	10.0	47	49	10	54	49	10	55	51	11	65	54	11
	11.0	63	53	11	73	44	12	70	55	12	73	56	12
	12.0	78	58	12	81	59	13	79	58	12	84	60	13
	13.0	87	62	14	85	61	13	90	63	14	95	66	15
	14.0	93	65	14	98	71	16	98	71	16	100	80	19
	15.0	100	80	19	100	80	19	100	80	19			

Continued

	15 - 30			30 - 45			45 - 60			60 - 75		
PASSAGES												
0- 1.0	2	29	4	0	20	0	4	33	5	5	34	5
1.0- 2.0	4	33	5	2	29	4	11	38	6	8	36	6
2.0- 3.0	6	35	6	6	35	6	16	40	7	14	39	7
3.0- 4.0	14	39	7	17	41	7	28	44	8	19	41	9
4.0- 5.0	20	42	8	27	44	8	41	48	9	332	45	9
5.0- 6.0	32	45	9	42	48	9	55	51	11	46	49	10
6.0- 7.0	41	48	9	54	51	10	65	54	11	54	51	10
7.0- 8.0	49	50	10	65	54	11	71	56	12	65	54	11
8.0- 9.0	57	52	11	77	58	12	78	58	12	73	56	12
9.0-10.0	65	54	11	79	58	12	83	60	13	84	60	13
10.0-11.0	76	57	12	85	61	13	90	63	14	89	63	14
11.0-12.0	82	59	13	94	66	15	96	67	15	95	66	15
12.0-13.0	89	63	14	96	67	15	98	71	16	95	66	15
13.0-14.0	93	65	14	98	71	16	98	71	16	95	66	15
14.0-15.0	97	69	16	98	71	16	99	76	17	100	80	19
15.0-16.0	98	71	16	100	80	19	100	80	19			
16.0-17.0	100	80	19									
17.0-18.0	100	80	19									
18.0-19.0	100	80	19									

Continued

		15 - 30			30 - 45			45 - 60			60 - 75		
VISUAL REP	0.	1	25	3	2	29	4	7	35	6	11	38	6
	1.0	2	29	4	10	37	6	16	40	7	27	44	8
	2.0	5	34	5	17	41	7	24	43	8	43	48	9
	3.0	8	36	6	25	43	8	35	46	9	49	46	10
	4.0	12	38	6	39	47	9	49	50	10	62	53	11
	5.0	18	41	7	39	47	9	55	51	11	68	55	12
	6.0	26	44	8	48	50	10	66	54	11	89	63	14
	7.0	32	45	9	54	51	10	76	57	12	92	64	14
	8.0	40	48	9	67	55	11	84	60	13	92	64	14
	9.0	51	49	10	75	57	12	93	65	14	92	64	14
	10.0	65	54	11	81	59	13	98	71	16	95	66	15
	11.0	79	58	12	87	62	14	99	75	17	97	69	16
	12.0	90	63	14	90	63	14	100	80	19	100	80	19
	13.0	98	71	16	96	67	15						
	14.0	100	80	19	100	80	19						

Continued

	15 - 30			30 - 45			45 - 60			60 - 75		
ASSOCIATE LEARNING												
2.0- 5.0	2	29	4	3	31	4	6	35	6	9	37	6
5.1- 7.0	6	35	6	22	42	8	18	41	7	29	45	8
7.1- 8.0	11	38	6	30	45	8	25	43	8	41	48	9
8.1- 9.0	15	40	7	32	45	9	37	47	9	62	53	11
9.1-10.0	20	42	8	41	48	9	51	50	10	65	54	11
10.1-11.0	30	45	8	46	49	10	66	54	11	68	55	12
11.1-12.0	39	47	9	54	51	10	68	55	12	79	58	12
12.1-13.0	47	49	10	62	53	11	77	58	12	82	59	13
13.1-14.0	52	51	10	76	57	12	77	58	12	88	62	14
14.1-15.0	62	53	11	81	59	13	83	60	13	91	64	14
15.1-16.0	69	55	12	84	60	13	92	64	14	91	64	14
16.1-17.0	78	58	12	89	63	14	96	68	15	97	69	16
17.1-18.0	87	62	14	95	66	15	96	68	15	100	80	19
18.1-19.0	94	66	15	95	66	15	99	75	17			
19.1-20.0	98	71	16	100	80	19	100	80	19			
20.1-21.0	100	80	19									

The means and standard deviations for each of the revised scales are presented according to age group in Table 42. Linear trend analysis indicated that all of the new scales dropped significantly as a function of increased age.

Conversion tables from raw scores to percentile scores, standard scores and scale scores are presented in Table 43.

TABLE 42

Means and standard deviations for each of the revised scales according to age group (15-30 years, 31-45 years, 46-60 years, 61-75 years).

	AGE												Test of Linear Trend		
	15 - 30			31 - 45			46 - 60			61 - 75					
	$\overline{X}$	σ	n	$\overline{X}$	σ	n	$\overline{X}$	σ	n	$\overline{X}$	σ	n	F	df	P
OVERALL MEM-REV	36.21	7.99	301	30.92	9.10	52	27.34	7.76	82	25.17	7.37	38	115.58		.0000
DAY TO DAY MEM-REV	35.96	7.62	301	30.50	8.87	52	26.54	7.86	82	23.71	7.16	38	146.02		.0000
REMOTE-REV	27.89	6.22	301	23.64	7.49	52	20.60	5.97	82	18.46	5.75	38	131.75		.0000
PRIOR TO ONSET-REV	16.93	4.30	301	14.78	4.53	52	13.15	3.80	82	12.40	4.38	38	71.35		.0000
SUBSEQ TO ONSET-REV	12.49	2.84	301	10.73	3.06	52	10.07	2.91	82	9.36	2.30	38	68.21		.0000
NEURO-REV	11.75	1.56	301	11.15	1.97	52	10.94	2.01	82	10.53	1.80	38	25.45		.0000
IMPAIRMENT-REV	21.75	7.58	301	16.70	8.92	52	12.82	7.36	82	9.82	6.15	38	141.09		.0000
NONVERBAL-REV	7.01	3.42	301	4.79	3.87	52	3.07	2.81	82	2.03	2.56	38	137.44		.0000
CAT7-REV	10.36	4.28	301	7.35	5.08	52	4.81	3.67	82	3.45	3.10	38	168.01		.0000
TPT-REV	4.68	2.56	301	2.92	2.69	52	1.48	1.72	92	.97	1.55	38	160.56		.0000
ATTENT-REV	12.75	4.96	301	9.80	5.90	52	7.67	4.58	82						
WMSQUOT-REV	35.26	11.79	301	29.51	11.87	52	23.54	11.60	82	23.37	10.41	38	69.96		.0000

TABLE 43

Raw score conversion tables of revised scales to percentiles, standard scores and scale scores.

Scale	Raw Score	AGE 15 - 30			30 - 45			45 - 60			60 - 75		
		%ile	Stand Score	Scale Score	%ile	Stand Score	Scale Score	%ile	Stand Score	Scale Score	%ile	Stand Score	Scale Score
OVERALL MEM-REV													
	0-17	2	29	4	10	37	6	6	35	6	16	40	7
	17.5-19.0	4	33	5	13	39	7	13	39	7	21	42	8
	19.5-21.0	6	35	6	15	40	7	21	42	8	34	46	9
	21.5-23.0	77	35	6	17	41	7	35	46	9	45	49	10
	23.5-25.0	11	38	6	23	43	8	44	49	9	53	51	10
	25.5-27.0	13	39	7	31	45	8	49	50	10	58	52	11
	27.0-29.0	18	41	7	35	46	9	63	47	11	66	54	11
	29.5-31.0	26	44	8	48	50	10	67	55	11	76	57	12
	31.5-33.0	33	46	9	58	52	11	73	56	12	84	60	13
	33.5-35.0	41	48	9	67	55	11	84	60	13	89	63	14
	35.5-37.0	51	50	10	75	57	12	90	63	14	97	69	16
	37.5-39.0	62	53	11	81	59	13	96	68	15	100	80	19
	39.5-41	70	55	12	87	62	14	98	71	16			
	41.5-43	80	58	12	94	66	15	98	71	16			
	43.5-45	88	62	14	96	68	15	99	75	17			
	45.5-47	95	66	15	98	71	16	99	75	17			
	47.5-49	99	74	17	100	80	19	100	80	19			
	49.5-51	100	80	19									

Continued

		15 - 30			30 - 45			45 - 60			60 - 75		
NEURO-REV	4							1	26	3			
	5	<1	22	2	2	29	4	2	29	4			
	6	<1	25	3	4	33	5	4	33	5			
	7	2	29	4	6	35	6	5	34	5	5	34	5
	8	4	33	5	8	36	6	10	37	6	16	40	7
	9	9	37	6	15	40	7	21	42	8	32	45	9
	10	16	40	7	35	46	9	34	46	9	45	49	10
	11	36	47	9	48	50	10	59	48	11	63	67	11
	12	70	56	12	77	58	12	79	58	12	90	63	14
	13	87	62	14	90	63	14	92	64	14	97	69	16
	14	100	80	19	100	80	19	100	80	19	100	80	19

Continued

	15 - 30			30 - 45			45 - 60			60 - 75		
DAY TO DAY MEMORY-REV												
0-20	5	34	5	13	39	7	21	42	7	34	46	9
20.5-22	6	35	6	19	41	7	35	46	9	47	49	10
22.5-24	8	36	6	21	42	8	45	49	10	58	52	11
24.5-26	11	38	6	31	45	8	50	56	10	63	33	11
26.5-28	17	41	7	40	48	9	59	48	11	68	55	12
28.5-30	22	42	8	44	49	9	65	54	11	74	57	12
30.5-32	29	45	8	60	53	11	77	58	12	87	62	14
32.5-34	36	47	9	67	55	11	83	60	13	95	66	15
34.5-36	46	49	10	69	55	12	89	63	14	100	80	19
36.5-38	57	52	11	77	58	12	95	66	15			
38.5-40	67	55	11	83	60	13	98	71	16			
40.5-42	78	58	12	92	64	14	98	71	16			
42.5-44	89	63	14	98	71	16	99	75	17			
44.5-46	95	66	15	100	80	19	100	80	19			
46.5-48	99	74	17									
48.5-50	100	80	19									

Continued

		15 - 30			30 - 45			45 - 60			60 - 75		
NONVERB-REV	0	5	34	5	17	41	7	24	43	8	42	48	9
	1	8	36	6	31	45	8	37	47	9	50	50	10
	2	13	39	7	37	47	9	49	50	10	63	53	11
	3	20	42	8	46	49	10	61	53	11	84	60	13
	4	26	44	8	50	50	10	71	56	12	90	63	14
	5	35	46	9	56	52	11	82	59	13	90	63	14
	6	42	48	9	64	54	11	88	62	14	95	66	15
	7	47	49	10	73	56	12	92	64	14	95	66	15
	8	55	51	10	77	58	12	94	66	15	95	66	15
	9	68	55	12	83	60	13	98	71	16	95	66	15
	10	81	59	13	89	63	14	99	75	17	100	80	19
	11	100	80	19	100	80	19	100	80	19			

Continued

	15 - 30			30 -45			45 - 60			60 - 75		
PRIOR TO ONSET-REV												
0-8	3	31	4	12	38	6	7	35	6	21	42	8
8.5-10	6	35	6	15	40	7	21	42	8	32	45	9
10.5-12	15	40	7	27	44	8	41	48	9	53	47	10
12.5-14	27	44	8	38	47	9	61	53	11	66	54	11
14.5-15	34	46	9	50	50	10	73	56	12	71	56	12
15.5-16	43	48	9	63	47	11	78	58	12	79	58	12
16.5-17	53	51	10	77	58	12	84	60	13	84	60	13
17.5-18	60	53	11	81	59	13	91	64	14	87	62	14
18.5-19	69	55	12	81	59	13	94	66	15	92	64	14
19.5-20	77	58	12	88	62	14	98	71	16	95	66	15
20.5-21	84	60	13	94	66	15	99	75	17	100	80	19
21.5-22	91	64	14	96	68	15	100	80	19			
22.5-24	96	67	15	100	80	19						
24.5-26	98	71	16									
26.5-28	99	74	17									
28.5-30	100	80	19									

Continued

	15* - 30			30 -45			45 - 60			60 -- 75		
SUBSEQ TO ONSET-REV												
0- 6.0	2	29	4	10	37	6	12	38	6	21	42	8
6.5- 8.0	8	36	6	21	42	8	27	44	8	40	48	9
8.5-10.0	24	43	8	44	49	9	60	53	11	66	54	11
10.5-12.0	47	49	10	77	58	12	74	57	12	84	60	13
12.5-13.0	56	52	11	85	61	13	89	63	14	90	63	14
13.5-14.0	71	56	12	87	62	14	98	71	16	97	69	16
14.5-15.0	89	63	14	92	64	14	98	71	16	100	80	19
15.5-16.0	94	66	15	94	66	15	100	80	19			
16.5-18.0	99	74	17	100	80	19						
18.5-20.0	100	80	19									

Continued

		15 - 30			30 -45			45 - 60			60 - 75		
IMPINDEX-REV	0- 6	5	34	5	17	41	7	23	43	8	34	46	9
	6.5- 8	6	35	6	21	42	8	33	46	9	47	49	10
	8.5-10	10	37	6	29	45	8	41	48	9	55	51	10
	10.5-12	12	38	6	35	46	9	50	50	10	68	55	12
	12.5-14	17	41	7	40	48	9	60	53	11	74	57	12
	14.5-16	25	43	8	46	49	10	70	55	12	82	59	13
	16.5-18	31	45	8	56	52	11	77	58	12	92	64	14
	18.5-20	37	47	9	60	53	11	82	59	13	92	64	14
	20.5-22	45	49	10	65	54	11	87	62	14	97	69	16
	22.5-24	56	52	11	73	56	12	93	65	14	97	69	16
	24.5-26	68	55	12	83	60	13	98	71	16	100	80	19
	26.5-28	79	58	12	88	62	14	98	71	16			
	28.5-30	90	63	14	98	71	16	99	73	17			
	30.5-32	96	67	15	100	80	19	100	80	19			
	32.5-34	100	80	19									

Continued

		15 - 30			30 - 45			45 - 60			60 - 75		
ATTENT-REV	0- 3	5	34	5	17	41	7	20	42	8	8	6	6
	3.5- 5	9	37	6	35	46	9	38	47	9	53	51	10
	5.5- 7	15	40	7	40	48	9	56	52	11	74	57	12
	7.5- 9	29	45	8	52	51	10	66	54	11	87	63	14
	9.5-11	40	48	9	56	52	11	76	57	12	90	63	14
	11.5-13	51	50	10	69	55	12	88	62	14	95	66	15
	13.5-15	63	53	11	79	58	12	96	68	15	97	69	16
	15.5-17	81	59	13	90	63	14	99	75	17	100	80	19
	17.5-19	94	66	15	94	66	15	100	80	19			
	19.5-21	100	80	19	100	80	19						

Continued

		15 - 30			30 - 45			45 - 60			60 - 75		
REMOTE-REV	0-12	2	29	4	8	36	6	9	37	6	16	40	7
	12.5-14	4	33	5	13	39	7	16	40	7	24	43	8
	14.5-16	6	35	6	15	40	7	24	43	8	39	47	9
	16.5-18	8	36	6	21	42	8	38	47	9	53	51	10
	18.5-20	13	39	7	29	45	8	50	50	10	58	52	11
	20.5-22	18	41	7	46	49	10	62	53	11	71	56	12
	22.5-24	26	44	8	56	52	11	71	56	12	84	60	13
	24.5-26	35	46	9	60	53	11	80	59	13	92	64	14
	26.5-28	47	49	10	69	55	12	90	63	14	97	69	16
	28.5-30	59	48	11	79	58	12	96	68	15	100	80	19
	30.5-32	73	56	12	85	61	13	98	71	16			
	32.5-34	86	61	13	96	68	15	99	75	17			
	34.5-36	95	66	15	98	71	16	100	80	19			
	36.5-38	99	75	17	100	80	19						
	38.5-40	100	80	19									

Continued

		15 - 30			30 - 45			45 - 60			60 - 75		
TPT-REV	0	7	35	6	23	43	8	35	46	9	50	50	10
	1	15	40	7	42	48	9	63	53	11	79	58	12
	2	23	43	8	52	51	10	81	59	13	92	64	14
	3	36	47	9	65	54	11	88	62	14	95	66	15
	4	47	49	10	71	56	12	92	64	14	95	66	15
	5	54	51	10	77	58	12	96	68	15	95	66	15
	6	68	55	12	85	61	13	99	75	17	97	69	16
	7	83	60	13	92	64	14	99	75	17	100	80	19
	8	100	80	19	100	80	19	100	80	19			
WMSQUOT-REV	0-10	2	29	4	8	36	6	9	37	6	11	38	6
	10.5-14.0	4	33	5	15	40	7	16	40	7	26	44	8
	14.5-18.0	10	37	6	17	41	7	28	44	8	37	47	9
	18.5-22.0	17	41	7	27	44	8	44	49	9	50	50	10
	22.5-26.0	24	43	8	37	47	9	56	52	11	68	55	12
	26.5-30.0	34	46	9	50	50	10	62	53	11	74	57	12
	30.5-34.0	43	48	9	65	54	11	76	57	12	87	62	14
	34.5-38.0	55	51	11	77	58	12	85	61	13	95	66	15
	38.5-42.0	68	55	12	85	61	13	91	64	14	95	66	15
	42.5-46.0	80	59	12	92	64	14	96	68	15	100	80	19
	46.5-50.0	92	64	14	96	68	15	99	75	17			
	50.5-54.0	99	75	17	100	80	19	100	80	19			
	54.5-58.0	99	75	17									
	58.5-62.0	100	80	19									

Continued

		15 - 30			30 - 45			45 - 60			60 - 75		
CAT7-REV	0	2	29	4	12	38	6	13	39	7	16	40	7
	1	5	34	5	12	38	6	23	43	8	37	47	9
	2	5	34	5	19	41	7	33	46	9	47	49	10
	3	8	36	6	29	45	8	40	48	9	58	52	11
	4	11	38	6	39	47	9	48	50	10	66	54	11
	5	15	40	7	44	49	9	61	53	11	74	57	12
	6	21	42	8	44	49	9	72	56	12	84	60	13
	7	27	44	8	52	51	10	77	58	12	92	64	14
	8	31	45	8	60	53	11	85	61	13	95	66	15
	9	39	47	9	67	55	11	88	62	14	95	66	15
	10	45	49	10	71	56	12	92	64	14	97	69	16
	11	52	51	10	77	58	12	93	65	14	97	69	16
	12	62	53	11	77	58	12	96	68	15	97	69	16
	13	71	56	12	83	60	13	99	75	17	100	80	19
	14	81	59	13	87	62	14	100	80	19			
	15	89	63	14	94	66	15						
	16	100	80	19	100	80	19						

DISCUSSION

Introduction

The aim of the present research was to determine if the Wechsler Memory Scale consisted of items that could usefully be employed to measure memory functions in patients referred for neuropsychological assessment. Neuropsychological investigations conducted since the construction of the WMS (Wechsler, 1945) have clarified the relationship between brain functions and memory. Based on the complex relation between cerebral pathology and memory functions, a number of external criterion were employed in order to evaluate the WMS as a test of these functions. The validation results indicated that the WMS subscales were significantly related to intelligence and impairment but only Orientation was significantly related to memory disorders among particular groups. The WMS as presently used was found to be primarily a measure of intelligence and impairment.

When the item analysis results were used to form revised scales consisting of items selected on the basis of their relationship to the external criteria summarized

Fig. 18 An illustration of the time frame covered by the clinical memory ratings.

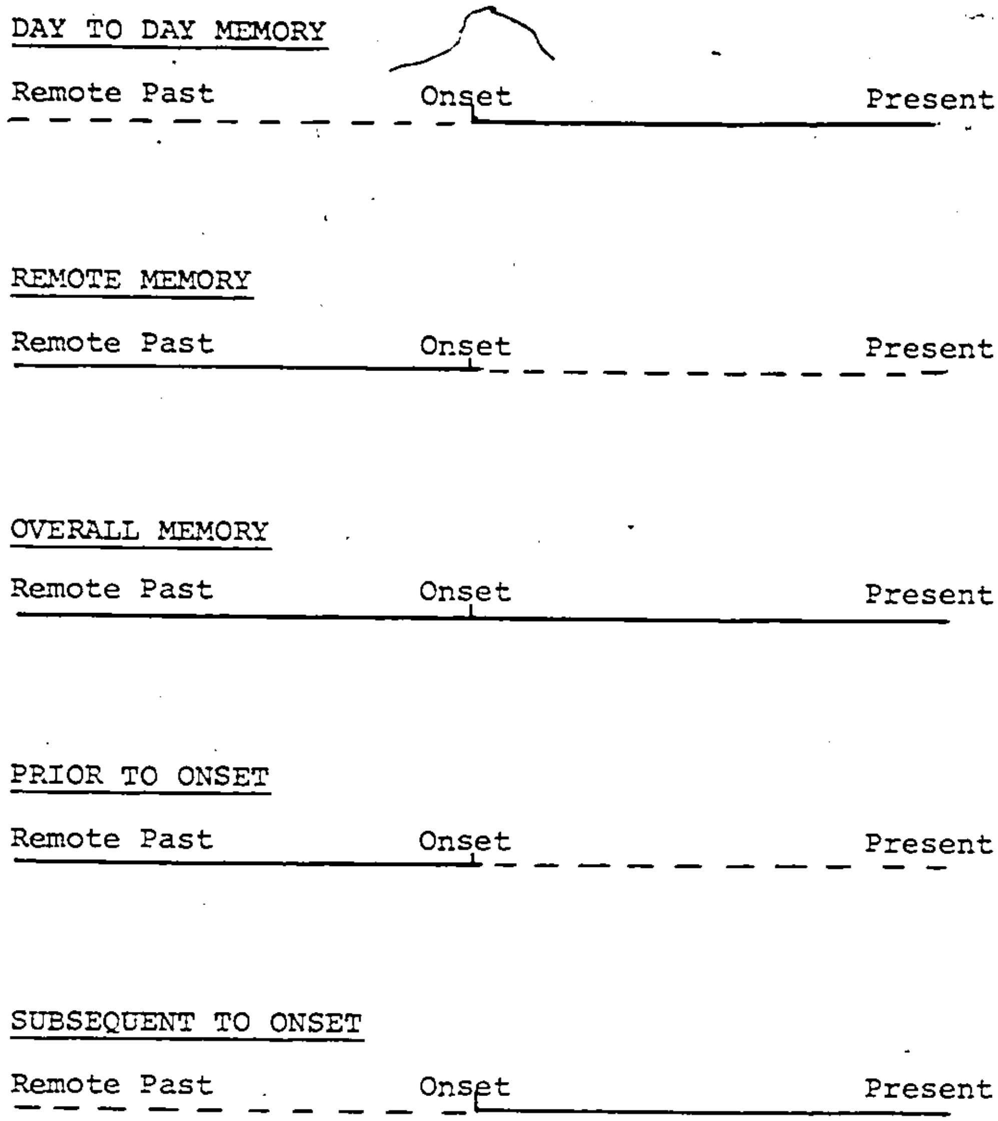

DAY TO DAY MEMORY
Remote Past
Onset
Present
REMOTE MEMORY
Remote Past
Onset
Present
OVERALL MEMORY
Remote Past
Onset
Present
PRIOR TO ONSET
Remote Past
Onset
Present
SUBSEQUENT TO ONSET
Remote Past
Onset
Present

Figure 18.

in Figure 18, they were also found to be related to intelligence and impairment. Unlike the WMS subscales however, these revised scales were found to be sensitive to memory dysfunction once intelligence and level of impairment were statistically controlled. These findings indicate that as Erickson and Scott (1978) postulated, some important information concerning memory function can be salvaged from the Wechsler Memory Scale.

Item Analysis

The results of the item analysis indicated that items included in the Wechsler Memory Scale range in difficulty from very easy to very difficult. These findings indicate that the test is sensitive over a wide range of ability. Thus the test can be administered to patients at quite low levels of ability, and some of the items will be passed. Similarly, some items would be a challenge for a patient with high ability levels.

It is interesting to note however that the easy items and the difficult items add little to the discriminative power of the Memory Quotient. Only those of medium difficulty contribute to the discrimination of high and low groups separated on the basis of the Memory

Quotient. On the other hand both difficult items and easy items are important discriminators of memory disorders. Thus items that did not bear a strong relationship to the Memory Quotient were included among the revised scales. These findings suggest that the revised scales can be useful discriminators over a wide range of ability levels while the Memory Quotient discriminates mainly among those with intermediate levels of ability.

It was found that many items were related to memory problems for the remote past. Similarly, many items were highly related to memory problems for day to day events. There were some items which were related to both of these criteria but many were related to day to day memory problems and not to remote memory problems while others were related to remote memory but not to day to day memory. Similarly, there was considerable overlap among the group of items that were related to the criteria overall memory, memory for events prior to and subsequent to onset.

In addition some of the items that were highly related to intelligence and impairment were also related to the memory ratings. Other items appeared to reflect memory function independent of intelligence and impairment. The item analysis provided the basis for constructing new scales of memory. Also, examination of the relationship between the items and various external criteria indicated that, as found with the validation results, the various scales were highly interrelated (sharing common items) and also were somewhat related to intelligence and impairment (sharing items in common with those related to these two criteria). Thus the validation of these scales focused not only on the ability of the scales to predict the external criteria but examined the relationship between the memory ratings and the scales with impairment and intelligence statistically controlled.

Validation of the New Scales

The finding that, when combined in discriminant function analysis the revised scales significantly differentiated the criterion groups indicated that patients with varying severity of memory difficulty could be identified on the basis of these tests. The new tests accurately identified those with day to day memory problems, remote memory problems, overall memory problems and problems with memory for events prior to the onset of pathology. The scales consisting of items maximally related to impairment, intelligence and attention were all available for inclusion in the stepwise discriminant function. The fact that the first scales selected for inclusion in the equation were DAYDAY-REV (for memory difficulties for day to day events), REMOTE-REV (for memory difficulties for remote events), OVERMEM-REV (for memory difficulty overall) and PRIOR-REV (for memory difficulty for events prior to onset) indicates that in each case the discrimination is being made primarily on the basis of those scales maximally related to memory functioning. Had the first scales included been the scales with items selected for their relation to intelligence, impairment or attention, it would have suggested the discrimination was being made primarily on this basis.

The results also indicated that these new scales were more accurate at classifying cases into two groups (no difficulty and mild memory problems in comparison the moderate and severe cases) than making a more subtle distinction between four groups (no difficulty, mild, moderate and severe). For the four group case, between 50% and 79% of the cases were accurately identified while between 69% and 84% of the cases were identified in the two group case. One factor which may account for the improvement in predictive accuracy is the a priori chance prediction rate. In the first case, only 25% of the subjects would be accurately identified by chance. In the two group case 50% would be identified by chance. By reducing the stringency of the decision to be made by the discriminant equation a greater number of cases can be accurately identified. Clinical use of the test is likely to be similarly more efficient if the test is used to identify patients with memory disorders than if an attempt is made to specify the severity of the disorder.

Another factor however which may influence the predictive accuracy (particularly in the four group case where more subtle distinctions must be made) concerns variables uncontrolled in this analysis. Barbizet (1970) discusses the affective disorders and their relation to memory functions. Some cases with intact cerebral structures will complain of memory impairment for events that have emotional valence. Among other patients there may be a mixed affective and organic condition. A case is discussed (Barbizet, 1970) in which the memory disorder that resulted from Wernicke's encephalopathy was exaggerated by an affective component. Patients with emotional disorders would thus likely perform on a memory test like the WMS fairly well, relative to their complaints since the items included in the test would be emotionally innocuous for these patients. The fact that personality characteristics among these cases are uncontrolled in the discriminant analysis may in part account for the relatively low prediction rates, particularly in the situation where subtle distinctions among the four groups are required. Other factors uncontrolled in the discriminant analysis are intelligence and impairment.

A number of previous studies (Bachrach and Mintz, 1974, Kljajic, 1975) have found that organic patients could be differentiated from non-organic patients on the basis of the WMS, suggesting that the test was sensitive to level of impairment. However, once intelligence was controlled (Prigatano, 1977) the ability to differentiate the groups was lost. These findings suggest that level of impairment as well as intelligence are important variables to control in the assessment of memory function and are consistent with Milner's (1968) dictum that a memory disorder must be distinguished from a disorder of attention, perception or general intellectual decline.

Thus, the Impairment Index (which includes measures of attention and perception) and the Wechsler Adult Intelligence Scale Full Scale I.Q. were used as covariates in the analysis of covariance which assessed the relationship between each of the revised scales and day to day memory. The results indicated both intelligence and impairment were related to the majority of the revised scales. The scale representing memory of forms was not related to intelligence but was significantly related to level of impairment. Similarly, when remote memory problems and overall memory problems were considered, both covariates were strongly related to the majority of the scales. The memory for forms scale was not related to intelligence but was significantly related to level of impairment. This relationship held for both the remote memory problem groups and the overall memory problem groups. These findings provide objective evidence supporting the notion that it is essential to control for general intelligence, perceptual, cognitive and attentional factors when conducting an assessment of memory functions. The findings have important implications not only for the clinical evaluation of memory disorders but for the experimental analysis of cognitive deficits associated with various amnesic conditions. When assessing memory functions it is essential to control for both intelligence and impairment.

Another major question addressed in this research was whether the Wechsler Memory Scale measures memory in a way that can be differentiated from the measurement of intelligence. This question was stimulated by the results of correlational studies (Fields, 1971) and factor analytic studies (Eysenck and Halstead, 1945) which suggested that memory tests are redundant measures of intellectual abilities. On the other hand, certain models of intelligence (Guilford, 1967) view memory as one of the component abilities contributing to a more general intellectual ability. The results of the analysis of covariance provide direct evidence bearing on this issue. It was found that both of the covariates were significantly related to the majority of the scales among the different clinical groups. This is due to the common variance among the scales and the covariates and reflects the high correlation between measures of memory and measures of intelligence previously reported (Fields, 1971; Hall & Toal, 1957).

The important question however is not whether measures of memory and intelligence are correlated (which can be expected in a model which assumes that memory is a component of intelligence) but whether memory is being measured in a way that can be differentiated from the measurement of intelligence (Erickson & Scott, 1977). Here it was found that once impairment and intelligence were statistically controlled, the majority of the scales were significantly related to the clinical ratings. This indicates that among these scales the variance which is defined uniquely from intelligence and impairment is significantly related to clinical memory ratings. This further illustrates the importance of considering intelligence and level of impairment in the memory assessment. The findings also indicate that memory can be measured in a way that is distinct from the measurement of general intelligence, an issue current in the psychometric literature concerning the Wechsler Memory Scale (Erickson & Scott, 1977). Memory was also found to be measured distinctly from level of impairment. These findings validate the revised scales as measures of memory.

Further validation of the scales was attained by examining the relationship of the raw scores to the clinical memory ratings and to age. For each of the clinical memory ratings the raw scores were found to drop in a linear fashion as a function of the severity of the disorder. In addition, the raw scores for each of the scales drop linearly with age. These findings further validate the scales since they are related to memory disorders in the expected direction and also appear sensitive to the effects of age. The age effects however are not controlled for intelligence and impairment and hence do not necessarily reflect declining memory as a function of age.

The scales generally were not found to be related to neurological diagnosis once intelligence and impairment were controlled. The analysis of variance which did not include covariates indicated that there were significant differences among the groups. This was accounted for by the poor performance of the right hemisphere group. This significant effect was lost when intelligence and impairment were statistically controlled. This suggests that the right hemisphere group was a more impaired group and the poor performance was due primarily to level of impairment. There were fewer right hemisphere cases and these were apparently more impaired than the other cases. It would appear that left hemisphere dysfunction is detected earlier and presents greater functional difficulty leading to earlier referrals than with right hemisphere dysfunction.

The nonverbal, or figural scales were not selectively reduced among those with right hemisphere dysfunction. This was somewhat unexpected since Milner (1968) has reported that those with medial temporal lobe lesions on the right have a specific memory disorder for nonverbal material. However, the cases used in the Milner series represent patients in which the precise location and extent of the lesion was known since the lesions represented surgical extirpation in the treatment of epilepsy. In our series, the location of the lesion was determined on the basis of neurodiagnostic techniques and represented a wide range of different types of pathology. On the basis of the information available, it was felt that a reliable distinction of lateralized pathology could be made, however within hemisphere distinctions were considered insufficiently accurate to be included in this research. Hence it remains to be determined if those with medial temporal lobe lesions are selectively impaired on those scales thought to reflect nonverbal memory.

Since it has not been shown that these nonverbal scales are specifically reduced among right hemisphere patients, it remains to be determined if these scales tap the type of memory abilities dependent upon right hemisphere function. It may be that some of these items are coded verbally among those with right hemisphere damage. Further research on this issue might examine the correspondance between these nonverbal scales and other nonverbal tests that have been shown to be reduced among right hemisphere damaged patients. Other tests that might be used include facial recognition tests (Milner, 1968).

Further, the finding that the covariates are significantly related to each scale may help to explain some of the errors of prediction in the discriminant analysis. When combined in discriminant analysis, the scales significantly predict memory groups. However, in this analysis both intelligence and impairment are uncontrolled. Thus, some cases may be identified by the discriminant equation as having a memory disorder primarily on the basis of impairment and intelligence and not on the component of the test related to memory functions. Were the groups homogenous and matched on the basis of intelligence and impairment, higher prediction rates may have been obtained. Such a design however would introduce another complicating factor. The group sizes in such a design would be equivalent, not reflecting the base rate against which the discrimination must be made clinically. Another possible method (beyond the scope of the present research) would be to apply the beta coefficients used to calculate the adjusted mean scores from the analysis of covariance to the raw scores to obtain raw scores adjusted for the covariates. These adjusted raw scores could then be used in a discriminant function analysis to obtain adjusted prediction rates. It would be expected that as in the clinical situation when the covariates are adjusted for the prediction rates would be increased.

Comparison with the WMS Subscales

It was found that even though the discriminant analysis using the WMS subscales predicted a significant proportion of the cases, according to group, the predictive accuracy was consistently lower than the results obtained with the revised scales. These findings indicate that the revised scales have greater predictive value. When combined in linear regression, the revised scales account for a significant proportion of the variance in the clinical ratings and adding the WMS subscales to the equation only increases the proportion of the variance accounted for by from about 3 to 20 percent depending upon the clinical rating. Thus the revised scales were found to be better predictors of memory disorders and inclusion of the WMS subscales increases the proportion of the variance accounted for by only a relatively small proportion.

It was also essential to determine if the WMS subscales (including the Memory Quotient) were significantly related to memory functions once intelligence and impairment were controlled. Orientation was significantly related to WAISFSIQ but after the variance accounted for by the intelligence measure was accounted for there was an interaction between neurological diagnosis and clinical memory rating. The interaction was significant among those with day to day memory problems and overall memory problems. It was found that for both of these ratings, those with bilateral lesions, with severe memory disorders obtained particularly low scores on Orientation. This finding indicates that a low score on Orientation reflects a severe memory disorder among bilateral patients.

Among those rated as having remote memory problems there was a significant interaction between the Memory Quotient and neurological diagnosis. That the Memory Quotient was low among left hemisphere cases with severe memory problems for the remote past indicates that the Memory Quotient may be tapping primarily left hemisphere functions. Also a low score on the Memory Quotient apparently reflects a memory disorder among those with left hemisphere dysfunction but not with right hemisphere dysfunction. The type of memory disorder is related to events of the remote past. Orientation was also found to be reduced among patients with left hemisphere lesions who had severe memory problems for the remote past. The low Memory Quotient among these cases probably reflects primarily the low score on Orientation. Since these were non aphasics, the low Orientation scores cannot be attributed simply to the incidence of aphasia among left hemisphere patients. It appears however that among left hemisphere cases Orientation measures memory for events of the remote past, while among bilateral patients memory for day to day events is measured by Orientation.

Among the other scales however, including the other analyses with the Memory Quotient there was no relationship between any of the scales or the Memory Quotient and clinical ratings of memory function after the variance accounted for by the covariates was extracted. This finding indicates that with the exception of Orientation each scale is primarily a measure of intelligence or impairment. The scales Information, Control, Passages, Digits, Visual Reproduction and the Memory Quotient were generally found to be highly related to both intelligence and impairment while Associate Learning was related to impairment. These findings have important implications indicating that even when both intelligence and level of impairment are controlled, the Wechsler Memory Scale is not significantly related to memory functions, except for the fact that Orientation seems to reflect severe memory disorders among bilateral and left hemisphere cases.

Thus the prediction results in the discriminate function analysis using these old scales reflects differences among the groups in terms of intelligence and level of impairment. These findings indicate that few clinical statements concerning memory function can be made on the basis of this test.

Further, it is common to employ paired associate learning tests and memory for passages in experimental designs aimed at evaluating the nature of memory disorders among various populations. For example, the increased performance on a memory for passages test reported by Davidoff, Butters, Gerstman and Mattis (1979) among Korsakoff's amnesics as a result of increased motivation was interpreted as an increase in memory functions. Since the groups were matched for intelligence but not for level of impairment, it is most likely (based on the present findings) that the performance increment was related to more general impairment than memory abilities per se. The results reported here indicate that this type of test is not related to memory functions once impairment and intelligence are controlled. Certain items within the Wechsler Memory Scale can, however, be selected which can be recombined, as in the revised scales, which reflect memory functions after intelligence and impairment are controlled.

Thus, these results indicate that the revised scales are an improved measure of memory function over the traditional WMS subscales. These scales have been validated in a number of ways. It has been shown that for each clinical rating of memory function, the revised scales are more highly correlated with memory functions than any of the WMS subscales. When combined in discriminant analysis the revised scales result in higher rates of accurate prediction. Linear regression has shown that the WMS subscales add little to the predictive power of the revised scales. Most importantly, the WMS subscales, with the exception of Orientation (which is only related to severe memory disorders among left hemisphere and bilateral patients) are unrelated to memory functions when intelligence and impairment are controlled. The revised scales however are linearly related to memory functions and although the covariates were significantly related to the revised scales, the relationship between the scales and clinical ratings held up after the adjustment for covariates.

The Measurement of Specific Memory Functions

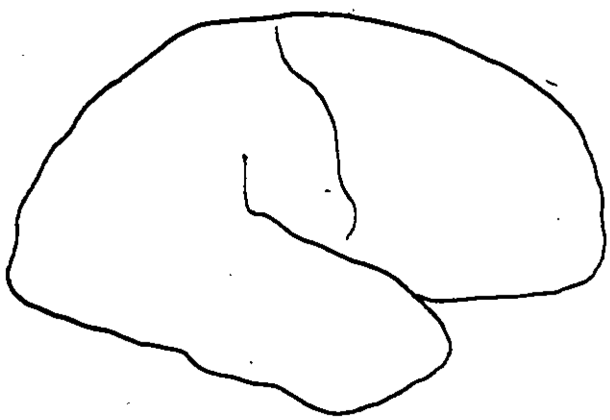
It was pointed out that the development of the clinical memory ratings was based on the evidence from neuropsychological studies of different types of memory disto discriminate groups on the basis of these factors. That items discriminate along these lines does not invalidate them as measures of memory. Other items, those included in the WMS subscales, but not included in the revised scales were found to be solely related to intelligence or level of impairment and could not be considered measures of memory.

Thus among the revised memory scales, none could be identified as a measure of a single aspect of memory function (for example memory for recent events) and not related to other aspects of memory function. This is possibly explained in part by the fact that many patients suffer both retrograde and anterograde amnesias. Thus the items selected for each scale overlap to some degree and these scales are highly correlated since the symptoms tend to be found amond the same patients.

Certain relations between the WMS scales however and memory functions were found to be related to lateralized dysfunction. These relationships can be seen in Figure 19. All of the revised scales were sensitive to memory disorders independent of the neurological diagnosis. Orientation however was sensitive to severe difficulty with day to day memory among bilateral patients. Among left hemisphere patients both Orientation and Memory

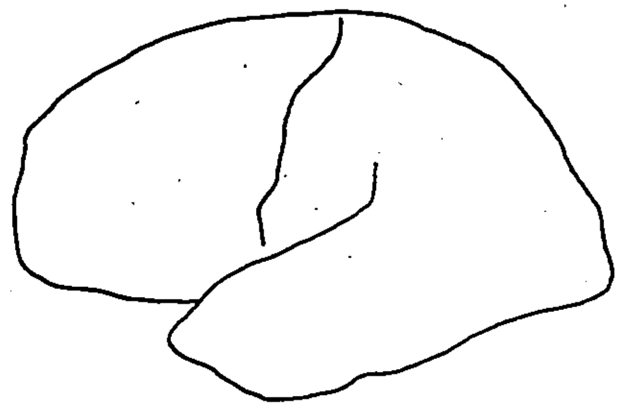
Fig. 19 Lateralized cerebral pathology in relation to reduced WMS scale scores and revised scale scores.

Right Hemisphere



All revised scales

Left Hemisphere



Orientation
Memory Quotient
All revised scales

Bilateral
Orientation
All revised scales

Figure 19.

Quotient were sensitive to severe memory difficulty for the remote past. Thus the relationship between Orientation and Memory Quotient to the clinical ratings depends on the severity of the disorder and location of cerebral dysfunction. In contrast the relationship between the revised scales and memory dysfunction was not dependent on lateralized cerebral dysfunction or the type of memory disorder (anterograde or retrograde).

In general then, clear distinctions between the revised scales have not been made on the basis of these results. This may be due to one of the following explanations. The items in the test tend to be of the same nature (measure of memory for new material). Secondly, memory disorders for recent events and remote events tend to be highly correlated in this population and third, the clinical ratings may be insensitive to the distinction between recent and remote memory.

Further research on this issue should employ laboratory tests among a select population of amnesics to separate those with specific memory disorders for recent events from those with memory disorders for remote events. An examination of the profiles of these two groups on the scales developed here would indicate if distinctions can be made on the basis of these scales. Further, it would be interesting to identify those with specific nonverbal memory disorders (using a facial recognition task for example) and compare their scores on the figural scales to those who do not have specific nonverbal memory disorders. It would also be of interest to determine if these scales are sensitive to specific forms of therapy designed to ameliorate the memory disorder.

Cross Validation

A cross validation of the predictive accuracy of both the WMS subscales and the revised scales was carried out using a subgroup of the original population who had subsequently been re-administered the Wechsler Memory Scale on a follow-up visit to the Neuropsychology Laboratory. One procedure commonly used in cross validation studies is to take one sample from a population and use the independent variables to predict the dependent variable in a linear regression as a validation. A test of cross validation is to use the coefficients obtained from the validation regression equation, and apply them to the independent variables among a second independently sampled group. If the correlation in the second sample is as high as the correlation in the first, then the independent variables have been cross validated, as well as the coefficients for the regression equation.

In this case a major question was: how many cases can be accurately identified by the use of the scales? Thus the validation strategy was to use a stepwise discriminant function analysis. Validation was attained by the finding that a significant proportion of the cases were accurately classified into various memory disorder groups. The cross validation sample represented a subpopulation of cases tested at a different point in time with respect to the original sample. The clinical memory ratings were conducted independent of the first rating. Since it would be expected that the memory disorder would change over test retest interval among these patients, it would not necessarily be expected that the same combination of variables in the cross validation group would provide the best classification results. This is particularly the case since impairment and intelligence cannot be statistically controlled in discriminant function analysis with the computer program software now available. Thus the strategy employed here was to permit the creation of a new set of discriminant function coefficients to predict group membership among the cross validation group. The focus of this cross validation procedure was not to arrive at a particular combination of variables at time A which identified the groups, but to determine if any combination of these scales at time B would predict as accurately as the combination at time A.

The classification rates for the WMS subscales in the cross validation sample compared favourably overall to the classification rates obtained in the original sample. For each of the memory ratings subjects were significantly classified according to groups both in the two groups and four group condition. This indicates a successful cross validation of the original findings.

Similarly the revised scales were successful at predicting cases according to group at a significant rate both in the two group case and the four group case. Additionally, it was once again found that the revised scales generally produce higher prediction rates than the old scales. Thus it can be concluded on the basis of this cross validation pattern that the revised scales are improved measures of memory than the old scales and are equally accurate at predicting a variety of memory dysfunctions among cases seen at first testing (tending to be in a more acute phase of their illness) as among patients seen on follow-up examination (tending to be in the more chronic stage).

Among those patients who were administered the test on the first assessment and then again on the second assessment test retest reliability coefficients were calculated for each scale. Considering many of these patients were seen during resolving phases of their illness these reliability coefficients are remarkably high and compare favourably with the few previous and incomplete reliability reports (Bloom, 1959; Ivinskis, Allen and Shaw, 1971).

Illustration of the use of the test

Age related norms are provided for both the revised scales and the seven WMS subscales of the Wechsler Memory Scale. This permits the construction of a profile of memory function in which the various scales can be compared by examining their scale scores. Use of the scale with a clinical case is presented in Appendix D.

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APPENDIX A

Discriminant function coefficients for WMS scale prediction of ratings of day to day memory, remote memory, overall memory, memory prior to onset, memory subsequent to onset and neurological diagnosis for the two group and four group conditions.

APPENDIX A ł

CROSS VALIDATION 4 GROUPS DDMEM

VARIABLE	FUNCTION 1	FUNCTION 2	FUNCTION 3
INFORM	-0.55174	-0.36286	0.85321
ORIENT	-0.55360	-0.53898	-0.22002
PASSAGES	-0.95785	1.27890	0.66391
MEMQUOT	0.72739	-0.51456	-1.53193

VALIDATION 4 GROUPS DDMEM

VARIABLE	FUNCTION 1	FUNCTION 2	FUNCTION 3
INFORM	-0.13176	0.10883	1.01056
ORIENT	-0.19964	0.85235	-0.64470
CONTROL	-0.36802	-0.20223	-0.24601
VISUALR	-0.60900	-0.63155	-0.13550
ASSOCL	-0.71906	0.04387	0.58198
MEMQUOT	0.68348	0.26566	-0.39002

CROSS VALIDATION 4 GROUPS REMMEM

VARIABLE	FUNCTION 1	FUNCTION 2
INFORM	1.02671	0.13583
CONTROL	-0.46202	-0.34291
PASSAGES	0.05111	1.86019
DIGITS	1.06343	0.30089
VISUALR	-0.47229	-0.40448
MEMQUOT	-1.26414	-1.40389

VALIDATION 4 GROUPS REMMEM

VARIABLE	FUNCTION 1	FUNCTION 2	FUNCTION 3
INFORM	-0.03773	0.89977	-0.18393
ORIENT	-0.36114	-0.09430	0.82661
PASSAGES	-0.34783	0.61501	-0.63780
VISUALR	-0.72732	-0.49529	-0.56457
ASSOCL	-0.44487	0.73415	-0.07258
MEMQUOT	0.65534	-1.17926	0.90234

CROSS VALIDATION 4 GROUPS OVERMEM

VARIABLE	FUNCTION 1	FUNCTION 2	FUNCTION 3
INFORM	0.18553	-0.62052	0.89347
ORIENT	0.17115	-0.71365	-0.77246
PASSAGES	0.84350	0.70915	-0.13917

VALIDATION 4 GROUPS OVERMEM

VARIABLE	FUNCTION 1	FUNCTION 2	FUNCTION 3
INFORM	-0.18754	-0.16293	0.87821
ORIENT	-0.20584	-0.87600	-0.41931
CONTROL	-0.35460	-0.26460	0.45203
VISUALR	-0.75605	0.61339	-0.14218
ASSOCL	-0.58281	0.03207	0.76087
MEMQUOT	0.73127	0.07682	-1.42049

CROSS VALIDATION 4 GROUPS PRIOTR

VARIABLE	FUNCTION 1	FUNGTION 2	FUNCTION 3
ORIENT	0.84272	0.08453	-0.72519
CONTROL	-0.12706	-1.11292	-0.07697
ASSOCL	-0.96017	0.58257	-0.39994

VALIDATION 4 GROUPS PRIOTR

VARIABLE	FUNCTION 1	FUNCTION 2	FUNCTION 3
ORIENT	-0.67858	0.83607	0.48031
DIGITS	-0.59262	0.74536	-0.95253
MEMQUOT	1.42190	-0.17434	0.38369

CROSS VALIDATION 4 GROUPS SUBSTR

VARIABLE	FUNCTION 1	FUNCTION 2	FUNCTION 3
ORIENT	0.43023	0.74937	0.60952
CONTROL	-0.98901	-0.28531	0.63624
ASSOCL	0.93728	-0.74300	-0.01051

VALIDATION 4 GROUPS SUBSTR

VARIABLE	FUNCTION 1	FUNCTION 2
INFORM	0.63464	-0.89422
ASSOCL	0.55511	0.94565

CROSS VALIDATION 4 GROUPS NDIAG

VARIABLE	FUNCTION 1	FUNCTION 2	FUNCTION 3
PASSAGES	-1.18024	0.19753	1.04775
VISUALR	0.10127	-1.24538	-0.16980
ASSOCL	1.49481	0.50746	0.05385

VALIDATION 4 GROUPS NDIAG

VARIABLE	FUNCTION 1	FUNCTION 2	FUNCTION 3
INFORM	-0.68106	-0.26085	-0.19670
DIGITS	-0.42184	-1.01354	-0.57478
VISUALR	-0.02581	-0.76455	0.94154
MEMQUOT	1.47597	0.92050	-0.40021

CROSS VALIDATION 2 GROUPS DDMEM

VARIABLE	FUNCTION 1
PASSAGES	-0.32358
VISUALR	-0.38672
MEMQUOT	0.74420

VALIDATION 2 GROUPS DDMEM

VARIABLE	FUNCTION 1
ORIENT	-0.27746
CONTROL	-0.38267
VISUALR	-0.60649
ASSOCL	-0.65031
MEMQUOT	0.61229

CROSS. VALIDATION 2 GROUPS REMMEM

VARIABLE	FUNCTION 1
INFORM	1.02643
CONTROL	-0.43231
DIGITS	1.05638
VISUALR	-0.44735
MEMQUOT	-1.24935

VALIDATION 2 GROUPS REMMEM

VARIABLE	FUNCTION 1
ORIENT	-0.39298
VISUALR	-0.77919
ASSOCL	-0.35289
MEMQUOT	0.32099

CROSS VALIDATION 2 GROUPS OVERMEM

VARIABLE	FUNCTION 1
PASSAGES	-1.18048
ASSOCL	-0.66573
MEMQUOT	1.03372
VISUALR	-0.27792

VALIDATION 2 GROUPS OVERMEM

VARIABLE	FUNCTION 1
ORIENT	-0.24284
CONTROL	-0.33953
VISUALR	-0.75699
ASSOCL	-0.50470
MEMQUOT	0.58373

CROSS VALIDATION 2 GROUPS PRIOTR

VARIABLE	FUNCTION 1
INFORM	-0.65783
ORIENT	-0.77704
PASSAGES	1.13570

VALIDATION 2 GROUPS PRIOTR

VARIABLE	FUNCTION 1
MEMQUOT	1.0000

CROSS VALIDATION 2 GROUPS SUBSTR

VARIABLE	FUNCTION 1
ORIENT	-0.78428
PASSAGES	1.05482

VALIDATION 2 GROUPS SUBSTR

VARIABLE	FUNCTION 1

CROSS VALIDATION 2 GROUPS NDIAG

VARIABLE	FUNCTION 1
ASSOCL	1.0000

VALIDATION 2 GROUPS NDIAG

VARIABLE	FUNCTION 1
INFORM	0.35351
ORIENT	-0.55671
DIGITS	-0.48678
VISUALR	-0.46216

APPENDIX B

Discriminant function coefficients for revised scales prediction of ratings of day to day memory, remote memory, overall memory, memory prior to onset, memory subsequent to onset and neurological diagnosis for the two group and four group conditions.

APPENDIX B

CROSS VALIDATION 4 GROUPS DDMEM

VARIABLE	FUNCTION 1	FUNCTION 2	FUNCTION 3
REMOTE	-0.04231	-2.81361	-0.53815
PRIOR	0.23297	1.96846	-1.35781
SUBSEQ	0.86169	-0.20433	1.11593
TPT	-0.04003	1.26783	0.83118

VALIDATION 4 GROUPS DDMEM

VARIABLE	FUNCTION 1	FUNCTION 2	FUNCTION 3
WMSQUOT	0.38797	-0.82466	1.33920
DAYDAY	-1.67514	-0.72299	-2.14148
SUBSEQ	-0.07692	1.27417	0.87588
NEURO	-0.29424	.80603	-0.00048
IMPINDEX	0.66256	.79492	0.20973
TPT	-0.15397	-1.09329	0.46105
TEMPORAL	0.34643	-0.26091	-0.73216

CROSS VALIDATION 4 GROUPS REMMEM

VARIABLE	FUNCTION 1	FUNCTION 2
REMOTE	3.13085	-1.15016
PRIOR	-0.50290	2.05741
IMPINDEX	-2.04653	-0.73120

VALIDATION 4 GROUPS REMMEM

VARIABLE	FUNCTION 1	FUNCTION 2	FUNCTION 3
WMSQUOT	-0.82669	0.27268	-1.85372
OVERMEM2	1.00642	-0.26295	3.22542
REMOTE	1.00222	0.52931	-3.89878
NEURO	0.22747	-0.97276	0.29853
IMPINDEX	-0.40791	0.35708	2.23709
TEMPORAL	-0.25586	-0.55867	-0.03214

CROSS VALIDATION 4 GROUPS OVERMEM

VARIABLE	FUNCTION 1	FUNCTION 2	FUNCTION 3
DAYDAY	2.12309	1.31752	-2.55228
PRIOR	0.23337	-1.83292	0.25912
IMPINDEX	-1.50689	0.42257	2.90431

VALIDATION 4 GROUPS OVERMEM

VARIABLE	FUNCTION 1	FUNCTION 2	FUNCTION 3
WMSQUOT	0.60989	-0.63692	-0.32920
DAYDAY	-1.51049	-0.03666	-0.29621
SUBSEQ	-0.21438	0.75487	1.14257
NEURO	0.26957	0.94991	-0.00022
CAT7	0.95006	-0.68046	-2.15259
TPT	-0.71770	-0.21705	1.86140
TEMPORAL	0.26631	0.10052	-0.39030

CROSS VALIDATION 4 GROUPS PRIOR

VARIABLE	FUNCTION 1	FUNCTION 2	FUNCTION 3
WMSQUOT	3.37546	-1.83368	-0.36636
REMOTE	-2.37801	-1.68113	-1.20733
PRIOR	-0.82547	1.38691	1.97636
INTELL	-2.64176	0.77083	-2.01065
NONVERB	-0.14332	-1.57733	0.41328
TEMPORAL	-0.54233	0.34278	-0.42324
ATTENT	2.49923	2.88384	1.28507

VALIDATION 4 GROUPS PRIOR

VARIABLE	FUNCTION 1	FUNCTION 2	FUNCTION 3
OVERMEM2	5.63711	1.47173	-1.84107
REMOTE	-4.73435	1.62209	0.37571
PRIOR	-0.81128	0.08300	1.55025
SUBSEQ	-2.75554	-0.32282	-0.74167
NEURO	-1.45060	-1.90132	-0.46480
IMPINDEX	-0.86280	-5.04952	1.56526
NONVERB	2.15692	-1.96698	3.26386
CAT7	2.79017	6.11942	-2.34387
TPT	-4.43973	-3.31830	-1.58542
TEMPORAL	1.49438	0.14152	-0.00628
ATTENT	2.46412	5.79595	0.50245

CROSS VALIDATION 4 GROUPS SUBSTR

VARIABLE	FUNCTION 1	FUNCTION 2	FUNCTION 3
REMOTE	-3.07205	3.60363	-0.53171
SUBSEQ	-0.87969	-1.82912	-0.47385
IMPINDEX	3.45681	-2.05056	1.87412

VALIDATION 4 GROUPS SUBSTR

VARIABLE	FUNCTION 1	FUNCTION 2	FUNCTION 3
WMSQUOT	-4.76521	1.77716	2.34418
SUBSEQ	1.25256	1.12101	0.59903
INTELL	4.60032	-1.57830	-3.23476
NONVERB	-1.16068	-0.38191	-0.37465
TEMPORAL	-0.38555	-0.65849	0.87280

CROSS VALIDATION 4 GROUPS NDIAG

VARIABLE	FUNCTION 1	FUNCTION 2	FUNCTION 3
PRIOR	-0.36482	-0.84372	1.63103
SUBSEQ	.47619	-0.59040	-1.66453
NEURO	.90077	1.01239	0.24038

VALIDATION 4 GROUPS NDIAG

VARIABLE	FUNCTION 1	FUNCTION 2	FUNCTION 3
PRIOR	- .36482	-0.84372	1.63103
SUBSEQ	.47619	-0.59040	-1.66453
NEURO	.90077	1.01239	.24038

CROSS VALIDATION 2 GROUPS DDMEM

VARIABLE	FUNCTION 1
SUBSEQ	1.0000

VALIDATION 2 GROUPS DDMEM

VARIABLE	FUNCTION 1
WMSQUOT	-0.61586
DAYDAY	2.16204
IMPINDEX	-0.72845
CAT7	-0.45866
TEMPORAL	-0.28738
ATTENT	0.62476

CROSS VALIDATION 2 GROUPS OVERMEM

VARIABLE	FUNCTION 1
WMSQUOT	-0.65851
DAYDAY	1.36983
REMOTE	0.61380
NONVERB	0.60138
CAT7	-1.39500
TEMPORAL	-0.24782
ATTENT	0.49959

VALIDATION 2 GROUPS OVERMEM

VARIABLE	FUNCTION 1
SUBSEQ	1.0000

CROSS VALIDATION 2 GROUPS PRIOTR

VARIABLE	FUNCTION 1
WMSQUOT	-4.40605
OVERMEM2	-2.36406
DAYDAY	2.65558
PRIOR	1.78655
SUBSEQ	0.77469
NEURO	-0.46492
INTELL	2.80181
NONVERB	-0.87856
TEMPORAL	.84363

VALIDATION 2 GROUPS PRIOTR

VARIABLE	FUNCTION 1
OVERMEM2	-3.68522
REMOTE	2.07527
PRIOR	1.27313
SUBSEQ	1.38379
IMPINDEX	-1.22672
TEMPORAL	-0.93409
ATTENT	1.43969

CROSS VALIDATION 2 GROUPS SUBSTR

VARIABLE	FUNCTION 1
OVERMEM2	1.54369
SUBSEQ	-1.92334
TEMPORAL	-0.44121

VALIDATION 2 GROUPS SUBSTR

VARIABLE	FUNCTION 1
SUBSEQ	1.62485
IMPINDEX	-1.06706
TEMPORAL	-0.64245

CROSS VALIDATION 2 GROUPS REMMEM

VARIABLE	FUNCTION 1
REMOTE	2.67942
INTELL	-0.80388
IMPINDEX	-1.31601

VALIDATION 2 GROUPS REMMEM

VARIABLE	FUNCTION 1
WMSQUOT	-1.31016
OVERMEM2	1.61006
NEURO	0.33337
TEMPORAL	-0.20799
ATTENT	0.37159

CROSS VALIDATION 2 GROUPS NDIAG

VARIABLE	FUNCTION 1
WMSQUOT	1.09920
PRIOR	1.07752
SUBSEQ	-1.94691
NEURO	-0.81213

APPENDIX C

Intercorrelations among WMS scales and revised scales.

TABLE 44

Intercorrelations among scales. All correlation coefficients are statistically significant $p < .000$.

	INFORM	ORIENT	CONTROL	PASSAGES	DIGITS	VISUALR	ASSOCL	MEMQUOT	WMSQUOT	OVERMEM	DAYDAY	REMOTE	PRIOR	SUBSEQ	NEURO	INTELL	IMPINDEX	NONVERB	CAT7	TPT	TEMPORAL	ATTENT
INFORM		.37	.27	.36	.29	.23	.35	.54	.48	.35	.35	.33	.36	.43	.41	.50	.31	.20	.24	.20	.38	.32
ORIENT			.19	.29	.22	.31	.41	.43	.41	.45	.45	.44	.40	.43	.51	.39	.36	.29	.34	.29	.28	.34
CONTROL				.41	.49	.40	.38	.58	.61	.51	.53	.47	.40	.46	.48	.62	.51	.37	.44	.44	.39	.57
PASSAGES					.35	.50	.60	.77	.82	.73	.65	.69	.83	.73	.49	.76	.65	.50	.57	.49	.49	.61
DIGITS						.37	.41	.62	.59	.48	.49	.45	.36	.45	.66	.64	.51	.37	.40	.40	.53	.65
VISUALR							.55	.61	.74	.83	.83	.85	.63	.75	.49	.78	.88	.94	.91	.90	.37	.89
ASSOCL								.71	.80	.83	.86	.82	.81	.71	.69	.73	.80	.54	.71	.54	.43	.68
MEMQUOT									.89	.80	.78	.77	.76	.76	.70	.87	.77	.58	.67	.57	.49	.77
WMSQUOT										.92	.91	.89	.85	.87	.73	.97	.91	.74	.83	.74	.55	.89
OVERMEM											.97	.97	.88	.89	.70	.90	.95	.83	.91	.81	.57	.89
DAYDAY												.97	.85	.87	.72	.89	.96	.83	.92	.82	.50	.89
REMOTE													.86	.87	.69	.88	.95	.85	.94	.84	.49	.90
PRIOR														.84	.65	.78	.80	.63	.73	.62	.49	.71
SUBSEQ															.64	.84	.82	.76	.80	.74	.53	.80
NEURO																.71	.67	.47	.58	.47	.58	.67

INTELL	.91	.78	.85	.78	.53	.93
IMPINDEX		.87	.95	.86	.46	.94
NONVERB			.96	.96	.35	.90
CAT7				.94	.40	.92
TPT					.34	.89
TEMPORAL						.49
ATTENT						

APPENDIX D

Use of WMS and revised scales with a clinical case.

APPENDIX D

Use of WMS and revised scales with a clinical case.

R.K. was a 30 year old graduate of a Canadian military college who was employed as a financial analyst for the federal government. The patient was seen in hospital in September of 1977 because of complaints of headache behind his eyes (of recent onset) and because of complaints of visual field defects. Neurological examination found his visual fields to be normal and no other definite abnormalities were found. The EEG investigation found some irregularity. Computerized axial tomography revealed a suprasellar tumour mass containing calcification. This was diagnosed as a craniopharingioma (tumour of the infindibulum) located in the region of the third ventricle. Angiography and pneumoencephalography determined that the third ventricle was elevated and the foramen of Monroe was partially blocked resulting in hydrocephalous which was indicated by the enlargement of the ventricles.

On Sept. 15, 1977 a right frontal craniotomy was carried out. An attempt to approach the tumour subfrontally was made. The right olfactory nerve was severed during the operation. The optic chiasm was visualized but no tumour mass could be seen. It was decided that the tumour could not be easily accessed and the wound was closed. One week later the craniatomy was reopened and the tumour was approached through the right lateral ventricle. The wall of the foramen of Monroe was retracted posteriorly and this allowed exposure of the dome of the craniopharyngioma. The cyst was punctured and 4 cc of yellow oily fluid was obtained. Following this, the cyst was seized with pituitary forceps and removal begun. A large amount of cyst was removed except for the portion which lay in the immediate suprachiasmatic and infindibular portion of the third ventricle, which was beyond afe exposure to remove. The wound was closed, the patient recovered from the anesthesia and appeared to be in satisfactory condition.

Neuropsychological assessment was conducted on October 24 and 25, 1977. The patient cooperated fully with testing and gave good effort throughout. When asked his age, he stated 27 which was incorrect by three years. At nine a.m. on the first day of testing, he thought it was time for lunch. He frequently asked the same question, "are these psychological tests?" and although an answer was given each time, he did not remember having asked the question previously. He did not remember that he had had an operation on his head. He could not remember his address. He stated that the Premier of Ontario was Robarts (the previous Premier). On the second day of testing, he did remember being in the room previously and was able to discriminate between the equipment that he had previously worked with from those that he had not. Also he gave no evidence of forgetting test instructions while he was involved with the test and his powers of concentration appeared to be quite good.

The patient was clinically rated as having a moderate memory disorder for day to day events, remote events, events prior to the onset of pathology (in this case the anterograde and retrograde amnesia began with the removal of the cyst), events subsequent to onset and a moderate memory disorder overall. He was rated as having confirmed damage to the right hemisphere.

A summary of the neuropsychological test results was as follows:

> "Tests of biological intelligence yielded results within the range of moderate impairment of cognitive and adaptive abilities dependent upon organic brain function. Psychometric scores varied considerably and were within the superior range on verbally weighted tests but much lower and in the low average range on nonverbal tests. Academic achievement levels were well maintained for reading and spelling. There was evidence of moderate to severe impairment of abstract reasoning skills and memory functions. Both auditory and visual attention

> span were moderately impaired. There were a number of motor and sensory deficits, maximized on the left body side. The pattern of impairment of nonverbal abilities in the face of intact verbal functions combined with left sided motor and sensory deficits was thought to be compatible with dysfunction of the right cerebral hemisphere."

This patient obtained a Memory Quotient of 81 on the Wechsler Memory Scale. Psychometric testing yielded a verbal I.Q. of 123, a Performance I.Q. of 90 and a Full Scale I.Q. of 109 on the Wechsler Adult Intelligence scale. Tests of biological intelligence yielded an impairment index of 0.8. The profile of subtest scores for the traditional scales of the WMS are presented in Table 45.

TABLE 45

The traditional WMS subscale scores: raw scores and scaled scores for case R.K.

Scale	Raw Score	Scaled Score
Information	2	8
Orientation	4	10
Mental Control	9	19
Passages	5.75	9
Digits	11	13
Visual Reproduction	9	12
Associate Learning	8	8

Examination of the scale scores indicate that a number of the scales are not sensitive to this patient's impaired cognitive function. He performed Mental Control perfectly and Visual Reproduction and Digits were well above average for his age. The relatively low scores on Information, Passages, Associate Learning and Memory Quotient reflects this patient's impaired cognitive abilities.

The pattern of scale scores on the new scales provides a clear picture of his memory disorder. Here it can be seen that on the WMS those items that are primarily related to memory (particularly verbal memory) were lower than items found to be related to impairment or attention. His lowest scale score was on the Scale Prior which was derived from items related to memory problems for events prior to the onset of pathology. This seemed consistent with the type of memory disorder seen clinically. He had both an anterograde and retrograde amnesia but the retrograde amnesia was somewhat more severe. The new memory scales were consistently low in this patient and the lowest scale score revealed the type of memory disorder seen clinically.

TABLE 46

The revised subscale scores: raw scores and scaled scores for case R.K.

Scale	Raw Score	Scaled Score
MEMORY QUOTIENTS		
OVERMEM-REV	29	7
MEMQUOT-REV	35½	11
ANTEROGRADE AMNESIA		
DAYDAY-REV	29	8
SUBSEQ-REV	12	10
RETROGRADE AMNESIA		
REMOTE-REV	18	6
PRIOR-REV	11	7
NONVERBAL		
CAT7-REV	10	10
TPT-REV	8	19
NONVERB-REV	6	9
CONTROL		
ATTENT-REV	16	13
IMPAIR-REV	21	10

It is also important to notice that he performed particularly well on the scales including figural items. These scales were included in an attempt to provide scales that would be sensitive to the nonverbal memory disorder seen among patients with mesial temporal lobe lesions of the right hemisphere. In spite of the fact that this patient had confirmed damage to his right hemisphere (based on the neurosurgeon's report) and the cognitive deficits on neuropsychological examination revealed a pattern consistent with right hemisphere dysfunction, his memory for figural (or nonverbal) items was maintained. It might be pointed out that on the second day of testing, he had no difficulty remembering the equipment that he had worked on the previous day.

The right hemisphere dysfunction in this patient was not related to the medial aspect of the temporal lobe but was primarily frontal and close to the midline as well as in the area of the third ventricle. The fact that those patients in this research with memory disorders and right hemisphere dysfunction, did not show a pattern of memory disorder specific to the nonverbal tests is likely due to the fact that accurate within hemisphere anatomical localization of cerebral damage was not always possible. Most likely among only a few of the right hemisphere cases was the damage related to the medial aspect of the temporal lobe. Further research is required to evaluate these scales as tests of nonverbal memory.

In summary, this case illustrates that, while the neurological information which provided evidence for lateralized dysfunction was not sufficiently localized to relate specific memory disorders to lateralized dysfunction, a number of aspects of the memory examination were clinically useful. The age related norms permit conversion to scale scores which allow direct comparison of performance on the various scales, both for the new scales and the traditional memory scales. In this single case, the pattern of scale score results was consistent with the clinically observed memory disorder. Further clinical use of these newly developed scales in a different population is planned in order to determine if all of the scales are required for a complete clinical memory assessment.

APPENDIX E

List of complete adult battery, Trites Neuropsychology Laboratory.

APPENDIX E

List of complete adult battery,
Trites Neuropsychology Laboratory.

- Halstead Category Test
- Halstead Tactual Performance Test (TPT)
- Finger Tapping Test
- Halstead Speech-Sounds Perception Test
- Seashore Rhythm Test
- Sensory Examination
  - Tactile, Auditory, Visual Imperception
  - Finger Agnosia
  - Perception of Numbers Written to the Fingertips
  - Visual Field Testing
  - Tactile Form Recognition Test
  - Sandpaper Test
- Wisconsin Aphasia Screening Test
- Trail Making Test
- Motor Examination
  - Motor Steadiness Battery
  - Maze Co-ordination Test
  - Holes Steadiness Test
  - Holes Resting Steadiness Test
- Grooved Pegboard Test
- Dynamometer Grip Strength Test
- Foot Tapping Test
- Lateral Dominance Examination
  - Hand
  - Eye
  - Foot
  - Ear

ABC Vision Scopes
Dichotic Digits Test
Right-left Discrimination Test
Verbal Concept Attainment Test
Knox Cube Test
Wechsler Adult Intelligence Test
Wide Range Achievement Test
Minnesota Multiphasic Personality Inventory
House-Tree-Person Drawings
Test de Rendement en Français
History Interview