THE CLINICAL ASSESSMENT OF VERBAL MEMORY

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I certify that this thesis contains no material which has been accepted for the award of any other degree or diploma in any university, and that to the best of my knowledge and belief, the thesis contains no copy or paraphrase of material previously published or written by another person, except where due reference is made in the text of the thesis

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INTRODUCTION

An assessment of verbal memory functioning must address a number of issues. A thorough and comprehensive evaluation needs to account for new and important models of memory function and dysfunction, and the significant implications which these may have for diagnosis and rehabilitation. Behaviourally based cognitive information must be integrated with neuropsychological data which provide neuroanatomical correlates for particular memory processes. Memory functioning is a diverse and complex phenomenon which can be accurately and comprehensively assessed, only when cognitive and neuropsychological perspectives are combined. Cognitive theories have had a significant influence on the clinical assessment of verbal memory, and the development of specific neuropsychological procedures. However, often clinical evaluations have tended to lag behind theoretical and experimental advances.

In the following review, current cognitive and neuropsychological models of memory function will be evaluated, with an emphasis on the most clinically useful developments dealing with the structure of short-term or working memory, the efficiency of acquisition, storage and retrieval processes, along with the fractionation of long-term memory. A number of commonly used neuropsychological procedures will be reviewed, and an evaluation made of their psychometric reliability and validity, including their ability to differentiate both the nature and severity of memory dysfunction. The tests to be considered are the National Adult Reading Test (NART), the verbal subtests of the Wechsler Memory Scale (WMS), the Rey Auditory Verbal Learning Test (RAVLT), and the Bushke Selective Reminding Test (BSRT).

NEUROPSYCHOLOGICAL ASPECTS OF MEMORY

MODELS OF MEMORY

SENSORY MEMORY

According to current models of memory, the first stage of processing occurs at the peripheral level. Different types of sensory information (eg. visual, auditory, olfactory) are held in a brief sensory register for between 50 and 500 milliseconds (Kalat, 1988). Iconic (visual) and echoic (verbal) memory feed into a more durable short term visual/auditory storage system which holds information for approximately 2-20 seconds (Baddeley, 1990). Information is evaluated for its significance, and if required, is further processed by working memory.

WORKING MEMORY

The concept of a working memory was first proposed by Baddeley and Hitch (1974). Since this time the working memory model has undergone a number of revisions, and has recently been reviewed by Baddeley (Baddeley, 1990). On a neuroanatomical level, it is believed that working memory is 'an intrinsic capacity of each cortical processing system' (Squire, 1986).

The Central Executive

The basic tenets of the working memory model centre around the operation of a controlling attentional component, the central executive, which co-ordinates a number of subsidiary slave storage systems. The activity of the central executive is generally assessed via dual-task procedures which place excess demands on attention (Baddeley, 1990). Research with a number of clinical groups including patients with closed head injuries (CHI) and dementia of the Alzheimer type (DAT) have indicated a specific impairment in the processing capacity and efficiency of the central executive, with subsidiary systems such as the phonolgical loop remaining unimpaired (Baddeley, Logie, Bresi, Della Sala & Spinnler, 1986; Morris, 1986). Impaired functioning of the central executive is also typical of the behaviours exhibited by patients suffering from what is termed frontal lobe or dysexecutive syndrome. In such cases, the ability to plan, organize and control actions is compromised. The primary activities of the central executive are believed to involve either the recoding of information to facilitate transfer between stores, or alternatively as a type of planning and organizational co-ordinator (Broadbent, 1984; Baddeley & Hitch, 1974).

The central executive co-ordinates a number of slave storage systems, and two of these, the articulatory or phonological loop and the visuospatial sketch pad, will be discussed.

The Phonological Loop

The phonological loop has received substantial investigation, largely because it is one of the easier components to delineate, and is related to a considerable body of data in prior short-term memory (STM) research (Baddeley, 1990). It is generally seen as a structure of limited capacity which is responsible for the manipulation of speech-based information (Parkin, 1987; Baddeley, 1990). The phonological loop is believed to consist of two components: the phonological store and an articulatory control process. The phonological store is capable of holding speech-based information for approximately two seconds, after which time the information fades and is unretrievable. The memory trace can be retained if the information is read from the store into the articulatory control process which can then feed information back into the phonological store. The phonological loop can account for a number of factors which influence immediate memory span, including phonological similarity, unattended speech, word length and articulatory supression (Baddeley, 1990). The phonological loop is involved in a number of everyday cognitive activites including the ability to read, the acquisition of vocabulary and the comprehension of spoken language (Baddeley, 1990; Parkin, 1987). Overall, the broad functioning of the phonological loop has received considerable attention, however quantitative features need to be specified including encoding and retrieval mechanisms, capacity and trace duration, and its relationship to the processes of speech perception and production (Baddeley, 1990).

The Visuospatial Sketch Pad

The second of the working memory subsidiary systems is the visuospatial sketch pad. Research on this component has only recently commenced and tends to be qualitatively and quantitatively broad. The visuospatial sketch pad is seen to be responsible for the organization and manipulation of visual imagery (Baddeley, 1990; Parkin, 1987). The sketch pad is involved in the use of visual imagery mnemonics, but not in the imageability effect present in long-term verbal memory (Baddeley, 1990). Overall, the sketch pad is believed to be a multi-faceted system with separable but interdependent visual and spatial components. This assumption has been supported through neuropsychological research with both brain injured and normal subjects (Baddeley, 1990).

Summary

The working memory system consists of a central attentional component which co-ordinates and facilitates the transfer of information between a number of subsidiary systems such as the phonological loop for verbal material, and the visuospatial sketch pad for visual and spatial information. The concept of a multi-dimensional working memory system provides a superior theoretical account than previous unitary STM models, for the data obtained from neuropsychological and normal populations. Currently, theories of the qualitative and quantitative aspects of working memory and its subsystems tend to be broad, although future research should change this.

Once information has been processed in working memory, it undergoes a transfer into long-term memory (LTM) . For the purposes of this review, the processes involved in LTM such as acquisition, storage and retrieval will be discussed. Following this, the fractionation of LTM will be examined, including evidence for declarative and procedural subsystems.

LONG-TERM MEMORY

Introduction

LTM has been defined as a memory system whose function is the storage and recall of information without rehearsal, for any period in excess of approximately 30 seconds; and may include information from the very recent to the remote past (Hart & Semple, 1990). Information may be encoded along a number of different modalities, and its capacity is believed to be unlimited (Reed, 1988). The loss of information from LTM may have a number of causative factors including the loss of accessibility to information or the loss of discriminability of memory traces due to interference (Reed, 1988). Accurate retrieval of information from LTM depends on the availability of relevant and distinct retrieval cues.

Acquisition

The acquisition of new information may be affected by a number of procedural variables including the rate of presentation, the relationship between items on a list, and stimulus type (ie. verbal or visual). With verbal material eg. words, properties such as frequency of occurrence, and ratings of imagery and concreteness will differentially affect acquisition and memorability (Morris, 1978). Further, the encoding operations performed during acquisition will influence subsequent storage and retrieval; with the retention of information determined by the depth of processing, including the elaboration and distinctiveness of memory codes (Craik & Lockhart, 1972; Craik & Tulving, 1975).

The processes of acquisition and retrieval in verbal learning have been examined through the efficiency of retrieval of list items as a function of their serial position in free recall tasks. In normal subjects, words presented at the end of the list tend to be recalled with greatest frequency, termed the recency effect. Words presented at the beginning of the list tend to be recalled more often than words in the middle of the list, termed the primacy effect. The middle section of the list, where recall tends to be weakest, is known as the asymptote(Parkin,1987). Evidence from experimental and neuropsychological data appeared to support the primacy/recency effect as representative of the dichotomy between working memory/short-term memory and long-term memory processing. The primacy effect was assumed to represent information which had passed into long-term storage, with the recency effect indicating the presence of information in STM or working memory. Though this dichotomy is still generally accepted, there are a number of problems with this interpretation, which will be discussed later, along with retrieval mechanisms.

Hence, the acquisition of verbal information may be influenced by a number of factors including procedural variables such as presentation rate and stimulus type. As well, various encoding operations and analyses carried out on incoming information, directly influence the formation of memory traces. Once the processes of acquisition and encoding have occurred, information then undergoes a period of consolidation and storage within LTM.

Consolidation and Storage

Once information has been encoded, it is transferred from the transient working memory system into one of the LTM subsystems for permanent storage or access. Permanent storage may be facilitated by the process of consolidation which 'provides for integration of new memories within the individual's existing cognitive/linguistic schema' (Sohlberg & Mateer, 1989). Appropriate encoding is therefore a necessary prerequisite for storage, but is no guarantee that effective consolidation or storage of information will occur. Currently, little has been learned about the processes which influence storage variation (Mayes, 1988).

The efficiency of storage in LTM is usually examined by a comparison of recall at different intervals after the initial period of learning, termed the rate of forgetting. Three main explanations have been put forward to account for the phenomenon of forgetting. Firstly, trace decay theory assumes that stored information decays with the passage of time (Ebbinghaus, 1885). Secondly, fragmentation of memory traces may occur and hence cause difficulties with retrieval, as new memories are laid down (Mayes, 1988; Baddeley, 1990). Finally, the interference hypothesis states that interference causes forgetting 'by degrading retrieval cues for target material by attaching cues to other memories as well' (Mayes, 1988).

Interference is certainly a major determinant of forgetting 'with the degree of interference increasing as the interfering material becomes more and more similar to the material learned' (Baddeley, 1990). Two types of interference are of considerable relevance for the study of verbal memory. Firstly, retroactive interference (RI) refers to the decremental effect of new learning on the recall of previously learned information. Secondly, proactive interference (PI) refers to the decremental effect of previously learned information on the ability to learn new information (Baddeley, 1990). A number of clinical groups fail to show release from PI including patients with frontal lobe damage, and certain types of amnesic syndromes including Korsakoff's syndrome (Kolb & Whishaw, 1985; Hart & Semple, 1990; Butters, Albert & Sax, 1979).

In summary, the processes of consolidation and storage are generally inferred from an examination of the rates of forgetting for different types of learned material. A number of explanations of forgetting have been offerred such as trace decay, fragmentation and interference. However the amount of information perceived to be in LTM is influenced by the availability of access. Therefore retrieval mechanisms are also critical processes in the long-term storage of verbal information.

Retrieval

The phenomena of forgetting occurs when material has been learned, but the information fails to be retrieved at a particular time. Baddeley (1990) suggests that retrieval mechanisms are of two main types: 'those processes of conscious recollection that are open to introspection, and the relatively automatic and involuntary retrieval processes that underlie much of our remembering'. Prominent models of retrieval will be mentioned, including the encoding specificity hypothesis, and generate-recognize models. Further, the different retrieval mechanisms involved in free recall, cued recall and recognition will be discussed.

Free Recall

The processes of acquisition, storage and retrieval are often inferred from the efficiency of retrieval of list items in free recall tasks. The serial position effect found in free recall tasks, is believed to represent the STM-LTM dichotomy, with the primacy effect reflecting the retrieval of words from LTM; and the recency effect reflecting retrieval of information from STM or working memory. However recent research suggests that the widely held belief that the recency effect reflects the mechanisms of a short-term or working memory are incorrect. Baddeley and Hitch (1974; 1977) demonstrated that if subjects attempted to simultaneously perform free recall of unrelated words while subvocally repeating a sequence of digits, performance was impaired. However the recency effect was preserved. According to STM models, the digit span and free recall task should have competed for the limited capacity short-term storage, and negated the recency effect. Therefore the recency effect in free recall may not reflect the contribution of a capacity limited short-term verbal store (Baddeley, 1990; Richardson, 1990; Parkin, 1987). Further, the so-called recency effect can survive long periods of distraction, and has been demonstrated in the recall of information, such as personal events, from LTM (Baddeley & Hitch, 1977; Baddeley, 1986). Some researchers now believe that the recency effect reflects an ordinary but optimal retrieval strategy, where the most recently presented items are recalled first, leaving prior information vulnerable to decay and output interference (Parkin, 1987; Richardson & Baddeley, 1975, Richardson, 1990). At the present time, the recency effect remains a problematic issue, and such interpretative problems place limitations on the serial position curve as reflective of the dichotomous functioning of a short-term or working memory and LTM.

Cued Recall

Tulving (1967) showed that retrieval may be inconsistent during free recall learning of a list of words, suggesting that words that are stored are often unable to be recalled. Later research has demonstrated that retrieval cues can be used to prompt the recollection of an item which has been learned, but cannot be spontaneously recalled (Baddeley, 1990). Cued recall involves the presentation of a partial aspect of the stimulus to be recalled eg. the letters 'pa' as a cue for the word 'passion'. Both instrinsic and extrinsic cues are important. Extrinsic cues such as context or environment, the psychological state of the individual, and mode of presentation, all influence retrieval to the extent that 'material learned in one environment or under one psychological state is shown to be best recalled in that environment or state' (Baddeley, 1990). The importance of intrinsic cues is the basis for Tulving's influential encoding specificity principle which states that 'specific encoding operations performed on what is perceived determine what is stored, and what is stored determines what retrieval cues are effective in providing access to what is stored' (Tulving & Thomson, 1973). Thus, retrieval cues are effective only if they represent encoding processes which occurred during original learning. The more numerous and distinctive the encoded cues are, the greater the retrieval accessibility.

In summary, retrieval cues are used to evoke an item which has been learned but cannot be spontaneously recalled. Cues may represent information specific to an item's interpretation, or reflect contextual, background features. According to the encoding specificity hypothesis, cues are most effective if they reflect encoding operations performed at the time of initial learning.

Recognition

Recognition tasks may be regarded as a special class of cued recall where the retrieval cue is the stimulus itself. Recognition tasks are believed to provide 'the most sensitive indication of the availability of items in memory as they render an active search strategy unnecessary and so make fewer processing demands upon the subject' (Hart & Semple, 1990). Recognition procedures tend to be of two types: forced choice or yes-no procedures.

The relationship between recall and recognition is complicated and controversial (Baddeley, 1990; Mayes, 1988). Generate-recognize models maintain that two processes are required for the accurate recall and recognition of information. With recall of verbal material eg. words, the first process involves the generation of possible candidate words; while the second process identifies whether the generated words have been presented previously or not (Baddeley, 1990). Recognition memory is believed to assist retrieval, as only the second process is required for correct identification of target information. Current theories of recognition suggest that there are two distinct processes involved. The first process is based on the familiarity of the item and relates to recently perceived items. The second process involves the retrieval of an item or event's context and relates to older and weaker memories (Mandler, 1980). As recognition and recall are differentially affected by a number of cues and procedural variables, they are generally held to represent partially distinct retrieval processes.

Summary

The learning of new information and its transfer into LTM depends on the processes of acquisition, storage and retrieval. Acquisition is affected by procedural variables, and the various encoding operations and analyses directly influence the durability of the memory trace. The consolidation and storage of memory has been inferred from studies of rates of forgetting, for both newly learned information and well established memories. Forgetting is influenced by the accuracy of retrieval mechanisms, with the most effective retrieval cues reflecting initial encoding operations. Once the processes involved in the establishment of LTM have been delineated, the characteristics and structure of LTM should be considered.

Declarative and procedural memory

The number of distinctions which can be made between the LTM subsystems is currently a matter of controversy. Tulving (1972; 1984) proposed that information held in LTM consisted of either episodic or semantic memories. Episodic memories are defined as a personally experienced autobiographical record of episodes or events, which are encoded with reference to a specific temporal and spatial context (Hart & Semple, 1990; Parkin, 1987). The majority of verbal memory research has employed procedures which tap episodic memory (Hart & Semple, 1990). Semantic memories represent a system of organized knowledge concerning the world, words, concepts and language, and the rules which govern their use (Hart & Semple, 1990; Parkin, 1987). Semantic memory is believed to be 'stored in a relatively context-free manner and lacks the autobiographical referents which characterize that held in episodic memory' (Hart & Semple, 1990). The activities of semantic and episodic memory are highly interdependent, with episodic information being crucial for the formation of new semantic memories (Parkin, 1987). Recently the distinction between episodic and semantic memory has been disputed on the grounds that it lacks a theoretical basis and relies solely on observed differences between the two supposed types of memories (Mayes, 1988).

Recently, Squire (1986) proposed a different system for fractionating LTM, based largely on neuropsychological studies of the amnesic syndrome. The proposed system distinguishes between declarative and procedural types of memory. Declarative memory is 'explicit and accessible to conscious awareness and it includes the facts, episodes, lists and routes of everyday life. It can be declared, that is, brought to mind verbally as a proposition or nonverbally as an image' (Squire, 1986). Episodic and semantic memories can be considered as components of declarative memory (Tulving, 1987; Squire, 1986).

In contrast, procedural knowledge is considered to be implicit and is 'accessible only through performance, by engaging in the skills or operations in which the knowledge is embedded' (Squire, 1986). Examples of procedural knowledge would include complex motor skills (eg. bicycle riding), perceptual skills (eg. reading mirror-reversed words), and intuitive cognitive skills (eg. one is usually unable to give an account of the complex grammatical rules which govern one's native language) (Mayes, 1988; Parkin, 1987). Priming is also regarded as evidence of procedural learning, and refers to increased efficiency or processing information as a result of prior exposure to the stimuli (Baddeley, 1990). This occurs independently of the capacity to recall or recognize the target information (Mayes, 1988).

The fractionation of LTM is an evolving area. Although a number of theories exist, the distinction between declarative and procedural memories is supported by a considerable body of neuropsychological data. A comprehensive neuropsychological examination of memory must delineate functioning not only in terms of structural components such as the capacity of working memory and the various LTM subsystems, but also the efficiency of acquisition, storage and retrieval processes. A knowledge of current cognitive models of human memory is essential for the accurate assessment and rehabilitation of memory disorders.

BASIC HUMAN ORGANIC MEMORY DISORDERS

INTRODUCTION

The neuroanatomical substrates of memory functioning have not been clearly defined, largely due to the divergent and complex nature of the higher cognitive functioning involved in memory (Tulving, 1985). Damage to particular structures has been correlated with specific memory impairments, although it has not been established which structures and connections are of critical importance (Squire, 1986). Five basic human organic memory disorders have been identified including: (1) STM deficits; (2) disorders of previously well established memories; (3) frontal cortex disorders (disturbances of the ability to plan encoding and retrieval strategies); (4) organic amnesia (an impairment in the ability to acquire and retain declarative memories); (5) disorders of skill learning and conditioning.

SHORT TERM MEMORY DEFICITS

Temporary information storage occurs independently of the medial temporal (MT) and diencephalic structures damaged in amnesia (Squire, 1986). STM deficits are associated with lesions to the parietotempero-occipital (PTO) association neocortex, which is functionally related to the final stages of analysis and interpretation of sensory information (Mayes, 1988). The PTO cortex has extensive direct and reciprocal connections with other cortical areas, thalamic nuclei and spinal cord nuclei (Barr & Kiernan, 1983).

STM deficits are demonstrated by poor performance on tests of immediate memory. Several kinds of fairly selective, modality specific deficits exist. The examination of verbal STM deficits has received the most attention to date (Mayes, 1986). A dissociation between impaired verbal STM and intact long-term verbal learning has been demonstrated in a number of cases (Shallice & Warrington, 1970; Basso, Spinnler, Vallar & Zanobio, 1982; Warrington & Weiskrantz, 1973). Neuropsychological and psychopharmacological research indicates that selective impairments of the articulatory loop system and the central executive can occur (Vallar & Baddeley, 1984; Morris, 1984; Allport, 1983; Rusted & Warburton, 1988). Some evidence also exists for impaired short-term processing of visual information (Warrington & Weiskrantz, 1973; Butters, Samuels, Goodglass & Brody, 1970).

DISORDERS OF PREVIOUSLY WELL-ESTABLISHED MEMORIES

Lesions to the PTO association neocortex also disturb access to previously well established episodic and semantic memories (Mayes, 1988; Kolb & Whishaw, 1985). These may be confined to highly specific types of information including knowledge of arithmetic, concrete or abstract words, animate objects, and inanimate objects such as fruit and vegetables (Mayes, 1988; Warrington, 1982; Warrington & McCarthy, 1983; Warrington & Shallice, 1984). The occurrence of some aphasic, agnosic and apraxic syndromes has been reinterpreted as a selective failure of semantic storage or access (Mayes, 1986). Although research in this area is far from definitive, evidence thus far provides significant information regarding the organization of semantic and episodic memories in the neocortex (Mayes, 1988).

FRONTAL CORTEX DISORDERS

Lesions to the frontal cortex, especially the prefrontal cortex and basal forebrain regions, disrupt memory because they impair the ability to plan and organize encoding and retrieval strategies (Mayes, 1988). The prefrontal cortex has extensive connections with parietal, temporal and occipital cortices, as well as reciprocal connections with the dorsomedial nucleus of the thalamus (Barr & Kiernan, 1983). Prefrontal lesions are associated with disturbances in certain memory functions including judgements of the temporal order and frequency of occurrence of events, and performance in self-ordered tasks (Mayes, 1988; Kolb & Whishaw, 1985; Petrides & Milner, 1982). Frontal lesions have been associated with impaired learning of complex material, with deficient free recall but intact recognition (Mayes, 1986). Frontal lobe patients also show an increased susceptibility to interference, show poor release from PI, fail to engage in elaborative semantic processing and demonstrate a poor awareness of the workings and effectiveness of their memory strategies (Mayes, 1986; Kolb & Whishaw, 1985). Along with the basal ganglia, the inferior frontal lobe may be involved in the initiation of retrieval processes (Risse, Rubens & Jordan, 1984). It has been noted that the effects of frontal lesions on memory processing appear qualitatively different from those produced by MT or diencephalic damage (Kolb & Whishaw, 1985; Mayes, 1986).

ORGANIC AMNESIA

The transfer of information from working memory into LTM (consolidation) requires the integrity of the MT and diencephalic regions which operate in conjunction with the relevant neocortical cell assemblies to produce LTM changes (Squire, 1986). In the later stages of consolidation and storage, information may be recalled and recognized without the involvement of MT and diencephalic structures (Squire, 1986; Mayes, 1988). It is well established that lesions to the MT or midline diencephalon cause deficits in the acquisition and retention of long-term episodic and semantic memories (Mayes, 1986). Typically, there exists 'impaired recall and recognition of pretraumatically acquired (retrograde amnesia) and of recently presented information (anterograde amnesia)' (Mayes, 1986). It has been argued that MT and diencephalic lesions produce different memory deficits (Squire, 1986). MT lesions are believed to cause a temporally graded retrograde amnesia and anterograde amnesia characterized by poor initial learning and faster rates of forgetting (Squire, 1986; Huppert & Piercy, 1979). Diencephalic lesions may produce a milder but flat retrograde amnesia without sparing of older memories, whereas anterograde amnesia is characterized by poor initial learning but normal rates of forgetting (Squire, 1986; Mayes, 1986).

Typically, organic amnesics without additional cortical pathology demonstrate intact intelligence and intact STM abilities (Mayes, 1986). Further organic amnesics are able to learn and retain procedural skills, condition normally, and show intact priming for information they are unable to recognize (Weingartner, Graffmen, Boutelle, Kaye & Martin, 1983; Mayes, 1986).

DISORDERS OF SKILL LEARNING AND CONDITIONING

Finally, lesions of the basal ganglia and cerebellum are believed to impair skill learning, retention, and conditioning (Mayes, 1988). Such types of procedural learning may depend on the integrity of extrapyramidal motor systems (Squire, 1986). However there is no evidence that priming (considered to be a type of procedural memory), is affected by these lesions. Priming may be impaired by lesions in the PTO or prefrontal association neocortex (Mayes, 1988; Squire, 1986).

CONCLUSION

The neuropsychology of memory functioning is a diverse and complex field which is best understood from a combination of the cognitive and neuropsychological perspectives. Cognitive models of memory are continually developing towards a fractionation of specific processes involved in memory. While based in experimental research, cognitive models enable the characterization of specific aspects of memory processing. The association of memory deficits with specific brain structures has aided the diagnosis and characterization of such disorders; and has enabled the development of neuroanatomical models of memory functioning. Adequate knowledge of such research is essential in order to effectively assess memory and cognitive functioning.

CLINICAL ASSESSMENT OF VERBAL MEMORY

ISSUES IN ASSESSMENT

In general terms, the clinical assessment of verbal memory function 'needs to become more comprehensive, more functionally based, and, at the same time, more attuned to new and important theoretical notions of memory function and dysfunction' (Sohlberg & Mateer, 1989).

The assessment of verbal memory functioning should include the following. First, the complete assessment of verbal memory functioning should include tests of intelligence (Mayes, 1986; Mayes, 1988). Some indication of premorbid intelligence can be obtained from the National Adult Reading Test (NART) which taps reading skills which have been established premorbidly and should reflect premorbid intelligence (Nelson, 1982). It is important that intelligence estimates are obtained, as it has been demonstrated that intelligence levels affect memory abilities, with memory being better in the more intelligent (Zola-Morgan, Cohen & Squire, 1982; Mayes, 1986; Wiens, McMinn & Crossen, 1988).

Second, the registration and retrieval of information within working memory should be examined (Cripe, 1987; Sohlberg & Mateer, 1989; Lezak, 1983; Erickson & Scott, 1977). Verbal working memory may be assessed using the Digit Span subtest from the Wechsler Memory Scale (WMS) (Wechsler, 1945). However, further tests should be conducted to assess the integrity of working memory subsystems, including the phonological loop and the central executive (Mayes, 1986). Functioning of the central executive should be examined using multiple measures of attention, including sustained, selective and alternating attention (Sohlberg & Mateer, 1989; Walsh, 1985).

Third, verbal material should be presented for learning, particularly multi-trial formats which describe the ability to benefit from repeated exposure and more adequately reflect learning ability (Sohlberg & Mateer, 1989; Mayes, 1986; Erickson & Scott, 1977). Learning should be assessed at immediate and delayed recall, with the latter having significant clinical utility (Mayes, 1988; Cullum, Kuck & Ruff, 1990; Lezak, 1983).

Fourth, recall of information should include both free recall and recognition formats (Mayes, 1988; Cripe, 1987; Mayes, 1986). Recognition procedures need to be incorporated into the assessment, in order to accurately differentiate retrieval problems (Lezak, 1983; Sohlberg & Mateer, 1989).

Fifth, rates of forgetting over brief (ie. 10 minutes) and extended (eg. one day, one week) time periods are important, and retention over time is considered to be 'the key test of memory' (Mayes, 1986).

Finally, three further aspects of memory should be assessed including: (a) memory for context information usually processed on the periphery of attention; (b) priming; and (c) sensitivity to interference for both recently presented and more remote memories (Mayes, 1986). The detection of memory dysfunction requires a comprehensive assessment as performance is affected by the length, type and complexity of task content, along with cognitive skills other than memory per se (Lezak, 1983; Macartney-Filgate & Vriezen, 1988). Further as Lezak notes 'because of the lack of systematic comparisons between the different verbal memory tests, their relative usefulness and potential interchangeability remain unknown' (Lezak, 1983).

In an attempt to address these issues, a review will be made of four widely used measures in the clinical assessment of verbal memory, before describing a research project to clarify the construct and concurrent validity of a number of clinical measures of verbal memory. The assessment procedures to be reviewed include: (a) the NART as a measure of premorbid intelligence; (b) the verbal components of the WMS, namely Logical Memory, Digit Span and Associate Learning; (c) the Rey Auditory Verbal Learning Test (RAVLT); and (d) the Bushke Selective Reminding Test (SRT).

NATIONAL ADULT READING TEST (NART)

THE ESTIMATION OF PREMORBID INTELLIGENCE

A comprehensive memory assessment should contain an indicator of intellectual functioning, given the influence of intelligence on memory abilities (Mayes, 1986). In cases of acquired brain injury, there are a number of clinical, medicolegal or research situations where the estimation of premorbid intelligence is important (Matarazzo, 1990; Crawford, 1989a). Ideally, this would be accomplished by the use of psychometric data obtained prior to the injury, although this is rarely available (Crawford, 1989a; Crawford, Besson, Parker, Sutherland & Keen, 1987). A number of methods of estimation have been proposed including a comparison between current levels of intelligence as measured by the Wechsler Adult Intelligence Scale - Revised (WAIS-R) (Wechsler, 1981), and clinical estimation based on the use of demographic variables, or performance on tests such as the Vocabulary subtest of the WAIS-R or the Mill Hill Vocabulary Test (Raven, 1982), which are assumed to be relatively insensitive to the effects of generalized cortical damage (Lezak, 1983). The most commonly used instrument for estimating premorbid intelligence has been the Vocabulary subtest (Crawford et al., 1987). However its use is now considered to be inappropriate as Vocabulary scores are impaired in a number of clinical conditions and are likely to significantly underestimate premorbid intelligence (Crawford, 1989a).

To qualify as an valid measure of estimated premorbid intelligence, a present ability measure must satisfy three criteria: (1) it must have adequate reliability; (2) it must correlate highly with intelligence in normal subjects; (3) it must be resistant to the effects of psychiatric and neurological disorders (Crawford, 1989a). Nelson and McKenna (1975) suggest that word reading ability is more resilient in dementing patients than other verbal skills, such as the ability to extract meaning from words, as measured by the Vocabulary subtest. Hence a measure of single word reading ability could provide a useful indicator of premorbid intelligence as it would assess the level of reading achieved before the onset of brain impairment (Nelson & McKenna, 1975; Spreen & Strauss, 1991). The best previously available measure, the

Schonell Graded Word Reading Test (SGWRT) (Schonell, 1942), had a number of problems including reliability and an inability to provide estimates of over 115 IQ points (Nelson & McKenna, 1975; Nelson & O'Connell, 1978). This led to the development of the National Adult Reading Test (NART) (Nelson, 1982).

DESCRIPTION

The NART is a single word reading test, consisting of 50 words which a subject has to read and pronounce. The utility of the test is dependent on its ability to provide 'a sensitive measure of previous familiarity with words, rather than a measure of continuing ability to analyze a complex visual stimulus' (Nelson, 1982). The stimulus words are predominantly short and of irregular pronunciation so that the application of grapheme-to-phoneme conversion rules or intelligent guesswork should not aid performance (Nelson, 1982). Therefore, it is suggested that successful performance is dependent upon previous familiarity with individual words, rather than current cognitive capacity (Nelson & O'Connell, 1978).

RELIABILITY

A valid premorbid intelligence estimate must have adequate reliability (Crawford, 1989a). Reliability is assessed along three domains: internal consistency, inter-rater agreeement and test-retest reliability. Split-half reliability coefficients have been reported at 0.93 (Nelson, 1982) and 0.90

(Crawford, Stewart, Garthwaite, Parker & Besson, 1988c) thus indicating that the NART has a high internal consistency. Inter-rater agreement has been reported at correlations of 0.89 to 0.99 (O'Carroll, Baikie & Whittick, 1987; Crawford, Parker, Stewart, Besson & De Lacey , 1989c). Using an Australian sample, Schlosser and Ivison (1989) reported correlations of 0.983 for a normal group and 0.97 for a DAT group. Therefore it can be concluded that the NART has a high inter-rater reliability. Finally test-retest reliability has been examined in a non-clinical sample. Crawford et al. (1989c) reported a reliability co-efficient of 0.98 for a sample of non-clinical subjects.

VALIDITY

The validity of the NART as a measure of intelligence has been addressed in a number of studies. In the standardization sample, the NART predicted the variance in 55% of WAIS Full Scale, 60% of Verbal IQ and 32% of Performance IQ scores (Nelson, 1982). In this study, WAIS IQ scores were prorated from seven subtests. Crawford et al. (1989c), administered the NART and a full WAIS to 151 normal subjects and found that the NART predicted 60%, 72% and 33% of the variance in WAIS Full Scale, Verbal and Performance IQ respectively. Thus is can be concluded that the NART is a reasonable predictor of WAIS Full Scale and Verbal IQ, but a relatively poor predictor of Performance IQ. Equations to predict WAIS-R (Wechsler, 1981) and WAIS-R Neuropsychological Index (NI) (Kaplan, Fein, Morris & Delis, 1991) have yet to be developed. The NART has been found to correlate highly with both WAIS and WAIS-R IQ in normal subjects (Crawford, 1989b; Crawford et al., 1987). Evidence of construct validity is derived from factor analytic studies. Crawford, Stewart, Cochrane, Parker and Besson (1989d) reported that the NART loaded highly (0.85) on 'g', an indicator of general intelligence.

It is important to determine if NART performance declines with advancing age in the normal population. In the NART standardization sample, NART error scores did not correlate with age (0.14) at an age range of 20 to 70 years (Nelson, 1982). Further research using similar age ranges also found no significant correlations between age and NART performance after the effects of education and social class had been partialled out (Crawford et al., 1988b; Crawford et al., 1989c). It can be concluded that age has little, if any, effect on reading ability within the 20 to 70 year age range. Recently this conclusion has been extended to include elderly groups up to 89 years (Schlosser & Ivison, 1989; Binks & Davies, 1984; Brayne & Bearsdel, 1989).

It is important that the NART be largely resistant to the effects of neurological and psychiatric disorders if it is to be considered as a valid estimate of premorbid intelligence. Initially, the NART was developed for use with dementing populations. When the NART standardization sample was compared with a group of patients with bilateral cortical atrophy, significant differences were found between the two groups on WAIS IQ ($p < .001$), but not for NART error scores (Nelson & O'Connell, 1978). This finding has been supported in a number of other studies with DAT patients (Nebes, Martin & Horn, 1984; O'Carroll et al., 1987; Ruddle & Bradshaw, 1982). However further research suggests that NART performance may not be entirely resistant to dementia in the later stages of disease progression (Stebbins, Wilson, Gilley, Bernard & Fox, 1988; Hart, Smith & Swash, 1986). This need not undermine the clinical utility of the measure, for as Crawford points out 'where cerebral dysfunction is severe enough to markedly impair performance on a test as robust as the NART, comparison of the obtained IQ score with the premorbid estimate would be largely unnecessary as intellectual deterioration would be all too readily apparent' (Crawford, 1989a).

Research with other clinical groups including alcoholic dementia, multi-infarct dementia, closed head injury (CHI), depression and Parkinson's disease indicates that NART performance 'holds' in these groups (Crawford, Besson & Parker, 1988a; Crawford et al., 1987). Longitudinal investigations of patients with progressive disease, eg. dementia, indicate that the NART remains relatively unaffected by the dementing process at a one year retest interval, while other measures (eg. Mill Hill Vocabulary Test and Clifton Assessment Procedures for the Elderly (CAPE)) declined (Crawford et al., 1987).

LIMITATIONS OF THE NART

Despite its demonstrated clinical utility, limitations exist for usage of the NART with certain clinical conditions. Firstly, the NART cannot be used with aphasic or dyslexic patients, nor with patients having significant articulatory or visual acuity problems (Spreen & Strauss, 1991; Crawford, 1989a). Secondly, the NART has a ceiling of 128 IQ points, and IQ's of 125+ cannot be reliably predicted (Nelson, 1982). The additional use of the SGWRT enables the accurate prediction of lower IQ groups (ie. <87 IQ points) (Nelson, 1982). Thirdly, the NART needs to be standardized on the WAIS-R and WAIS-R-NI. Finally, NART equations can only be used with validity in their country of origin (Crawford, 1989a). The North American Adult Reading Test (NAART) has been developed for use with North American populations, and has been validated against the WAIS-R (Blair & Spreen, 1989). Currently, Australian use of the NART relies on the UK standardization using the WAIS, and this situation needs to be addressed in future research.

SUMMARY

In general, research indicates that the NART is reasonably resistant to a range of neurological and psychiatric disorders. In comparison with the commonly used Vocabulary subtest, the NART is consistently found to have greater reliability and validity especially in the presence of neurological and psychiatric disorders, and is therefore the instrument of choice in estimating premorbid intelligence.

WECHSLER MEMORY SCALE (WMS)

DESCRIPTION AND LIMITATIONS

The WMS (Wechsler, 1945) is one of the most frequently used clinical measures of memory (Erickson & Scott, 1977; Richardson, 1990). It consists of seven subtests, which were designed to measure different aspects of memory; and exists in two forms (1 and 2) (Wechsler, 1945; Wechsler & Stone, 1946). The seven subtests are:

1) Personal and Current Information (questions regarding age, date of birth, and current government figures)
2) Orientation (assesses orientation to time and place)
3) Mental Control (requires the subject to count backward from 20, recite the alphabet and count (eg. by 3's or 4's) under time pressure)
4) Logical Memory (examines the recall of two short prose passages)
5) Digit Span (assesses the recall of sequences of digits in a forward and backwards direction)
6) Visual Reproduction (requires the drawing of simple geometric figures from memory)
7) Associate Learning (a multi-trialled paired associate learning task)

The patients raw score's on each subtest are summed, and an age correction factor added, to obtain a summary score, the Memory Quotient (MQ).

The reliability, validity, standardization and structure of the WMS have been extensively criticized (Erickson & Scott, 1977; Lezak, 1983; Prigatano, 1978;

Franzen, 1989; Spreen & Strauss, 1991). These criticisms refer to a number of issues including: (a) inadequate normative data; (b) the use of a summary score (MQ) which does not discriminate different types of memory dysfuntion; (c) failure to evaluate retention of information with a delay; (d) imprecise scoring criteria especially for Logical Memory; (e) the over-reliance on verbal tasks; (f) the inclusion of subtests which are not genuine measures of memory eg. Mental Control, Orientation.

Despite difficulties with the WMS as a whole, recent research has demonstrated the sensitivity of the subtests themselves (Franzen, 1989). The various subtest scores are capable of discriminating between a number of clinical conditions, and allow an assessment of a number of different cognitive functions (Ivison, 1977; Franzen, 1989; Spreen & Strauss, 1991; Walsh, 1985). Given this, it is important to consider the clinical utility of the individual subtests, therefore three of the most commonly used subtests will be evaluated: Digit Span, Logical Memory and Associate Learning.

DIGIT SPAN

The Digit Span subtest of the WMS and WAIS-R, has been widely used as a measure of immediate verbal recall, attention and concentration (Franzen, 1989; Levin, 1986; Lezak, 1983). The subtest consists of two different tests: (a) digits forward, which requires the repetition of a sequence of digits in the exact order as spoken by the examiner; (b) digits backward, which requires the repetition of a sequence of digits in an exactly reversed order as spoken by the examiner. The standard rate of presentation is one digit per second. Original scoring procedures combined scores from the two parts, to give an overall span estimate. Using this score, test-retest reliability coefficients of 0.77 have been reported for Digit Span (Ivison, 1984). Factor analytic studies of the WMS indicate the Digit Span consistently loads on an Attention/Concentration factor, along with the Mental Control subtest (Ivison, 1984; Davis & Swenson, 1970; Kear-Colwell, 1973; Bachrach & Mintz, 1974; Kear-Colwell & Heller, 1978; Skilbeck & Woods, 1980).

However recent research suggests that the use of a combination score is inappropriate and may obscure important clinical information (Spreen & Strauss, 1991; Lezak, 1983). Until approximately 50 years of age, digits forward and backward are highly correlated (Lezak, 1983). However with advancing age, digits forward span tends to remain stable while digits backward span tends to decrease (Lezak, 1983). A similar pattern of dissociation between the two spans is found with brain injured populations (Costa, 1975; Lezak, 1979; Weinberg, Diller, Gerstman & Schulman, 1972). The digits forward procedure is believed to be primarily a measure of attention (Franzen, 1989; Lezak, 1983). Digits forward is relatively stable with increasing age, although it begins to decline around the seventh decade of life (Hulicka, 1966; Klonoff & Kennedy, 1966). Digits forward is sensitive to laterality of damage (Lezak, 1983) and appears to be resistant to certain types of brain damage resulting in memory impairment eg. CHI, dementia, and Korsakoff's syndrome (Brooks, 1976; Walsh, 1985; Hart & Semple, 1990). Lezak (1983) suggests that a normal digits forward span is 6 $\pm$ 1 digit, and that ' a span of 5 may be marginal to normal limits, a span of 4 is definitely borderline, and

3 is defective'.

In comparison, digits backward is believed to be a more difficult task, requiring not only the memorization inherent in digits forward, but also the manipulation of items held in working memory. Digits backward span demonstrates a similar pattern of performance to digits forward span, with increasing age (Lezak, 1983). However, digits backward tends to be more sensitive to left hemisphere damage, diffuse damage associated with dementia, trauma and psychosurgery (Hart & Semple, 1990; Weinberg et al., 1972; Lezak, 1979b; Lezak, 1983). Lezak (1983) suggests that a digits backward span of 4-5 digits is within normal limits, with 3 digits indicating a borderline performance, and 2 digits representing a defective performance. It is also important to consider the effects of education and age when evaluating digits backward performance (Lezak, 1983).

In conclusion, the digit span procedure has been widely used in both clinical and experimental research, as a simple assessment of immediate verbal recall. Digits forward span is primarily a measure of attentional capacity. Digits backward span is a more sensitive instrument and is believed to more accurately represent the capacity of working memory. Both digit span procedures are sensitive to the effects of age and brain impairment (Franzen, 1989). Digits backward span is affected by advancing age and a range of clinical conditions. Normative data are available for digits forward and digits backward spans (Spreen & Strauss, 1991).

LOGICAL MEMORY

The paragraph recall task is one of the most popular measures of verbal memory (Cullum et al., 1990). The most commonly used version is the Logical Memory subtest of the WMS Form 1 (Wechsler, 1945). Subjects are required to free recall each of two short prose passages following auditory presentation. Recall can be immediate and with a delay. Delayed recall (20 to 30 minutes later) is of significant clinical utility (Cullum et al., 1990). Recall is scored by allocating one point of credit for each of the story ideas which are correctly recalled (Wechsler, 1945). A major criticism of the WMS has been the imprecise scoring criteria for the Logical Memory subtest (Abikoff, Alvir, Hong, Sukoff, Orazio, Solomon & Saraway, 1987; Crosson, Hughes, Roth, Monkowski, 1984; Prigatano, 1978). Recently, detailed scoring criteria for WMS Forms 1 and 2 have been developed, which account for past criticisms (Schwartz & Ivnik, 1980; Abikoff et al., 1987). When examining story performance on Story A and B of Logical Memory, it is important to remember that Story B appears to be an inherently difficult more passage to recall than Story A, therefore lowered recall on Story B should not be attributed to proactive interference (Henry, Adams, Buck & Buchanan, 1990; Bloom, 1959).

The Logical Memory subtest assesses the recall of structured, meaningful material and has more ecological validity than traditional list recall tests of learning and memory (Levin, 1986). Test-retest reliability coefficients of 0.82 have been reported for Logical Memory (Ivison, 1984). Depending on the precision of the scoring criteria, inter-rater reliability can be high (0.99) (Spreen & Strauss, 1991).

According to factor analytic studies of the WMS, Logical Memory tends to load on an immediate recall and learning factor, along with the Associate Learning and Visual Reproduction subtests (Ivison, 1984; Ernst, Warner, Morgans & Townes, 1986; Davis & Swenson, 1970; Dujovne & Levy, 1971; Kear-Colwell, 1973; Kear-Colwell & Heller, 1978; Dye, 1982; Skilbeck & Woods, 1980).

Performance on Logical Memory is sensitive to laterality of damage, with left hemisphere lesions producing impaired performance in comparison with right hemisphere damage (Barbizet & Cany, 1969; Chlopan, Hagen & Russell, 1990). Logical Memory is also sensitive to brain pathology associated with CHI, DAT and Korsakoff's syndrome (Hart & Semple, 1990; Walsh, 1985; Brooks, 1976; Richardson, 1990). Performance is also affected by advancing age, as well as years of education (Spreen & Strauss, 1991; Zagar, Arbit, Stucky & Wengel, 1984; Stanton, Jenkins, Savageau & Zyzanski, 1984). Normative data are available for both immediate and delayed recall conditions for the original Form 1 WMS stories and the Australian adaptation (Spreen & Strauss, 1991; Ivison, 1986).

In conclusion, the Logical Memory subtest is one of the more popular clinical measures of verbal memory. It appears to provide evidence of good reliability and validity, provided that precise scoring criteria are used. Logical Memory is also sensitive to the type and location of brain injury, and is affected by advancing age. Good normative data are now available.

ASSOCIATE LEARNING

The Associate Learning subtest of the WMS has had widespread clinical and experimental use (Franzen, 1989; Cullum et al., 1990; Lezak, 1983). The subtest consists of ten word pairs which are presented on three trials, at a rate of one pair per two seconds; the task being to learn which word pairs go together. There are six 'easy' or high frequency pairs (eg. Up - Down) and four 'hard' or low frequency pairs (eg. Obey - Inch). Performance on Associate Learning is affected by the degree of association between each pair of words, the number of presentations, and attributes of each word such as frequency and imagery rating (Levin, 1986).

Although little published research is available on reliability, Ivison (1984) reports test-retest reliability coefficients of 0.81 for Associate Learning. Similar figures have been reported by other researchers (Margolis, Dunn & Taylor, 1985; Des Rosiers & Ivison, 1988). Factor analytic studies consistently demonstrate that Associate Learning loads on an immediate learning and recall factor, along with the Logical Memory and Visual Reproduction subtests (Ivison, 1984; Davis & Swenson, 1970; Kear-Colwell, 1973; Kear-Colwell & Heller, 1978; Skilbeck & Woods, 1980). The Associate Learning subtest appears to measure the ability to learn novel or complex information (Lezak, 1983; Ernst et al., 1986). Performance on Associate Learning is affected by increasing age (Brooks, 1976; Ivison, 1977; Levin, 1986; DesRosiers & Ivison, 1988). Sex differences have also been noted, with females performing consistently better than males (Ivison, 1977; Zagar et al., 1984; DesRosiers & Ivison, 1988). Associate learning procedures have proven to be highly sensitive to a number of clinical conditions including CHI (Brooks, 1979; Cullum et al., 1990), post-encephalitic memory impairment (Cermak, 1976), dementia (Kaszniak, Garron & Fox, 1979; Hart & Semple, 1990), Korsakoff's syndrome (Winocur & Weiskrantz, 1976, Walsh, 1985), and the effects of drug-induced amnesia (Hennessy, Kirkby & Montgomery, 1991). Typically, patients find it difficult or impossible to learn the 'hard' pairs, while being able to retain the 'easy' pairs. With a delay period, this difference may be highlighted (Levin, 1986). As with the Logical Memory subtest, Associate Learning is also sensitive to laterality of lesion site, with left hemisphere lesions producing greater deficits than right hemisphere damage (Levin, 1986).

In summary, associate learning tasks have proven to be highly sensitive to a range of clinical conditions. The Associate Learning subtest of the WMS Form 1 have found evidence of good reliability and validity, although research is still limited. Normative data for both immediate and delayed recall conditions are now available (Spreen & Strauss, 1991).

REY AUDITORY VERBAL LEARNING TEST (RAVLT)

DESCRIPTION

The Rey Auditory Verbal Learning Test (RAVLT) was developed by Rey (1941; 1964) and described in English by Taylor (1959) and Lezak (1983). It uses a word list learning format adapted from experimental psychology. Subjects are read aloud a 15 word list of concrete nouns (List A), with one second intervals between each word. This occurs for five consecutive trials, with each trial followed by an immediate free recall test. The order of word presentation is fixed across trials. After the fifth trial, a second list of 15 nouns (List B) is read aloud, followed by immediate free recall of List B. Immediately following, recall of List A (Trial 6) is tested without further presentation of the word list. At this point a recognition test may be given in either of two formats:(1) an auditory yes/no recognition test consisting of words from Lists A and B, embedded among semantically and phonetically related words; (2) a visually presented story format where subjects are asked to circle all the words recognized from List A (Lezak, 1983). Following Trial 6, an optional delayed recall of List A can be given. Current research uses a variety of delay intervals ranging from 10 to 30 minutes. It should be noted that the recognition test should be given after the final delayed free recall trial, whether this occurs after Trial 6 or after the delay recall period.

The RAVLT has been widely used in clinical neuropsychology because of the usefulness of its multiple measures of learning and memory, and the brevity and ease of its administration. Detailed scoring criteria have been provided by Geffen, Moar, O'Hanlon, Clark and Geffen (1990). The RAVLT provides information regarding immediate memory span, learning ability, the effects of proactive and retroactive interference, the effects of a delay period, and differentiation of retention versus retrieval difficulties through the use of a recognition trial. It has been suggested that the number and type of errors (repetitions and extra-list intrusions), and several newly developed RAVLT indices including serial position, and measures of subjective organization may be of clinical significance (Spreen & Strauss, 1991; Peaker & Stewart, 1989; Mungas, 1983; O'Donnell, Radtke, Leicht & Caesar, 1988).

Current research using the RAVLT employs a number of procedural variations to the standard procedure including different numbers of learning trials (Christodolou, Kokkevi, Lykourase, Stefanis & Papamitriou, 1981); omitting List B (Miceli, Caltagirone, Gainotti, Masullo & Silveri, 1981); omitting delayed recall (Trial 6) (Coughlan & Hollows, 1984); re-ordering words on each presentation (Squire & Shimamura, 1986); giving cued recall (Mungas, Ehlers, Walton & McCutchen, 1985); and using a recognition form of the test (Butters, Wolfe, Martone, Gransholm & Cermak, 1985; Butters, Wolfe, Granholm & Martone, 1986). Such procedural variations attest to the robustness of the RAVLT, and some changes, such as the development of a recognition format, have potential clinical significance. However such variations limit comparisons between studies, especially when variations are not adequately described.

Lesser procedural variations with RAVLT administration may also be of significant influence. For example, the rate of presentation of words differs depending on the source reference used. Rey (1941; 1984) and Taylor (1959) suggest an interval of one second between each word; but instructions by Lezak (1983) advise a rate of one word per second. This may have significant effects on performance, with slower presentation rates allowing rehearsal time. Recent reviews of the RAVLT suggest that it is advisable to adhere to Rey's guidelines for future research (Peaker & Stewart, 1989; Spreen & Strauss, 1991).

RELIABILITY

Due to the nature of the test, split-half reliability is not an issue. Likewise, neither is inter-rater agreement as judgement in scoring the RAVLT is minimal.

Lezak (Lezak, 1983) investigated the test-retest reliability of List A of the RAVLT in a sample of male normal controls, and found significant practice effects at retest intervals ranging from six months to one year. Research suggests that when alternate forms of the RAVLT are administered, metamemoric influences do not significantly contribute to any improvements in performance (Crawford, Stewart & Moore, 1989e). However, Shapiro and Harrison (1990) found that even with the use of alternate forms, a general practice effect does occur when test administrations are up to five days apart. This effect may be more prominent for younger age groups than an older patient populations (Shapiro & Harrison, 1990). Clearly, further research is needed to clarify this issue, particularly in clinical populations. Lezak (1983) suggests the use of List C as an alternate word list. However research suggests that List C is significantly more difficult than the original List A (Ryan & Geisser, 1986; Ryan, Geisser, Randall & Georgemiller, 1986). More recently, a new alternate form has been developed which appears to be more satisfactory (Crawford et al., 1989e).

Test-retest reliability co-efficients for List A have been reported ranging between 0.53 to 0.73 (Lezak, 1982). Similarly Snow, Tierney, Zorzitto, Fisher and Reid (1988) reported reliability co-efficients of 0.55 over one year intervals. Alternate form reliability co-efficients are generally highly significant and have been reported ranging from 0.60 to 0.77 (List A and List C) (Ryan & Geisser 1986), and between 0.67 and 0.90 (List A, List C and two matched alternate forms) (Shapiro & Harrison, 1990). The RAVLT appears to have good test-retest reliability for both repeat administration and use of alternate forms. Due to the limited number of studies, these results should be considered preliminary and test-retest reliability has yet to be examined in a chronically impaired group (Franzen, 1989).

VALIDITY

The validity of the RAVLT as a measure of verbal learning and memory has been demonstrated in a number of factor analytic studies (Ryan, Rosenberg & Mittenberg, 1984; Moses, 1986; Moses, 1989) . The RAVLT loads highly on a verbal learning and memory factor and yields information different from that provided by tests of attention and concentration, perceptual organization and verbal intelligence (Ryan et al., 1984; Moses, 1986; Moses, 1989). When administered along with Digit Span, the RAVLT loads on three factors: a long term memory factor, a short term memory factor with high demands on control processes such as rehearsal, coding and retrieval strategies, and a short-term memory factor with low coding demands (Talley, 1986).

The influence of age, educational status, intellectual ability and sex on a number of RAVLT measures have been verified in recent research (Bleecker, Bolla-Wilson, Agnew & Meyers, 1988; Geffen et al., 1990; Wiens et al., 1988; Ivnik, Malec, Tangalos, Petersen, Kokmen & Kurland, 1990). A number of RAVLT components including delayed recall, learning and recognition are negatively correlated with increasing age (Query & Berger, 1980; Query & Megran, 1983; Wiens et al., 1988). A limited number of studies suggest that performance on the RAVLT is consistent with intelligence (as measured by the WAIS-R or the NART) within the range 80-130 IQ points (Peaker & Stewart, 1989). Higher intellectual abilities (IQ = 130+) appear to be associated with superior recall ability (Wiens et al., 1988).

The sensitivity of the RAVLT to verbal memory dysfunction has been demonstrated through comparisons of numerous clinical groups. When administered to groups of right and left hemisphere brain-damaged patients, left hemisphere patients perform consistently worse than right hemisphere patients on a number of RAVLT measures (Miceli et al., 1981; Mungas et al., 1985; Ivnik, Sharbrough & Laws, 1987). The RAVLT has also been used as a sensitive indicator of memory impairment in neuropsychological investigations of the effects of lithium on memory (Christodolou et al., 1981); the effects of depression (Coughlan & Hollows, 1984; Query & Megran, 1984; Tucker, Roeltgen, Wann & Wertheimer, 1988; Sternberg & Jarvik, 1976); memory deficits associated with multiple sclerosis (Litvan, Grafman, Vendrell, Martinez, Junque, Vendrell & Barraquer-Bordas, 1988); cognitive functioning in Fragile-X syndrome (Madison, George & Moeschler, 1986); neuropsychological dysfunction in transient global amnesia (Regard & Landis, 1984); cognitive deficits following thalamic infarction (Speedie & Heilman, 1983; Graff-Radford, Damasio, Yamada, Eslinger & Damasio, 1985); neuropsychological disturbance in hemiparkinson's disease (Starkstein, Leiguarda, Gershanik & Berthier, 1987); memory impairment in myasthenia gravis (Tucker et al., 1988); the effect of chronic low level mercury exposure (Uzzell & Oler, 1986); and cognitive functioning associated with tardive dyskinesia (Wolf, Ryan & Mosnaim, 1983). The RAVLT has also been used in a number of psychopharmacological investigations (Fayen, Goldman, Moulthrop &

Luchins, 1988; Miller, Richardson, Jyu, Lemay, Hiscock & Keegan, 1988).

Information from the RAVLT can be used to differentiate between different types of memory dysfunction. Butters et al. (1985; 1986) found that RAVLT delayed recall and recognition measures discriminated between Huntington's disease patients, amnesic patients and normal controls. The two clinical groups performed worse than the normal controls on recall and recognition measures, however the performance of the Huntington's disease group was significantly better than the amnesic group on the recognition test (Butters et al., 1986). Similar findings have been reported in comparisons between alcoholic Korsakoff's, anoxic, and electroconvulsive therapy (ECT) patients (Squire & Shimamura, 1986); between groups of DAT, Huntington's disease, Korsakoff's and control subjects (Shimamura et al., 1987); and dementia patients (Haddad & Nussbaum, 1989; Butters et al., 1986). These studies consistently demonstrate the clinical utility of the RAVLT in discriminating not only type but severity of memory impairment.

NORMATIVE DATA

The existence of normative data is essential for the accurate identification of the type and degree of severity for specific deficits (Mayes, 1986; 1988). At present there are few normative studies for the RAVLT. The norms reported by Lezak (1983) cannot be used because: (a) they are based on a Swiss population and a number of the words used in the English translation differ from the original words; (b) the current administration differ from that used by Rey (1964); (c) many individuals cannot be easily assigned to the five adult groups (Wiens et al., 1988;

Peaker & Stewart, 1989). Wiens et al. (1988) present normative data for healthy young adults (19-51 years) by WAIS-R Full Scale IQ, age and education. Query and Megran (1983) provide normative data for males aged 15-70 years, but do not account for education or intellectual levels. Geffen et al. (1990) provide extensive normative data for healthy males and females, aged between 16 and 84 years, of above average IQ. Ivnik et al. (1990) extend the normative data to include healthy elderly individuals from 55 to 97 years.

SUMMARY

The RAVLT has been widely used in clinical neuropsychology because of the utility of its multiple measures of memory and learning, and the brevity and ease of administration. Recent research indicates that the RAVLT is psychometrically robust. The development of an alternate form (Crawford et al., 1989a) has alleviated problems associated with practice effects on retesting. The RAVLT is sensitive to the presence or absence of memory impairment, laterality of damage, and to the nature and severity of verbal memory deficits in a wide variety of clinical groups. Most of the research on the RAVLT is limited, and in need of replication and extension in a number of areas, especially the development of new RAVLT measures which may have clinical sensitivity. Importantly, a standard procedure for RAVLT administration needs to be defined as minor procedural variations (eg. rate of word presentation) and major modifications (eg. number of learning trials, use of different word lists) may significantly affect performance and limit comparison between studies. Finally normative data needs to be developed which account for subject variables eg. age, sex and intellectual status, which may affect performance.

BUSHKE SELECTIVE REMINDING TEST (BSRT)

DESCRIPTION

The Buschke Selective Reminding Test (BSRT) was first described by Bushke (1973; Bushke & Fuld, 1974) and has been revised by Hannay and Levin (1985; Levin, 1986). The procedure involves reading the subject a list of twelve words at a rate of two seconds per word. The subject then recalls as many of these words as possible in any order. In each subsequent learning trial, the subject is selectively reminded only of those words that were not recalled on the immediately preceeding trial. Testing continues for twelve trials or until the entire list has been correctly recalled on three consecutive trials. Cued recall is given after the twelfth or last free recall trial, with the subject being shown a series of twelve cards each consisting of the first two or three letters of each list word; the task being to identify the corresponding list word. Following the cued recall trial, a recognition trial is given using a multiple-choice format. The subject is presented with a series of twelve cards, and is required to identify the list word with each card containing four words: a target list word, a synonym, an homonym and an unrelated distractor word. A delayed recall trial may be given thirty minutes after the recognition trial.

The BSRT has become one of the more widely used procedures for assessing verbal memory disorders (Hannay & Levin, 1985; Paniak, Shore & Rourke, 1989; Bigler, 1988). The use of a selective reminding format enables the simultaneous analysis of initial storage, retention and retrieval from LTM (Bushke & Fuld, 1974). The BSRT also tends to maximize learning by directing attention towards unlearned items (Bushke & Fuld, 1974; Lezak, 1983). A number of adaptations of the BSRT exist including the type of words used, length of the word list, number of trials, use of cued recall, recognition recall, and a delayed recall trial (Levin, 1986; Paniak et al., 1989; Hannay & Levin, 1985). The original lists used words from a single category eg. animals, which may facilitate retrieval, and encourage the use of invited guessing (Bushke & Fuld, 1974; Erickson & Scott, 1977; Lezak, 1983). Therefore current BSRT word lists consist of unrelated words (Spreen & Strauss, 1991). A number of alternate forms exist, although it has proven difficult to develop lists of equal difficulty and reliability (Hannay & Levin, 1985; Kraemer, Peabody, Tinklenberg & Yesavage, 1983). The format of the BSRT has been adapted for use with children (Clodfelter, Dickson, Wilkes & Johnson, 1987; Morgan, 1982); and with DAT (Peters & Levin, 1982).

RELIABILITY

A limited number of studies address the reliability of the BSRT. Test-retest reliability coefficients have been reported ranging from 0.48 to 0.84 for normal subjects (Clodfelter et al., 1987; Hannay & Levin, 1985; Morgan, 1982; Ruff, Quayhagen & Light, 1988). Similar figures have been obtained with demented groups (Masur, Fuld, Blau, Thal, Levin & Aronson, 1989). Such figures are generally lower than acceptable for neuropsychological tests, and indicate a need to refine the BSRT and demonstrate higher test-retest reliability before accurate statements can be made concerning the memory performance of individual subjects (Hannay & Levin, 1985). Further, there appears to be a significant practice effect with the administration of alternate forms (Richardson, 1990; Hannay & Levin, 1985). This may reflect 'the ability to learn how to perform a complex task, and not exclusively the ability to remember words' (Spreen & Strauss, 1991).

VALIDITY

As a measure of verbal memory, the BSRT has modest correlations with other tests of verbal learning and memory eg. California Verbal Learning Test (Shear & Craft, 1989). One of the reasons for the popularity of the SRT has been its purported ability to fractionate verbal memory into distinct components. Scoring of the SRT provides measures of short-term recall (STR), long-term storage (LTS), long-term recall (LTR), consistent long-term recall (CLTR), random long-term recall (RLTR) and total recall (TR). The feasability of differentiating the short-term and long-term components with the SRT is supported by a number of researchers (Kraemer et al., 1983; Hannay & Levin, 1985). However, recent research indicates that highly significant correlations exist between the various SRT scores in both normal and clinical groups; thus the SRT scores may not represent discrete processes (Kenisten, in Kraemer et al., 1983; Loring, in Loring & Papanicolaou, 1987). Recent research demonstrates that the LTR and CLTR scores are the most valid of the BSRT scores, and represent sensitive and discriminating indices of cognitive processing deficits in a number of clinical conditions (Paniak et al., 1989;

Levin, Grossman, Rose & Teasdale, 1979b; Spreen & Strauss, 1991).

The BSRT is sensitive to the nature and severity of verbal memory impairment in a number of clinical groups. It is one of the most widely used procedures for the assessment of memory functioning following closed head injury and is sensitive to severity of impairment in children, adolescents and adults (Richardson, 1990; Paniak et al., 1989; Levin et al., 1979; Shores, Marosszeky, Sandman & Batchelor, 1986; Levin & Eisenberg, 1979a; Levin, 1986). The SRT is also sensitive to memory impairment associated with DAT (Peters & Levin, 1982; Masur et al., 1989); Korsakoff's syndrome (Bushke & Fuld, 1974); and post-encephalitic amnesia (Peters & Levin, 1977). Further the BSRT is sensitive to laterality of damage (Richardson, 1990; Spreen & Strauss, 1991). However patients with diffuse cerebral lesions perform about the same as patients with focal left hemisphere lesions, hence the BSRT should be given in combination with the other verbal memory measures before predicting left hemisphere abnormalities (Spreen & Strauss, 1991).

NORMATIVE DATA

Both age and sex affect performance on the BSRT (Spreen & Strauss, 1991). Various components (eg. CLTR) of the SRT decline with age, especially after 50 years (Spreen & Strauss, 1991). Females consistently perform better than males (Spreen & Strauss, 1991). The influence of education and intelligence have not been adequately delineated. Larrabee (Larrabee, Trahan, Curtiss & Levin, 1988) provide normative data for seven age groups from 18 to 91 years of age.

Similar data is provided by Ruff (Ruff et al., 1988) and Masur (Masur et al., 1989). Normative data is also available for children and adolescents between the ages of 5 and 18 years (Morgan, 1982; Clodfelter et al., 1987; Levin & Grossman, 1976).

SUMMARY

The BSRT is considered to be a brief and efficient method of assessing the initial storage, retention and retrieval mechanisms of verbal long-term memory. It is one of the few procedures to examine the efficiency of retrieval processes, the efficiency of which has significant implications for rehabilitation. Limited research suggests that the BSRT has adequate reliability, and a number of BSRT scores in particular LTR and CLTR, provide sensitive and reliable indices of memory impairment. Good normative data for a wide range of age groups have been developed.

CONCLUSION

The neuropsychology of memory functioning is a diverse and complex area which is best understood using a combined cognitive and neuropsychological perspective. Cognitive models of memory are continually developing towards a fractionation of specific processes involved in memory, such as the development of a multi-dimensional working memory system. While based in experimental research, cognitive models enable the characterization of specific aspects of memory processing, including the acquisition, storage and retrieval processes involved in the establishment of long-term memory , and the fractionation of long-term memory systems. The association of memory deficits with specific brain structures has aided the diagnosis and characterization of such disorders; and has enabled the development of neuroanatomical models of memory functioning. Adequate knowledge of such research is essential for the effective assessment of memory function and dysfunction.

The clinical assessment of verbal memory functioning needs to become more comprehensive, functionally based, and in keeping with important advances in cognitive psychology and neuropsychological research. The complete assessment of memory functioning should include: (i) the estimation of premorbid intelligence; (ii) the registration and retrieval of information within working memory, including measures of attention; (iii) the use of multi-trial learning tasks which describe the ability to benefit from repeated exposure and more adequately reflect learning ability; (iv) immediate and delayed recall trials for newly learned verbal information, as retention over time is of significant clincial utility; and (v) the inclusion of a recognition trial in order to accurately differentiate retrieval problems. The detection and differentiation of memory dysfunction requires a comprehensive assessment as performance is affected by the length, type and complexity of task content, along with cognitive skills other than memory per se (Lezak, 1983; Macartney-Filgate & Vriezen, 1988).

The instrument of choice for the estimation of premorbid intelligence is the NART. In comparison with the commonly used Vocabulary subtest from the WAIS-R, the NART is consistently found to have greater reliability and validity in the presence of neurological and psychiatric disorders. However, current Australian use of the NART relies on the UK standardization using the WAIS, which may affect the validity of NART IQ estimates.

The clinical assessment of memory functioning continues to use tradtional scales such as the WMS. Although the reliability, validity, standardization and structure of the WMS have been extensively criticized (Erickson & Scott, 1977; Franzen, 1989; Spreen & Strauss, 1991), recent research has demonstrated the sensitivity of individual WMS subtests. The most clinically useful subtests for the assessment of verbal memory dysfunction appear to be Digit Span, Logical Memory and Associate Learning. In recent years a number of verbal learning tests have been developed, using a word list format adapted from experimental psychology. The RAVLT has been widely used in clinical neuropsychology due to the utility of its multiple measures of memory and learning, and the brevity and ease of its administration. Recent research indicates that the RAVLT is psychometrically robust, and is sensitive to the nature and severity of verbal memory deficits. Further, the BSRT uses a similar word learning format to the RAVLT, and additionally provides a number of theoretically derived indices of verbal memory processing. The BSRT has recently been revised, and its psychometric properties, reliability and validity have yet to adequately established. The BSRT does have significant clinical potential as it is one of the few assessment measures which addresses the integrity and efficiency of retrieval mechanisms. In general, it appears that a number of neuropsychological measures have gained considerable clinical popularity before their psychometric properties have been adequately established. Further research needs to address the reliability and validity of frequently used neuropsychological tests; and consider the need for developing Australian normative data for such tests, given the cultural differences which exist between Australian, North American and English populations.

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Subtests of the Wechsler Memory Scale, Rey Auditory Verbal Learning Test, and Bushke Selective Reminding Test were administered to 20 patients with documented neurological damage, and 20 healthy normal controls matched on age and estimated premorbid intelligence. For the Wechsler Memory Scale only recall of Logical Memory Story A, and Associate Learning Hard Items, differentiated between the groups. The majority of RAVLT and BSRT subscores were highly sensitive to neurological injury. Intercorrelations between selected subscales revealed generally modest relationships among measures. Increased task complexity and differing attentional and mnemonic demands significantly influenced the sensitivity of individual tests to neurological damage. These findings have significant clinical and research implications.

The nature and severity of memory dysfunction may be differentially affected by a number of neurological and psychiatric conditions. It is important that the clinician has access to neuropsychological measures with adequate reliability and validity to ensure accurate assessment, diagnosis, and the development of appropriate rehabilitative strategies. As Sohlberg and Mateer (1989) point out, the clinical assessment of verbal memory function 'needs to become more comprehensive, more functionally based, and, at the same time, more attuned to new and important theoretical notions of memory function and dysfunction.'

The recently developed multi-dimensional working memory system provides a superior theoretical and functional account for the data obtained from experimental and neuropsychological studies, when compared to earlier unitary short-term memory models (Baddeley, 1990; Hart & Semple, 1990). The working memory system consists of a central attentional component (the central executive) which co-ordinates and facilitates the transfer of information between a number of subsidiary systems such as the phonological loop for verbal material, and the visuospatial sketch pad for visual and spatial material (Baddeley, 1990). Clinical research has demonstrated that the working memory model can differentiate impaired memory functioning for different clinical groups. For example, patients with dementia of the Alzheimer type, or with frontal lobe or dysexecutive syndrome, demonstrate a specific impairment in the processing capacity and efficiency of the central executive (Hart & Semple, 1990; Baddeley, 1990).

Such impaired functioning impacts on the ability to plan and initiate effective encoding and retrieval strategies.

Given the sensitivity of long-term memory (LTM) to brain dysfunction, theoretical developments in this area are also significant. The learning of new verbal information and its transfer between working memory and LTM, depends on the processes of acquisition, storage and retrieval. Acquisition is affected by a number of procedural variables; and the various encoding operations and analyses directly influence the durability and retrieval of the memory trace (Morris, 1978; Craik & Lockhart, 1972). The consolidation and storage of verbal material has been inferred from studies of rates of forgetting, for both newly learned and well-established memories (Baddeley, 1990). The loss of information from LTM, may have a number of causative factors, such as the loss of accessibility to information or discriminability of memory traces due to interference, with accurate retrieval of information depending upon the availability of relevant and distinct retrieval cues (Reed, 1988, Tulving & Thomson, 1975).

The structure of LTM has a number of hypothesized divisions. Tulving (Tulving, 1972; Tulving, 1984) proposed a distinction between episodic and semantic long-term memories. Episodic memories refer to a personally experienced autobiographical record of events, encoded with reference to a specific temporal and spatial context (Hart & Semple, 1990; Parkin, 1987). Semantic memories represent a system of organized knowledge and rules governing usage, which is stored in a context-free manner and lacks autobiographical referents (Hart & Semple, 1990). The activities of episodic and semantic memory are interdependent, with episodic information playing a significant role in the formation of new semantic memories (Parkin, 1987). Further, current memory theories make the distinction between declarative and procedural memories. Declarative memories are 'explicit and accessible to conscious awareness and...can be declared, that is, brought to mind verbally as a proposition or nonverbally as an image' (Squire, 1986). Episodic and semantic memories can be considered as components of declarative memory (Tulving, 1987; Squire, 1986). Procedural knowledge is considered to be implicit and 'accessible only through performance, by engaging in the skills or operations in which the knowledge is embedded (Squire, 1986). The majority of verbal memory research has employed procedures which tap episodic memory.

The use of cognitive and neuropsychological theories have had a significant influence on the clinical assessment of verbal memory, and the development of specific neuropsychological procedures. However, clinical evaluations may fall behind theoretical and experimental advances (Loring & Papanicolaou, 1987). For example, the assessment of short-term memory functioning should not rely soley on a procedure such as Digit Span. Further testing should occur 'to see whether all measures of short-term memory are impaired, whether phonological or other kinds of rehearsal are normal, or whether phonological and other kinds of storage are normal' (Mayes, 1986). Recent research suggests that a comprehensive assessment of verbal memory functioning should include: (a) tests of current and premorbid intelligence; (b) the registration and retrieval of information within working memory; (c) the presentation of verbal material for learning with immediate and delayed recall; (d) the use of a recognition format to accurately differentiate retrieval problems; and (e) an evaluation of retention over both brief (ie. ten minutes) and extended (ie. one day, one week) time periods (Mayes, 1986; Cripe, 1987; Sohlberg & Mateer, 1989).

The detection of memory dysfunction needs to consider the influence of procedural variables on performance such as the length, type and complexity of task content; along with cognitive skills other than memory per se (Lezak, 1983; Macartney-Filgate & Vriezen, 1988). Differences in task format, and content eg. word lists versus prose passages, may make significantly different demands on attentional and mnemonic processing. Further as Lezak notes 'because of the lack of systematic comparisons between the different verbal memory tests, their relative usefulness and potential interchangeability remain unknown' (Lezak, 1983).

In an attempt to address these issues, research was undertaken to clarify the construct and concurrent validity of a number of widely used clinical measures of verbal memory. A range of assessment procedures with differing formats and levels of task complexity were chosen to examine the extent to which such procedural variations would affect performance. Further, the interrelationships between the various test subscales was also examined as an indicator of concurrent validity, and related to current theoretical models of memory function and dysfunction.

METHOD

Subjects

To investigate the sensitivity of the selected neuropsychological measures to verbal memory impairment, 20 neurologically impaired individuals and 20 healthy normal controls, were compared. All participants in the study were volunteers. The 20 neurologically impaired individuals had documented neurological defects on CT and MRI scans. This group consisted of eleven males and nine females, with an average age of 35.45 years. Eight individuals presented with a diffuse CHI and were assessed approximately 30 weeks post-trauma. Twelve individuals with focal injuries (three with predominantly left brain damage; seven with predominantly right brain damage; one with bilateral brain damage) were assessed approximately 5 weeks post-injury. All participants in the neurologically impaired group had been hospitalized, however unavailability of medical records, or variability in the documentation of states of consciousness of the participants, prevented relating the neuropsychological scores to duration of coma, post-traumatic amnesia, or Glasgow Coma Scale scores.

The healthy normal control group (n=20) was matched to the neurological group on age and estimated premorbid intelligence. The group consisted of six males and fourteen females with an average age of 35.3 years, and was recruited from the general community.

Ethics approval for the project was obtained from the Royal Hobart Hospital, and the Douglas Parker Rehabilitation Centre.

Procedure

All subjects completed the same battery of neuropsychological tests: (1) National Adult Reading Test (NART) (Nelson, 1982); (2) the Digit Span, Logical Memory and Associate Learning subtests of the Wechsler Memory Scale (WMS) (Wechsler, 1945); (3) Rey Auditory Verbal Learning Test (RAVLT) (Rey, 1964; Spreen & Strauss, 1991); (4) Bushke Selective Reminding Test (BSRT) (Bushke & Fuld, 1974; Spreen & Strauss, 1991). Test protocols may be viewed in Appendix B. These were administered in a counterbalanced order with either the BSRT or the RAVLT being given first. In all cases, the WMS subtests of Digit Span, Logical Memory and Associate Learning were given during the 20 minute delay period between RAVLT trials 6 and 7.

The NART was included to facilitate group matching on premorbid intellectual levels, and requires the subject to read aloud a list of 50 words. The stimulus words are predominantly short and of irregular pronunciation so that the application of grapheme-to-phoneme conversion rules or intelligent guesswork should not aid performance (Nelson, 1982). Successful performance should therefore be dependent upon previous familiarity with individual words, rather than current cognitive capacity (Nelson & O'Connell, 1978). The NART error score (50 - number of words read correctly=Error Score) can be converted into a predicted WAIS Full Scale (FS) IQ using the equation: Predicted Full-Scale IQ = 128 - 0.83 x NART error score (Nelson, 1982).

The WMS subtests of Digit Span (DS), Logical Memory (LM) and Associate Learning (AL) were administered according to standard instructions (Wechsler, 1945). Digit Span requires the repetition of a sequence of digits in either a forward or reversed order, and is widely used as a measure of immediate verbal recall, attention and concentration (Franzen, 1989; Lezak, 1983). DS scores are: (i) number of digits correctly repeated in forward order (DSF); (ii) number of digits correctly repeated in reversed order (DSB); (iii) combined forward and reversed span scores (DS). The Logical Memory subtest requires the immediate repetition of two short prose passages. The Logical Memory passages used in the current study were adapted for use with an Australian population (Walsh, personal communication). Scoring for Logical Memory used the detailed gist-scoring criteria developed by Abikoff (Abikoff, Alvir, Hong, Sukoff, Orazio, Solomon & Saraway, 1987). Three scores were generated: (i) Number of ideas recalled from Story A (LMA) (max = 22); (ii) Number of ideas recalled from Story B (LMB) (max = 22); (iii) Total number of ideas from Stories A and B (LM A+B). The Associate Learning subtest assesses the immediate recall of a series of related and unrelated word pairs. Three scores were derived: (i) the standard AL score (max.= 21); (ii) total number of related pairs learned (ALE) (max.=18); (iii) total number of unrelated pairs learned (ALH) (max.=12).

The RAVLT requires the free recall of a 15-item word list (List A), which is read aloud (with a one second interval between each word) for five consecutive learning trials, each followed by a free recall test (Rey, 1964; Spreen & Strauss, 1991). A single presentation of a second word list (List B) then occurs, followed by a free recall of that list. Immediately following this, free recall of the first list (List A) occurs, without further presentation. After a 20 minute delay period, free recall and recognition of List A may be given (Spreen & Strauss, 1991). The recognition trial exists in two formats: (a) a 50 item word list containing words from List A, List B and semantic and phonetically related words; (b) a story format. The former format was used in the current study. The RAVLT provides information regarding immediate memory span for words (Trial 1), learning ability (Total recall on Trials 1-5), the effects of proactive interference (comparison of recall on Trial B and Trial 1), retroactive interference (comparison of recall on Trial 6 and Trial 5), the effects of a delay period (comparison of recall on Trial 6 and 7), and the differentiation of retention versus retrieval difficulties through the use of a recognition trial. Acquisition rates can be assessed with the Learning Index derived from the difference between recall on Trial 5 and Trial 1(Query & Megran, 1983; Wiens, Crossen & McMinn, 1988). Geffen (Geffen, Moar, O'Hanlon, Clark & Geffen, 1990) suggest the use of interference and efficiency indices derived from a comparison of clinically relevant pairs of trials. These indices include: (i) information overload or encoding efficiency (Trial 1: DSF); (ii) proactive interference (Trial B: Trial 1); (iii) retroactive interference (Trial 7: Trial 5); and (iv) Forgetting (Trial 7: Trial 6).

The BSRT involves a maximum of 12 free recall trials of a 12-item word list, with the individual being reminded only of those words not recalled on the previous trial (Bushke & Fuld, 1974). Form 1 of the version developed by Hannay and Levin (Hannay & Levin, 1985). was used in the current study. The BSRT is designed to assess different aspects of verbal memory, and uses of number of different scores (Bushke & Fuld, 1974; Hannay & Levin, 1985; Spreen & Strauss, 1991). If a word is recalled on two consecutive trials, it is assumed to be in long-term storage (LTS) from that point on. When a word is recalled that has entered LTS, it is scored as long-term retrieval (LTR). When a word in LTS is recalled consistently on all subsequent trials, it is also scored as consistent long-term retrieval (CLTR). Inconsistent retrieval of a word in LTS is scored as random long-term retrieval (RLTR). Short-term retrieval (STR) refers to the recall of a word that has not entered LTS. The Total Recall on each trial is the sum of STR and LTR. The number of reminders given by the examiner, and any intrusions are also recorded for each trial (Spreen & Strauss, 1991).

RESULTS

The neurologically impaired patients and the healthy normal controls did not differ with respect to age (neurological gp: m=35.45, sd=15.49; normal control gp: m=35.3, sd=13.72; t=-.032, df (38), p=.974). However the difference between the two groups on the NART approached significance (t=1.84, df(1,38), p=.073), with the control group tending to have higher estimates of intellectual ability. Table 1 shows the means on all subscales for normal and impaired groups, with the probability from t-tests of the differences between the two groups (df (1,38)). Due to the number analytical comparisons, the possibility of Type 1 error can be controlled by the use of the Bonferroni correction; which requires an alpha of .0012 (Keppel, 1982). Scores which are significant at $p \leq .05$ will be considered as trends towards significance.

Mean performance scores and significance levels for the neuropsychological measures are summarized in Table 1. T values and significance levels for each of the scores are presented in Appendix C. For the WMS subtests, significant differences were found for recall of LM Story A, and the number of AL Hard (ALH) items learned. Figure 1 illustrates the comparison between performance on the various WMS subscores for the two groups.

The majority of RAVLT measures were sensitive to neurological impairment. Figure 2 illustrates the comparison between the neurological group and healthy normal control group for the RAVLT learning trials. Performances on RAVLT Trial 1 to Trial 5, Total Trials 1-5, Trial B and Trial 7 were able to differentiate performance between the two groups. Scores for Trial 6, the Recognition trial, and the Geffen indices of Forgetting, and Information Overload approached significance. The majority of the included BSRT measures were highly sensitive to neurological impairment, with the

TABLE 1: Means and standard deviations of scores on the neuropsychological tests for healthy normal and neurologically impaired groups.

	Healthy Normal		Neurologically Impaired		
	M	sd	M	sd	p
NART FS IQ	112.10	5.31	108.00	6.87	.0730
WMS Subtests:					
Digit Span	12.45	2.21	11.45	2.64	.2025
Digit Span Forward	7.00	1.21	6.60	1.05	.2713
Digit Span Backward	5.45	1.28	4.85	1.98	.2619
LM Story A	11.95	2.52	8.30	3.13	.0002**
LM Story B	10.35	3.83	8.75	3.38	.1696
LM A+B	22.30	5.12	17.05	5.88	.0046*
AL Score	17.80	3.21	13.80	4.33	.002*
ALE (Easy items)	16.20	3.04	15.70	2.20	.5547
ALH (Hard items)	9.20	2.98	5.00	3.59	.0003**
RAVLT:					
Trial 1	8.20	2.26	5.80	1.64	.0005**
Trial 2	10.80	2.65	7.65	2.06	.0002**
Trial 3	12.70	2.13	8.80	3.16	.0001**
Trial 4	13.35	2.23	9.45	3.65	.0002**
Trial 5	13.40	1.96	10.20	3.61	.0012**
Total	58.85	10.41	41.90	12.80	.0001**
Errors	0.30	0.66	0.70	1.75	.3447
Repetitions	1.60	2.21	3.10	4.46	.1857
List B	7.70	3.08	4.65	1.69	.0004**
Trial 6	11.45	3.93	7.30	4.61	.004*
Trial 7 (Delay)	11.10	3.91	6.00	4.88	.0008**
Recognition	14.15	1.18	11.05	4.41	.0043*
Total False Positives	2.30	3.79	3.10	5.07	.5749
Learning Index	5.20	1.54	4.40	2.48	.2280
Proactive Interference	0.93	0.24	0.81	0.26	.1376
Retroactive Interference	0.83	0.25	0.65	0.29	.046*
Forgetting	0.92	0.24	0.63	0.38	.0067*
Information Overload	1.19	0.30	0.89	0.29	.0036*
BSRT:					
Trial 1	6.60	2.26	4.40	1.39	.0007*
Total Recall	113.20	19.16	81.20	23.59	.0001*
LTS	106.00	24.84	63.35	29.46	.0001*
STR	13.70	11.05	28.00	10.95	.0002*
LTR	98.60	28.61	53.55	30.74	.0001*
CLTR	78.10	39.14	30.60	27.08	.0001*
RLTR	20.50	15.68	22.90	9.32	.5515
Reminders	39.95	17.80	70.90	21.25	.0001*
Intrusions	4.00	3.39	7.25	7.22	.0762
Cued Recall	9.90	2.49	6.80	3.25	.0017
Recognition	11.80	0.70	10.95	2.33	.1260

Significant $p \leq .05^*$, $p \leq .001^{**}$

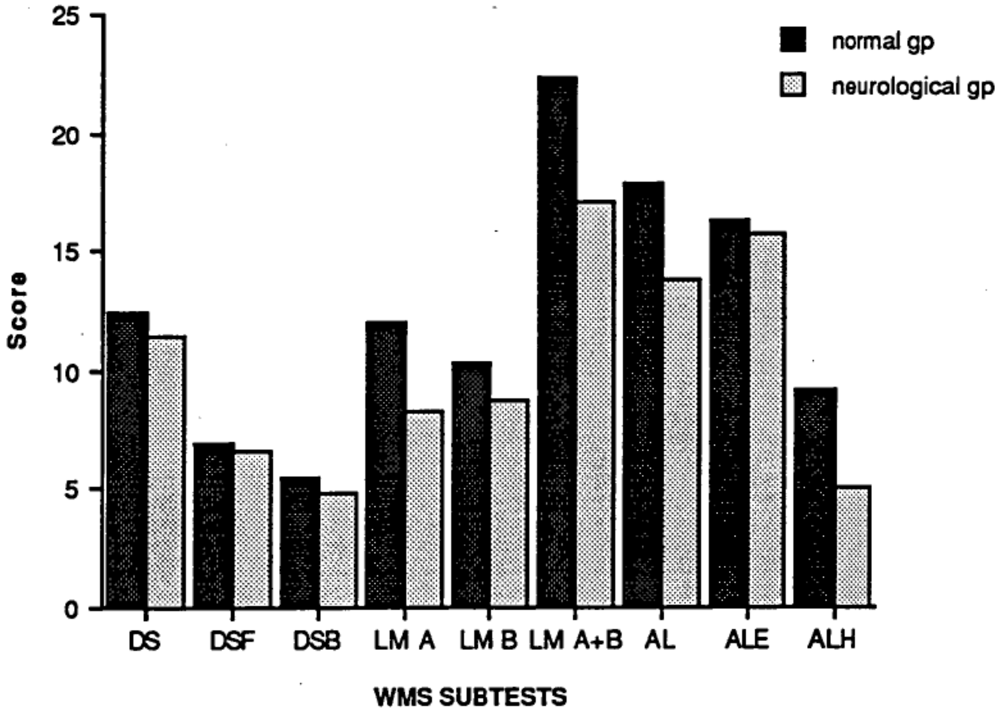

Figure 1 Scores for WMS subtests

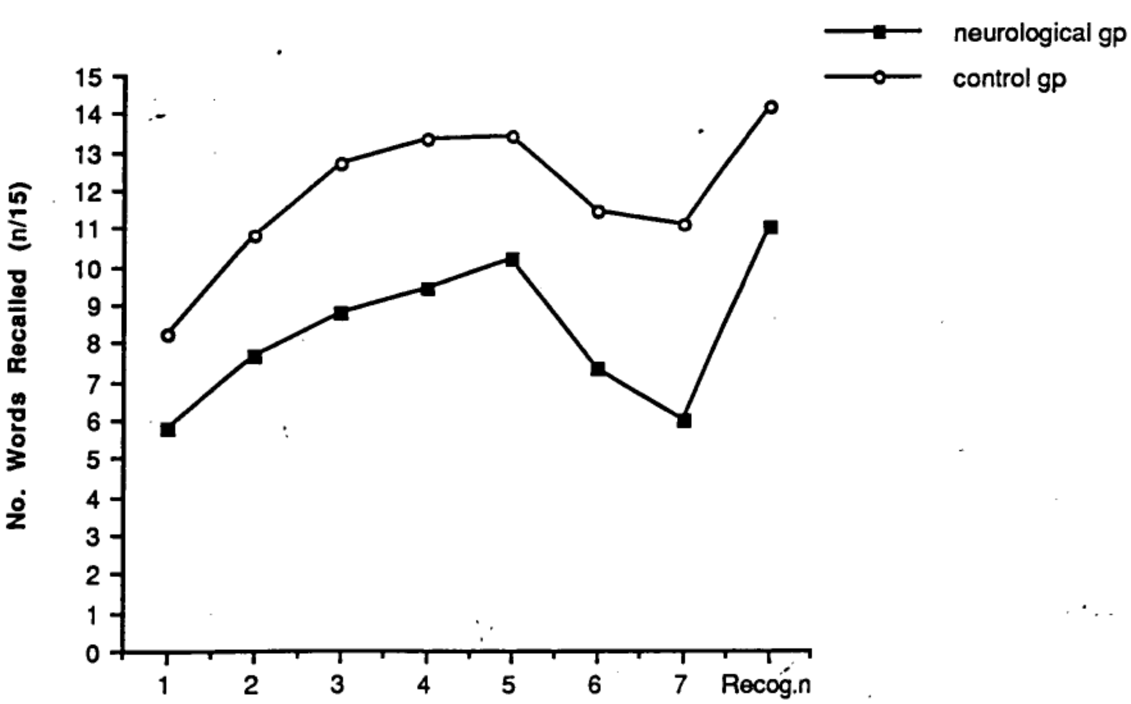

Figure 2 Recall scores for the RAVLT

exception of RLTR, Intrusions and the Recognition trial. Cued recall approached significance. Figure 3 illustrates the comparison between the neurological and control groups, for the BSRT scores.

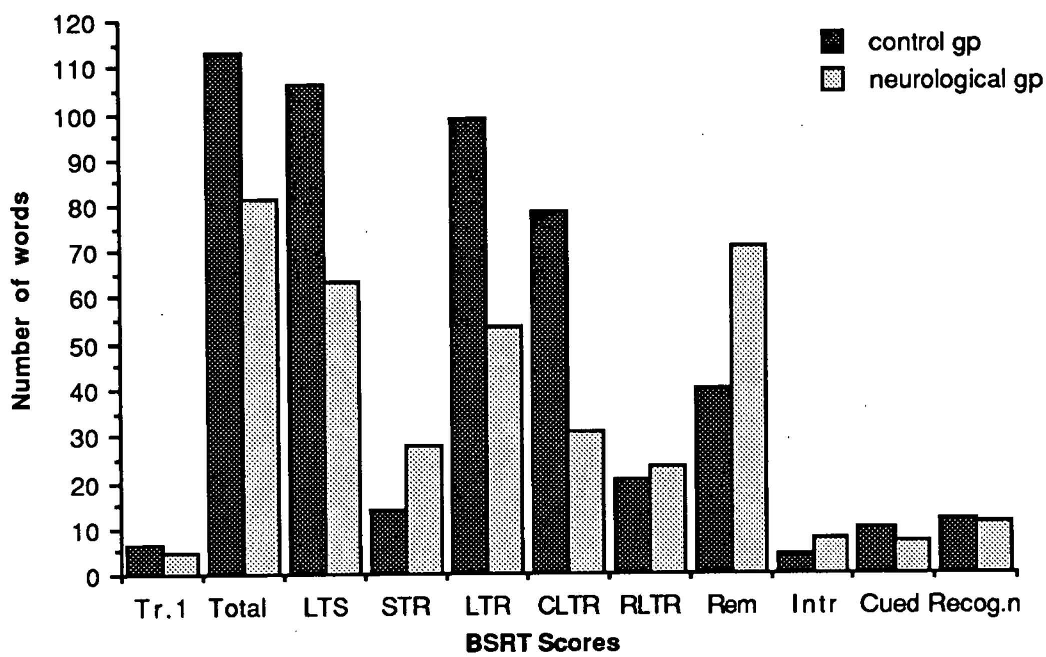

Figure 3: Scores on the BSRT

A correlational analysis was used to examine the interrelationships between the memory tests and their subscores. Due to the large number of obtained subscores, those which were highly intercorrelated within a particular memory test were not included in the final analysis. Table 2 shows the correlations of age, sex and NART FS IQ with the subscores selected for further analysis. Given the size of the correlational analysis, the same

TABLE 2: Correlations of Age, Sex and the NART FS IQ with the neuropsychological measures

	NORMAL GROUP			NEUROLOGICAL GROUP		
	Age	Sex	NART FS IQ	Age	Sex	NART FS IQ
TESTS:						
WMS:						
DS	-0.22	-0.17	0.65	0.24	-0.16	0.63
LM A+B	-0.29	-0.03	0.05	-0.09	-0.25	0.58
ALE	-0.43	0.38	0.16	-0.13	0.13	-0.14
ALH	-0.62	0.27	0.48	0.03	-0.06	-0.14
RAVLT:						
Trial 1	-0.43	0.36	0.00	-0.16	-0.07	0.35
Total Trials 1-5	-0.48	0.40	0.23	-0.07	-0.02	0.42
Trial 6	-0.64	0.36	0.21	-0.12	0.09	0.18
Trial 7 (Delay)	-0.68	0.33	0.31	-0.08	0.15	0.18
Recognition	-0.34	0.46	0.39	0.06	0.11	0.21
Learning Index	0.06	0.01	0.48	0.18	0.14	0.36
BSRT:						
Trial 1	-0.61	0.33	-0.06	-0.28	-0.04	0.18
Total Recall	-0.51	0.09	0.00	-0.16	-0.02	0.39
CLTR	-0.63	0.05	0.04	-0.09	-0.01	0.46
Cued Recall	-0.54	0.29	0.07	-0.07	0.21	0.19
Recognition	-0.61	0.45	-0.12	0.10	0.19	0.32

Correlations of .444 or greater are significant at $p \leq .05$
Correlations of .561 or greater are significant at $p \leq .01$
Correlations of .679 or greater are significant at $p \leq .001$

Bonferroni correction used for multiple t-tests was applied to significance levels for correlation scores. Correlations of 0.679 or greater are significant at $p \leq .001$. However correlations of 0.444 and greater ($p \leq .05$) will also be considered. Unless otherwise specified, correlations discussed within the text are significant at $.001 \leq p \leq .05$.

The relationship of age, sex and NART FS IQ to verbal memory performance is summarized in Table 2. For the neurological group, age and sex were not significantly related to performance on any of the memory measures. NART FS IQ was moderately related to performance on DS, LM, and to CLTR on the BSRT in the neurological group. For the control group, moderate negative correlations were found between age and performance on: ALH; RAVLT measures for the Total Trials 1-5, Trial 6, Trial 7 and the Recognition trial; and all of the included BSRT measures. Low correlations were found between sex and the recognition trials for the RAVLT and BSRT for the control group only. Low to moderate correlations were found between NART FS IQ and performance on DS and the RAVLT Learning Index.

Correlations between the WMS subtests and the RAVLT revealed significant but moderate relationships between the various scores, as seen in Table 3. For the neurological group significant but moderate correlations were found between performance on DS and RAVLT Trial 1, Total Trials 1-5, and the Recognition trial. For the control group, significant but low correlations were found betwen DS and RAVLT Total Trials 1-5 and Trial 7.

For the neurological group, moderate to high correlations were found between LM A+B and performance on the RAVLT Trial 1, Total Trials 1-5, Trial 6, Trial 7, and the Learning Index; but not for the Recognition trial. However for the control group performance on LM A + B were significantly

TABLE 3: Correlations of Wechsler Memory Scale and Rey Auditory Verbal Learning Test

	NORMAL CONTROLS WMS:				NEUROLOGICALLY IMPAIRED WMS:			
	DS	LM A+B	ALE	ALH	DS	LM A+B	ALE	ALH
RAVLT:								
Trial 1	0.42	0.29	0.46	0.52	0.51	0.76	0.33	0.34
Total Trials 1-5	0.44	0.30	0.49	0.68	0.60	0.84	0.29	0.51
Trial 6	0.37	0.47	0.66	0.81	0.43	0.63	0.32	0.66
Trial 7 (Delay)	0.47	0.44	0.62	0.84	0.38	0.65	0.39	0.63
Recognition	0.34	0.27	0.34	0.74	0.65	0.36	0.37	0.54
Learning Index	0.00	-0.02	-0.04	0.17	0.43	0.62	0.18	0.53

Correlations of .444 or greater are significant at $p \leq .05$
Correlations of .561 or greater are significant at $p \leq .01$
Correlations of .679 or greater are significant at $p \leq .001$

related only to Trial 6 . Although not included in the final correlational analysis, performance on the LM Story A and Story B were significantly correlated in the neurological group ($r=.628$, $p \leq .01$), but not in the control group ($r=.269$, ns).

Performance on ALE was unrelated to any of the RAVLT measures for the neurological group; however for the control group, significant low to moderate correlations were found with performance on RAVLT Trial 1, Total Trials 1-5, Trial 6 and Trial 7. For the neurological group signficant moderate correlations were found between performance on ALH and RAVLT Total Trials 1-5, Trial 6, Trial 7, the Learning Index, and the Recognition trial. For the control group, significant moderate to high correlations were found between ALH and performance on the RAVLT Trial 1, Total Trials 1-5, Trial 6, Trial 7, and the Recognition trial.

Table 4 summarizes the correlations between the WMS subtests and the BSRT. For the neurological group, low correlations were found between performance on DS and BSRT Total Recall, Cued Recall and the Recognition trial. For the control group, performance on DS was unrelated to the included BSRT measures. Performance on LM A+B demonstrated significant moderate relationships with BSRT Total Recall and Cued Recall for the neurological group; but was unrelated to the BSRT measures for the control group.

TABLE 4: Correlations of Wechsler Memory Scale and Bushke Selective Reminding Test

	NORMAL CONTROLS BSRT:					NEUROLOGICALLY IMPAIRED BSRT:				
	Trial 1	Total Recall	CLTR	Cued Recall	Recog.	Trial 1	Total Recall	CLTR	Cued Recall	Recog.
WMS:										
DS	0.34	0.26	0.31	0.26	0.13	0.23	0.50	0.37	0.51	0.66
LM A+B	0.19	0.13	0.14	0.27	0.36	0.40	0.64	0.69	0.31	0.41
ALE	0.46	0.33	0.44	0.53	0.64	0.02	0.15	0.12	0.23	0.32
ALH	0.48	0.49	0.57	0.65	0.53	0.29	0.47	0.39	0.52	0.04

Correlations of .444 or greater are significant at $p \leq .05$
Correlations of .561 or greater are significant at $p \leq .01$
Correlations of .679 or greater are significant at $p \leq .001$

The pattern of performance between ALE and BSRT measures was similar to that for ALE and the RAVLT. Performance on ALE was unrelated to the BSRT measures for the neurological group; but significant low to moderate correlations were found between ALE and BSRT Trial 1, CLTR, Cued Recall and the Recognition trial for the control group . For the neurological group performance on ALH was moderately correlated with BSRT Total Recall and Cued Recall; and was significantly related to all the included BSRT measures for the control group.

Table 5 summarizes the relationship between the RAVLT and the BSRT. Significant moderate to high correlations were found between most of the scores.

TABLE 5: Correlations of Rey Auditory Verbal Learning Test and the Bushke Selective Reminding Test

	NORMAL CONTROLS BSRT:					NEUROLOGICALLY IMPAIRED BSRT:				
	Trial 1	Total Recall	CLTR	Cued Recall	Recog.	Trial 1	Total .Recall	CLTR	Cued Recall	Recog.
RAVLT:										
Trial 1	0.76	0.70	0.72	0.77	0.40	0.54	0.66	0.58	0.62	0.48
Total Trials 1-5	0.66	0.70	0.69	0.86	0.44	0.56	0.82	0.76	0.60	0.46
Trial 6	0.54	0.60	0.63	0.78	0.61	0.51	0.79	0.74	0.61	0.30
Trial 7 (Delay)	0.58	0.61	0.66	0.73	0.55	0.55	0.76	0.74	0.55	0.36
Recognition	0.24	0.35	0.32	0.52	0.42	0.53	0.63	0.53	0.65	0.66
Learning Index	-0.35	-0.18	-0.25	-0.13	0.04	0.38	0.71	0.73	0.28	0.32

Correlations of .444 or greater are significant at $p \leq .05$
Correlations of .561 or greater are significant at $p \leq .01$
Correlations of .679 or greater are significant at $p \leq .001$

For the neurological group, moderate to high correlations were found between performance on the RAVLT Trial 1 and BSRT Trial 1, Total Recall, CLTR, Cued Recall and Recognition. For the control group, this pattern was repeated with moderate to high correlations found between RAVLT Trial 1 and performance on BSRT Trial 1, Total Recall, CLTR, and Cued Recall.

For the neurological group, moderate to high correlations were found between performance on RAVLT Total Trials 1-5 and BSRT Trial 1, Total Recall, CLTR, Cued Recall and Recognition. Again, the performance pattern for the control group was similar, as performance on RAVLT Total Trials 1-5 displayed high correlations with BSRT Trial 1, Total Recall, CLTR, and Cued Recall.

The pattern of performance for Trial 6 and Trial 7 and the BSRT measures was identical for the two groups. For the neurological group, significant moderate correlations were found between performance on Trial 6 and Trial 7 and BSRT Trial 1, Total Recall, CLTR, and Cued Recall. For the control group, Trial 6 and Trial 7 was significantly related to all of the included BSRT measures.

For the neurological group, performance on the RAVLT Recognition trial demonstrated significant moderate correlations with all of the included BSRT measures; however was moderately correlated only with Cued Recall in the control group. The RAVLT Learning Index was moderated related to performance on the BSRT Total Recall, and CLTR for the neurological group; but was unrelated to the BSRT scores for the control group.

DISCUSSION

In keeping with the findings of previous research, performance on the LM and AL subtests of the WMS, the RAVLT and the BSRT were sensitive to verbal memory impairment in a mixed neurological group, in comparion with a control group of healthy normal individuals, matched on age and NART FS IQ.

The registration and retrieval of verbal information within working memory was impaired following neurological injury. DS is widely used as an indicator of attention and immediate verbal memory span (Franzen, 1989). DSF is known to be resistant to certain types of brain damage resulting in memory impairment (Walsh, 1985; Hart & Semple, 1990). DSB is considered to be more sensitive to the presence of neurological impairment (Franzen, 1989; Lezak, 1983). However, neither DSF or DSB were sensitive to brain injury in the current study. This suggests that attention, concentration and working memory capacity were unimpaired for the immediate recall of simple, structured material in the neurological group. Performance on DS and Trial 1 of the RAVLT, are often used in combination to provide an estimate of the capacity of working memory span (Lezak, 1983). The significant but modest relationship found between these measures in the current study appears to partly support this conclusion. Given that the two measures are moderately related, the sensitivity of the RAVLT Trial 1 to neurological impairment, may be the result of increased task complexity. Similar relationships were found between DS and BSRT

Trial 1.

The relationship between DS and the other memory measures appeared to differ between the two groups. Performance on DS and the various RAVLT and BSRT scores was unrelated in the control group. In contrast, the performance of the neurological group on DS was significantly related to the majority of RAVLT and BSRT learning indices. This may indicate that the neurologically impaired individual increasingly relies on the resources of working memory subsystems in an attempt to learn novel and complex verbal material. In general, it appears that neurological injury may impair attentional and working memory capacities. Performance on simple, structured tasks such as DS may lack sensitivity, and accurate estimates of mnemonic functioning require the use of more complex verbal material.

The sensitivity of different learning formats was examined. If the immediate recall of verbal information reflects encoding efficiency, then neurological injury compromises the use of effective acquisition strategies. Immediate recall of a short prose passage (LM Story A), unrelated word pairs (ALH), and lists of concrete (RAVLT Trial 1) and abstract (BSRT Trial 1) were all affected by neurological damage. Encoding efficiency is increasingly impaired as the length, format and complexity of the task increases. The moderate intercorrelations between these measures, is consistent with the assumption that they assess the ability to effectively encode verbal information.

It is interesting to note that, of the two short prose passages which make up the LM subtest, only Story A was sensitive to neurological injury. Further, the two stories were significantly related in the neurological group ($r=.604$, $p \leq .05$), but not in the control group ($r=.269$, ns). This may be the result of a number of factors such as a restricted range of scores on Story A for the control group, or problems with scoring criteria which may effect reliability. Differences in performance recall between the two passages may also be the result of proactive interference. However, recent research suggests that Story B appears to be an inherently more difficult passage to recall than Story A, and lowered recall should not be attributed to proactive interference (Henry, Adams, Buck & Buchanan, 1990).

Performance on the AL subtest demonstrates the clinical utility of examining separate scores for the learning of related (ALE) and unrelated (ALH) word pairs. Consistent with previous research, ALE was not sensitive to neurological impairment, and was unrelated to any other score for the neurological group (Macartney-Filgate & Vriezen, 1988). Following neurological impairment, ALE appears to represent the recall of well learned semantic associations, and not the ability to learn novel and complex verbal information (Macartney-Filgate & Vriezen, 1988). In contrast, ALH significantly related to the majority of RAVLT and BSRT learning measures, for both the neurologically impaired and control groups; indicating ALH is related to the ability to effectively encode, retain and retrieve information from verbal long-term memory.

The AL subtest is a relatively structured test of verbal learning. Multi-trial learning formats using immediate and delayed recall, are considered to be highly sensitive to verbal memory impairment (Levin, 1985). Performance on the RAVLT and BSRT support this assumption. In general BSRT measures were more sensitive to verbal memory impairment than the RAVLT scores. This is likely to be the result of differences in procedural variables such as word type (abstract versus concrete), frequency and imagery values for individual words, along with task length and complexity. In comparison with healthy normal controls, neurological injury produced a significant decrease in immediate memory span for words (BSRT Trial 1 and RAVLT Trial 1). Even with the conservative significance levels, the RAVLT learning trials (Trials 1-5) were highly sensitive to verbal memory impairment. Control subjects consistently recalled approximately 3 extra words per trial, than individuals with neurological impairment. It is interesting to note that the Learning Index failed to differentiate performance between the two groups. This index is derived from the recall of Trial 5 - Trial 1 (Query & Megran, 1983). A prominent ceiling effect was found for this measure in the control group, as high recall on Trial 1 prevented the accurate estimation of learning ability. Performance on the BSRT scores suggest that neurological injury impairs the ability to effectively encode information into verbal long-term memory. The neurological group retained significantly more words than the control group on the STR index. This supports the finding from the interrelationship between DS and the various verbal learning scores, that individuals with neurological impairment increasingly rely on the capacity of working memory in an attempt to perform complex verbal learning tasks.

Comparisons between selected RAVLT trials enabled an assessment of the effects of interference on verbal learning. Proactive interference did not influence performance for either group. The effects of retroactive interference displayed a trend towards significance (p=.05), although this difference did not differ between the two groups. Recall of List A after an interference trial, diminished by approximately three words for both groups.

The ability to effectively retain newly learned information was also impaired by neurological damage. Forgetting after a 20 minute delay indicated a trend towards significance (p=.004) with the neurological group demonstrating poorer recall.

As well as an impaired ability to effectively encode and retain information within declarative long-term memory, neurological injury also impacts on the ability to retrieve information. In comparison with the healthy control group, neurologically impaired individuals were significantly impaired in the ability to consistently retrieve newly learnt verbal information from long-term memory. It should be noted that whilst the BSRT scores were highly sensitive to neurological impairment, highly significant correlations were found between the various BSRT scores in both the healthy control and neurologically impaired groups. This finding is consistent with recent research which indicates that the BSRT scores may not represent discrete memory processes (Loring & Papanicolaou, 1987).

Given that free recall is impaired with neurological injury, the effect of cues and additional information was also investigated. Performance on RAVLT Recognition, BSRT Cued Recall and Recognition were moderately related for both groups. Only Cued Recall and RAVLT Recognition displayed a trend towards significance between the groups. Although a number of procedural differences exist between the RAVLT and BSRT, it appears that the yes/no recognition format is more sensitive to neurological impairment than the forced choice recognition format used in the BSRT. The performance on the Cued Recall and Recognition trial for the BSRT produced a number of interesting results. For both groups, the use of cues did not assist recall. When recall on Trial 12 of the BSRT was examined, Cued Recall actually produced a decrease in the number of words recalled (Controls: Trial 12 =10.95, Cued Recall = 9.90, p=.123; Neurological Groups: Trial 12 = 7.0, Cued Recall = 6.8, p=.152), which approached significance. Consistent with previous research, the additional information presented in the BSRT recognition trial produced a significant increase in recall, in comparison with free recall and cued recall for neurological group (Trial 12 vs Recognition, p=.0008; Cued Recall vs Recognition, p=.0001). Similar trends approached significance in the control group, however ceiling effects in the control group are likely to have influenced these results. A similar pattern of performance was found for the RAVLT Recognition trial.

The apparent difficulty of subjects in both groups with BSRT Cued Recall may be explained with reference to the encoding specificity hypothesis (Tulving & Thomson, 1973). According to this theory, retrieval cues are effective only if they represent encoding processes which occurred during original learning. The cues used here were primarily orthographic and/or phonological. If subjects spontaneously used elaborative semantic processing during acquisition, then the retrieval cues used here will be largely ineffective as they do not accurately reflect encoding operations performed at the time of initial learning.

In conclusion, the current study is consistent with previous research demonstrating the sensitivity of the AL and LM subtests of the WMS, the RAVLT and the BSRT to neurological impairment. Increased task complexity and differing attentional and mnemonic demands significantly influenced the sensitivity of individual tests to neurological impairment. This suggests that the accurate assessment of mnemomic functioning requires the use of both simple, structured tasks and more complex verbal material. Neurological injury produced a number of significant deficits effecting encoding efficiency, storage and retention over time, and an inability to consistently retrieve information from declarative long-term memory. Neurological injury appears to necessitate an over-reliance on the processing capacities of working memory, in an attempt to learn novel and complex verbal material.

Finally, the interrelationships between various memory measures tended to be moderate to high , indicating that they may assess similar memory constructs. However their concurrent use is by no means redundant as differences in task format, complexity and use of cognitive skills other than memory per se, may significantly influence clinical sensitivity. The current findings therefore support the need for multiple assessment techniques to accurately evaluate different aspects of working memory, and long-term memory functioning.

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APPENDICES

APPENDIX A

STATEMENT OF INFORMED CONSENT

ROYAL HOBART HOSPITAL
DOUGLAS PARKER REHABILITATION CENTRE

DEPARTMENT OF PSYCHOLOGY / PSYCHIATRY

CONSENT TO PARTICIPATE IN A RESEARCH PROJECT

I, ____

of ____

have been invited to participate in a research project entitled

'THE CLINICAL SENSITIVITY OF A NUMBER OF VERBAL LEARNING TASKS'

The aim of the project is to examine a three verbal memory tasks, which look at the different ways people learn and remember verbal information. This research will help us understand the normal workings of memory which are not fully understood. It will also aid in the devlopment of more accurate and reliable tests, which will help the assessment, diagnosis and treatment of people with memory problems.

In relation to this project I have been informed of the following points:

(1) Approval has been given by the Ethics Committee of the Royal Hobart Hospital.

(2) The results which will be obtained may not be of any direct benefit to myself.

(3) The procedure will involve the learning of verbal information, in the form of lists of words, and short stories. The entire session will take approximately one hour.

(4) Should I develop a problem which I suspect might have resulted from my involvement in this study, I am aware that I should contact Maria Hennessy on 354897.

(5) The results of any tests or information regarding my medical history will not be published in any way that could reveal my identity.

(6) I have been given adequate opportunity to ask questions about this project and my involvement, and I know that if I have other questions in the future I may contact Maria Hennessy on 354897, or Dr K Kirkby on 354855.

(7) I understand that I can refuse to take part in this study or withdraw from it at any time.

Participants Initials .... Witness Initials ....

After considering all of these points, I accept the invitation to participate in this project.

Signature ....

Witness Signature ....

Witness Name (Print) ....

Address ....

Date ....

Statement by Researcher

I have explained this project and the implications of participation in it to this patient, and believe he/she understands it, and that this consent is based on adequate information.

Signature ....

Name (Print) ....

APPENDIX B

TEST PROTOCOLS:

National Adult Reading Test

Wechlser Memory Scale
(Digit Span, Associate Learning)

Logical Memory (Australian Version)

Rey Auditory Verbal Learning Test

Bushke Selective Reminding Test

National Adult Reading Test (NART)
Word Card

CHORD
ACHE
DEPOT
AISLE
BOUQUET
PSALM
CAPON
DENY
NAUSEA
DEBT
COURTEOUS
RAREFY
EQUIVOCAL
NAIVE
CATACOMB
GAOLED
THYME
HEIR
RADIX
ASSIGNATE
HIATUS
SUBTLE
PROCREATE
GIST
GOUGE

SUPERFLUOUS
SIMILE
BANAL
QUADRUPED
CELLIST
FACADE
ZEALOT
DRACHM
AEON
PLACEBO
ABSTEMIOUS
DETENTE
IDYLL
PUERPERAL
AVER
GAUCHE
TOPIARY
LEVIATHAN
BEATIFY
PRELATE
SIDEREAL
DEMESNE
SYNCOPE
LABILE
CAMPANILE

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WECHSLER MEMORY SCALE FORM I

David Wechsler
Bellevue Hospital, New York

NAME ______________________ AGE ______ SEX ______

REFERRED FOR ______________________ DATE ______ EXAMINER ______

		Score
I.	Information	___
II.	Orientation	___
III.	Mental Control	___
IV.	Memory Passages	___
V.	Digits Total	___
VI.	Vis. Reprod.	___
VII.	Associate Lng.	___
	Total Raw Score	___
	Age Correction	___

V. (A) DIGITS FORWARD / (B) DIGITS BACKWARD

Draw a line through any series failed. Circle score for maximum number repeated correctly.

(A) DIGITS FORWARD	Score	(B) DIGITS BACKWARD	Score
6-4-3-9	4	2-8-3	3
7-2-8-6	4	4-1-5	3
4-2-7-3-1	5	3-2-7-9	4
7-5-8-3-6	5	4-9-6-8	4
6-1-9-4-7-3	6	1-5-2-8-6	5
3-9-2-4-8-7	6	6-1-8-4-3	5
5-9-1-7-4-2-3	7	5-3-9-4-1-8	6
4-1-7-9-3-8-6	7	7-2-4-8-5-6	6
5-8-1-9-2-6-4-7	8	8-1-2-9-3-6-5	7
3-8-2-9-5-1-7-4	8	4-7-3-9-1-2-8	7

Forward Score _____ Backward Score _____ Digits Total _____

ASSOCIATE LEARNING

First Presentation	Second Presentation	Third Presentation
Metal - Iron	Rose - Flower	Baby - Cries
Baby - Cries	Obey - Inch	Obey - Inch
Crush - Dark	North - South	North - South
North - South	Cabbage - Pen	School - Grocery
School - Grocery	Up - Down	Rose - Flower
Rose - Flower	Fruit - Apple	Cabbage - Pen
Up - Down	School - Grocery	Up - Down
Obey - Inch	Metal - Iron	Fruit - Apple
Fruit - Apple	Crush - Dark	Crush - Dark
Cabbage - Pen	Baby - Cries	Metal - Iron

First Recall	Easy	Hard
North	___	
Fruit	___	
Obey		___
Rose	___	
Baby	___	
Up	___	
Cabbage		___
Metal	___	
School		___
Crush		___
TOTAL	___	___

Second Recall	Easy	Hard
Cabbage		___
Baby	___	
Metal	___	
School		___
Up	___	
Rose	___	
Obey		___
Fruit	___	
Crush		___
North	___	
TOTAL	___	___

Third Recall	Easy	Hard
Obey		___
Fruit	___	
Baby	___	
Metal	___	
Crush		___
School		___
Rose	___	
North	___	
Cabbage		___
Up	___	
TOTAL	___	___

Easy 1) ___
2) ___
3) ___
(A) Total ___
A ÷ 2
Hard 1) ___
2) ___
3) ___
(B) Total ___

SCORE

$\frac{A}{2} + B =$ ___

WECHSLER MEMORY SCALE - FORM 1

MEMORY FOR PROSE MATERIAL

1. Anna Thompson / of East Sydney / employed / as a cleaning woman / in an office building / reported / at the Eastern District / Police Station / that she had been held up / on Smith Street / the night before / and robbed / of fifteen dollars. / She had four little children / the rent was due / and they had not eaten / for two days. / The sergeant / touched by the woman's story / took up a collection / of money / for her.

2. The American / liner / "New York" / struck a reef / near Fiji / last Monday evening. / In spite of gale force / winds / and darkness / the thousand passengers / and four hundred / crew / were all rescued / though the lifeboats / were tossed about like corks / in the heavy seas. / The damaged vessel / was towed into port / the next morning / by a German / freighter.

RAVLT LIST A

List A	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5
drum					
curtain					
bell					
coffee					
school					
parent					
moon					
garden					
hat					
farmer					
nose					
turkey					
colour					
house					
river					
TOTAL					

RAVLT LIST A

List B	Recall B	Recall A	List A	Delayed Recall A	Recognition
desk			drum		
ranger			curtain		
bird			bell		
shoe			coffee		
stove			school		
mountain			parent		
glasses			moon		
towel			garden		
cloud			hat		
boat			farmer		
lamb			nose		
gun			turkey		
pencil			colour		
church			house		
fish			river		
TOTAL					

recognition list A/B

Recognition	Yes	No	List A	List B	Sem.A	Sem.B	Phon.A	Phon.B
bell								
window								
hat								
barn								
ranger								
nose								
weather								
school								
hand								
pencil								
home								
fish								
moon								
tree								
balloon								
bird								
mountain								
coffee								
mouse								
river								
towel								
curtain								
flower								
colour								
desk								
gun								
crayon								
church								
turkey								
fountain								
boat								
hot								
parent								
water								
farmer								
rose								
cloud								
house								
stranger								
garden								
glasses								
stocking								
shoe								
teacher								
stove								
nest								
children								
drum								
toffee								
lamb								

Bushke Selective Reminding Test: Form 1 from Hannay and Levin (1985)

1) Word List	2) Cued Recall
bowl	BO
passion	PA
dawn	DA
judgement	JUD
grant	GR
bee	-
plane	PL
county	COU
choice	CH
seed	SE
wool	WO
meal	ME

3) Multiple Choice Items

1.	bowl	dish	bell	view
2.	love	poison	conform	passion
3.	dawn	sunrise	bet	down
4.	blackboard	verdict	judgement	fudge
5.	grand	grant	give	jazz
6.	see	sting	fold	bee
7.	pain	plane	pulled	jet
8.	county	state	tasted	counter
9.	voice	select	choice	cheese
10.	flower	seed	herd	seek
11.	date	sheep	wool	would
12.	mill	queen	food	meal

APPENDIX C

T-values

TABLE: T values (df (1, 38)) and significance levels of scores on the neuropsychological tests for healthy normal and neurologically impaired groups.

	Healthy Normal		Neurologically Impaired			
	M	sd	M	sd	p	t values
NART FS IQ	112.10	5.31	108.00	6.87	.0730	1.84
WMS Subtests:						
Digit Span	12.45	2.21	11.45	2.64	.2025	1.29
Digit Span Forward	7.00	1.21	6.60	1.05	.2713	1.12
Digit Span Backward	5.45	1.28	4.85	1.98	.2619	1.14
LM Story A	11.95	2.52	8.30	3.13	.0002**	4.06
LM Story B	10.35	3.83	8.75	3.38	.1696	1.40
LM A+B	22.30	5.12	17.05	5.88	.0046*	3.01
AL Score	17.80	3.21	13.80	4.33	.002*	3.32
ALE (Easy items)	16.20	3.04	15.70	2.20	.5547	0.59
ALH (Hard items)	9.20	2.98	5.00	3.59	.0003**	4.02
RAVLT:						
Trial 1	8.20	2.26	5.80	1.64	.0005**	3.84
Trial 2	10.80	2.65	7.65	2.06	.0002**	4.20
Trial 3	12.70	2.13	8.80	3.16	.0001**	4.58
Trial 4	13.35	2.23	9.45	3.65	.0002**	4.08
Trial 5	13.40	1.96	10.20	3.61	.0012**	3.49
Total	58.85	10.41	41.90	12.80	.0001**	4.49
Errors	0.30	0.66	0.70	1.75	.3447	-0.96
Repetitions	1.60	2.21	3.10	4.46	.1857	-1.35
List B	7.70	3.08	4.65	1.69	.0004**	3.88
Trial 6	11.45	3.93	7.30	4.61	.004*	3.06
Trial 7 (Delay)	11.10	3.91	6.00	4.88	.0008**	3.65
Recognition	14.15	1.18	11.05	4.41	.0043*	3.04
Total False Positives	2.30	3.79	3.10	5.07	.5749	-0.57
Learning Index	5.20	1.54	4.40	2.48	.2280	1.22
Proactive Interference	0.93	0.24	0.81	0.26	.1376	1.52
Retroactive Interference	0.83	0.25	0.65	0.29	.046*	2.06
Forgetting	0.92	0.24	0.63	0.38	.0067*	2.87
Information Overload	1.19	0.30	0.89	0.29	.0036*	3.10
BSRT:						
Trial 1	6.60	2.26	4.40	1.39	.0007*	3.71
Total Recall	113.20	19.16	81.20	23.59	.0001*	4.71
LTS	106.00	24.84	63.35	29.46	.0001*	4.92
STR	13.70	11.05	28.00	10.95	.0002*	-4.11
LTR	98.60	28.61	53.55	30.74	.0001*	4.79
CLTR	78.10	39.14	30.60	27.08	.0001*	4.46
RLTR	20.50	15.68	22.90	9.32	.5515	-4.99
Reminders	39.95	17.80	70.90	21.25	.0001*	-0.60
Intrusions	4.00	3.39	7.25	7.22	.0762	-4.99
Cued Recall	9.90	2.49	6.80	3.25	.0017	3.38
Recognition	11.80	0.70	10.95	2.33	.1260	1.56

Significant p≤.05*, p≤.001**

APPENDIX D

RAW DATA

	Subject No.	Group	Age	Sex 2	Years Educ.
1	1	1	17	Male	12
2	2	1	22	Female	13
3	3	1	71	Female	8
4	4	1	23	Female	17
5	5	1	48	Male	17
6	6	1	45	Female	10
7	7	1	43	Female	18
8	8	1	24	Female	15
9	9	1	21	Female	15
10	10	1	21	Female	15
11	11	1	24	Male	17
12	12	1	24	Female	17
13	13	1	37	Female	12
14	14	1	35	Male	9
15	15	1	30	Female	10
16	16	1	32	Female	13
17	17	1	37	Female	10
18	18	1	37	Male	14
19	19	1	42	Female	10
20	20	1	73	Male	6
21	21	2	20	Male	13
22	22	2	17	Female	10
23	23	2	31	Male	12
24	24	2	62	Female	16
25	25	2	24	Female	10
26	26	2	29	Female	11
27	27	2	34	Male	10
28	28	2	38	Male	10
29	29	2	29	Male	13
30	30	2	50	Female	15
31	31	2	58	Female	10
32	32	2	34	Female	12
33	33	2	37	Male	10
34	34	2	36	Male	10
35	35	2	33	Female	8
36	36	2	28	Male	12
37	37	2	67	Female	7
38	38	2	23	Male	10
39	39	2	34	Male	12
40	40	2	25	Male	10

	Type Injury	Left
1		•
2		•
3		•
4		•
5		•
6		•
7		•
8		•
9		•
10		•
11		•
12		•
13		•
14		•
15		•
16		•
17		•
18		•
19		•
20		•
21	mild-moderate CHI, multiple trauma	•
22	severe CHI	•
23	severe CHI	•
24	R CVA	•
25	severe CHI	•
26	R facial nerve neuroma, Bells palsy, R glomous jugulare tumour	•
27	CHI, fr. base skull, bifrontal contusions	•
28	significant CHI	•
29	R SAH, clipping R internal carotid, R MCA aneurysm	•
30	L SAH, L frontal haematoma, clipping aneurysm L cma, R mca, aca	1
31	R SAH, clipping aneurysm R mca	•
32	L SAH	1
33	R frontoparietal SDH, oedema, R-L midline shift 1.5cm	•
34	L temporal lobectomy, high grade astrocytoma	1
35	L frontoparietal tumour, hi gradeastrocytoma, midline shift, o...	1
36	R arachnoid cyst	•
37	R SAH, clipping pcaa	•
38	CHI	1
39	moderate CHI, fr base skull scattered ich, haematoma, hydroc...	•
40	CHI	•

	Right	Diffuse	Time s...	NART FS IQ	Digit Span	Digit span for...
1	•	•	•	113	15.000	8.000
2	•	•	•	111	14.000	8.000
3	•	•	•	115	13.000	8.000
4	•	•	•	115	12.000	8.000
5	•	•	•	118	13.000	6.000
6	•	•	•	110	14.000	8.000
7	•	•	•	120	15.000	8.000
8	•	•	•	113	13.000	8.000
9	•	•	•	113	15.000	8.000
10	•	•	•	114	13.000	7.000
11	•	•	•	113	15.000	8.000
12	•	•	•	110	12.000	7.000
13	•	•	•	115	10.000	5.000
14	•	•	•	103	9.000	5.000
15	•	•	•	101	9.000	5.000
16	•	•	•	109	12.000	7.000
17	•	•	•	110	11.000	6.000
18	•	•	•	112	15.000	8.000
19	•	•	•	105	8.000	5.000
20	•	•	•	112	11.000	7.000
21	•	1	8	106	12.000	7.000
22	•	1	30	95	9.000	5.000
23	•	1	52	112	12.000	7.000
24	1	•	12	123	15.000	8.000
25	•	1	28	106	6.000	6.000
26	1	•	8	115	12.000	6.000
27	•	1	10	100	6.000	6.000
28	•	1	56	113	14.000	7.000
29	1	•	8	105	11.000	7.000
30	1	•	8	110	10.000	6.000
31	1	•	2	107	10.000	5.000
32	•	•	1	113	14.000	8.000
33	1	•	2	110	15.000	8.000
34	•	•	12	105	10.000	6.000
35	•	•	1	100	10.000	6.000
36	1	•	2	111	13.000	8.000
37	1	•	4	102	13.000	7.000
38	•	•	40	111	15.000	8.000
39	•	1	42	118	12.000	6.000
40	•	1	16	103	10.000	5.000

	Digit span bac...	LM Story A	LM Story B	LM A +B	AL Score	Total no. easy
1	7.000	14.000	14.000	28.000	21.000	18.000
2	6.000	14.000	13.000	27.000	21.000	18.000
3	5.000	11.000	11.000	22.000	15.000	18.000
4	4.000	13.000	16.000	29.000	21.000	18.000
5	7.000	8.000	18.000	26.000	17.500	15.000
6	6.000	16.000	13.000	29.000	20.000	18.000
7	7.000	13.000	10.000	23.000	20.000	18.000
8	5.000	18.000	9.000	27.000	21.000	18.000
9	7.000	9.000	6.000	15.000	20.000	18.000
10	6.000	10.000	11.000	21.000	19.500	17.000
11	7.000	13.000	10.000	23.000	19.000	16.000
12	5.000	11.000	11.000	22.000	18.000	18.000
13	5.000	11.000	3.000	14.000	19.500	17.000
14	4.000	11.000	8.000	19.000	11.000	14.000
15	4.000	13.000	12.000	25.000	13.000	16.000
16	5.000	11.000	9.000	20.000	17.500	17.000
17	5.000	9.000	5.000	14.000	15.000	8.000
18	7.000	14.000	12.000	26.000	17.000	16.000
19	3.000	11.000	12.000	23.000	19.000	18.000
20	4.000	9.000	4.000	13.000	11.000	8.000
21	5.000	3.000	6.000	9.000	16.500	15.000
22	4.000	8.000	8.000	16.000	18.000	18.000
23	5.000	11.000	8.000	19.000	6.500	13.000
24	7.000	9.000	11.000	20.000	14.000	14.000
25	0	6.000	4.000	10.000	9.000	18.000
26	6.000	13.000	12.000	25.000	20.000	18.000
27	0	4.000	4.000	8.000	19.000	12.000
28	7.000	15.000	12.000	27.000	18.500	17.000
29	4.000	7.000	11.000	18.000	14.000	16.000
30	4.000	7.000	5.000	12.000	9.000	16.000
31	5.000	7.000	8.000	15.000	13.500	17.000
32	6.000	10.000	9.000	19.000	15.500	15.000
33	7.000	8.000	8.000	16.000	16.000	18.000
34	4.000	5.000	11.000	16.000	9.500	17.000
35	4.000	6.000	4.000	10.000	7.000	12.000
36	5.000	9.000	7.000	16.000	7.000	14.000
37	6.000	5.000	7.000	12.000	16.000	16.000
38	7.000	11.000	11.000	22.000	17.000	18.000
39	6.000	10.000	17.000	27.000	13.000	12.000
40	5.000	12.000	12.000	24.000	17.000	18.000

	Total no. hard	RAVLT tr1	RAVLT tr2	RAVLT tr3	RAVLT tr4	RAVLT tr5
1	12.000	9.000	12.000	14.000	14.000	15.000
2	12.000	12.000	12.000	14.000	15.000	15.000
3	6.000	7.000	7.000	10.000	13.000	13.000
4	12.000	10.000	13.000	15.000	15.000	15.000
5	10.000	6.000	12.000	13.000	14.000	14.000
6	11.000	12.000	15.000	15.000	15.000	15.000
7	11.000	7.000	11.000	12.000	15.000	13.000
8	12.000	5.000	7.000	10.000	9.000	12.000
9	11.000	12.000	15.000	15.000	15.000	15.000
10	11.000	10.000	13.000	15.000	15.000	15.000
11	11.000	8.000	11.000	12.000	14.000	13.000
12	9.000	7.000	12.000	14.000	15.000	14.000
13	11.000	7.000	11.000	12.000	13.000	14.000
14	4.000	5.000	7.000	8.000	7.000	8.000
15	5.000	8.000	9.000	12.000	13.000	12.000
16	9.000	10.000	12.000	15.000	15.000	15.000
17	6.000	7.000	11.000	13.000	13.000	14.000
18	9.000	9.000	11.000	12.000	13.000	14.000
19	10.000	8.000	10.000	14.000	14.000	13.000
20	2.000	5.000	5.000	9.000	10.000	9.000
21	9.000	5.000	9.000	9.000	6.000	8.000
22	9.000	7.000	10.000	8.000	15.000	15.000
23	0	6.000	6.000	7.000	9.000	9.000
24	7.000	6.000	8.000	10.000	10.000	14.000
25	0	5.000	6.000	5.000	4.000	4.000
26	4.000	8.000	10.000	14.000	13.000	14.000
27	7.000	3.000	4.000	6.000	4.000	5.000
28	10.000	8.000	10.000	15.000	15.000	14.000
29	6.000	5.000	4.000	6.000	9.000	12.000
30	1.000	4.000	7.000	5.000	4.000	7.000
31	5.000	4.000	6.000	9.000	9.000	11.000
32	8.000	7.000	10.000	12.000	13.000	14.000
33	7.000	5.000	8.000	9.000	8.000	10.000
34	1.000	4.000	6.000	6.000	6.000	6.000
35	1.000	3.000	6.000	4.000	6.000	5.000
36	0	7.000	6.000	9.000	10.000	7.000
37	8.000	7.000	10.000	7.000	9.000	10.000
38	8.000	7.000	9.000	12.000	13.000	12.000
39	1.000	7.000	10.000	13.000	13.000	14.000
40	8.000	8.000	8.000	10.000	13.000	13.000

	RAVLT tr6	RAVLT tr7...	RAVLT recog...	RAVLT recog fp	RAVLT trB
1	12.000	14.000	13.000	0	13.000
2	13.000	15.000	15.000	0	13.000
3	7.000	7.000	13.000	4.000	7.000
4	15.000	15.000	15.000	0	11.000
5	14.000	13.000	14.000	0	8.000
6	15.000	15.000	15.000	0	8.000
7	10.000	9.000	15.000	0	6.000
8	11.000	11.000	15.000	3.000	5.000
9	15.000	15.000	14.000	0	13.000
10	15.000	15.000	15.000	0	9.000
11	12.000	12.000	15.000	0	7.000
12	14.000	13.000	14.000	2.000	6.000
13	13.000	14.000	15.000	0	8.000
14	4.000	4.000	11.000	8.000	3.000
15	11.000	10.000	13.000	0	6.000
16	13.000	11.000	14.000	5.000	11.000
17	9.000	9.000	15.000	1.000	6.000
18	14.000	11.000	15.000	3.000	4.000
19	12.000	8.000	15.000	5.000	6.000
20	0	1.000	12.000	15.000	4.000
21	6.000	4.000	15.000	3.000	5.000
22	15.000	13.000	13.000	1.000	7.000
23	3.000	0	3.000	0	4.000
24	12.000	11.000	15.000	2.000	7.000
25	0	0	3.000	0	2.000
26	14.000	13.000	15.000	1.000	7.000
27	4.000	1.000	2.000	4.000	3.000
28	9.000	9.000	14.000	2.000	7.000
29	7.000	5.000	13.000	2.000	6.000
30	0	0	13.000	23.000	3.000
31	7.000	6.000	7.000	1.000	4.000
32	12.000	10.000	15.000	0	3.000
33	7.000	7.000	13.000	8.000	4.000
34	2.000	0	8.000	3.000	5.000
35	3.000	3.000	9.000	4.000	2.000
36	4.000	1.000	13.000	4.000	6.000
37	7.000	5.000	14.000	1.000	4.000
38	12.000	9.000	13.000	2.000	3.000
39	9.000	8.000	8.000	0	5.000
40	13.000	15.000	15.000	1.000	6.000

	RAVLT total no. 1-5	Learning...	Errors	Repet...	Serpos 1-3	SerPos 4-6
1	64.000	6.000	0	0	2.000	2.000
2	68.000	3.000	0	2.000	3.000	3.000
3	50.000	6.000	0	1.000	2.000	1.000
4	68.000	5.000	0	0	3.000	3.000
5	59.000	8.000	0	0	3.000	1.000
6	72.000	3.000	0	2.000	3.000	2.000
7	58.000	6.000	0	4.000	3.000	2.000
8	43.000	7.000	0	0	2.000	0
9	72.000	3.000	0	0	3.000	3.000
10	68.000	5.000	0	0	3.000	1.000
11	58.000	5.000	0	1.000	2.000	1.000
12	62.000	7.000	1.000	0	2.000	1.000
13	57.000	7.000	0	0	1.000	1.000
14	35.000	3.000	2.000	0	2.000	2.000
15	54.000	4.000	0	2.000	0	3.000
16	67.000	5.000	1.000	4.000	3.000	0
17	58.000	7.000	0	2.000	3.000	1.000
18	59.000	5.000	2.000	3.000	2.000	1.000
19	59.000	5.000	0	2.000	2.000	3.000
20	38.000	4.000	0	9.000	3.000	1.000
21	37.000	3.000	0	1.000	1.000	0
22	55.000	7.000	7.000	4.000	2.000	1.000
23	37.000	3.000	4.000	3.000	1.000	1.000
24	48.000	8.000	1.000	2.000	2.000	1.000
25	24.000	0	0	1.000	1.000	1.000
26	59.000	6.000	0	2.000	3.000	1.000
27	22.000	2.000	0	0	1.000	0
28	62.000	6.000	1.000	0	2.000	1.000
29	36.000	7.000	0	2.000	1.000	2.000
30	27.000	3.000	1.000	0	0	2.000
31	39.000	7.000	0	2.000	2.000	0
32	56.000	7.000	0	0	2.000	2.000
33	40.000	5.000	0	0	2.000	3.000
34	28.000	2.000	0	4.000	2.000	0
35	24.000	2.000	0	0	0	0
36	39.000	0	0	10.000	3.000	0
37	43.000	3.000	0	5.000	3.000	3.000
38	53.000	5.000	0	3.000	3.000	1.000
39	57.000	7.000	0	19.000	3.000	0
40	52.000	5.000	0	4.000	2.000	2.000

	SerPos 7-9	Serpos 10-12	Serpos 13-15	pi	ri	forget...	info over...
1	2.000	2.000	1.000	1.440	.800	1.167	1.125
2	1.000	2.000	3.000	1.080	.860	1.150	1.500
3	0	3.000	1.000	1.000	.538	1.000	.875
4	2.000	1.000	1.000	1.100	1.000	1.000	1.250
5	1.000	0	1.000	1.330	1.000	.930	1.000
6	3.000	2.000	2.000	.660	1.000	1.000	1.500
7	0	1.000	1.000	.860	.770	.900	.875
8	1.000	0	2.000	1.000	.916	1.000	.625
9	2.000	1.000	3.000	1.083	1.000	1.000	1.500
10	2.000	2.000	2.000	.900	1.000	1.000	1.430
11	2.000	2.000	1.000	.875	.923	1.000	1.000
12	1.000	1.000	2.000	.857	1.000	.920	1.000
13	0	2.000	3.000	1.143	.930	1.077	1.400
14	0	0	1.000	.600	.500	1.000	1.000
15	1.000	2.000	2.000	.750	.916	.910	1.600
16	1.000	3.000	3.000	1.100	.860	.850	1.430
17	1.000	0	2.000	.857	.643	1.000	1.167
18	1.000	2.000	3.000	.440	1.000	.786	1.125
19	1.000	1.000	1.000	.750	.923	.660	1.600
20	0	0	1.000	.800	0	0	.714
21	1.000	2.000	1.000	1.000	.750	.660	.714
22	1.000	2.000	1.000	1.000	1.000	.860	1.400
23	1.000	3.000	0	.500	.330	0	.860
24	1.000	1.000	1.000	1.167	.860	.916	.750
25	0	0	3.000	.400	0	0	.830
26	0	3.000	1.000	.875	1.000	.930	1.330
27	0	0	2.000	1.000	.800	.250	.500
28	0	2.000	3.000	.875	.643	1.000	1.143
29	0	1.000	1.000	1.200	.583	.714	.714
30	0	0	2.000	.750	0	0	.660
31	0	1.000	1.000	1.000	.640	.860	.800
32	0	1.000	2.000	.430	.860	.830	.875
33	0	0	0	.800	.700	1.000	.625
34	1.000	0	1.000	1.250	.330	0	.660
35	0	1.000	2.000	.660	.600	1.000	.500
36	1.000	2.000	1.000	.857	.571	.250	.875
37	0	1.000	0	.570	.700	.710	1.000
38	1.000	1.000	1.000	.430	1.000	.750	.875
39	0	1.000	3.000	.710	.640	.880	1.167
40	1.000	1.000	2.000	.750	1.000	.920	1.600

	BSRT tr1	BSRT total re...	BSRT LTS	BSRT STR	BSRT LTR	BSRT CLTR	BSRT RLTR
1	10.000	141.000	140.000	1.000	140.000	140.000	0
2	8.000	126.000	124.000	8.000	121.000	105.000	16.000
3	5.000	98.000	89.000	22.000	76.000	41.000	35.000
4	9.000	139.000	125.000	2.000	125.000	125.000	0
5	3.000	96.000	83.000	22.000	74.000	35.000	39.000
6	7.000	118.000	111.000	14.000	104.000	73.000	31.000
7	6.000	95.000	67.000	36.000	59.000	42.000	17.000
8	6.000	82.000	52.000	38.000	44.000	24.000	20.000
9	12.000	143.000	142.000	1.000	142.000	142.000	0
10	6.000	96.000	90.000	6.000	90.000	90.000	0
11	6.000	122.000	120.000	8.000	114.000	96.000	18.000
12	5.000	110.000	103.000	16.000	94.000	60.000	34.000
13	6.000	129.000	128.000	4.000	125.000	114.000	11.000
14	4.000	94.000	88.000	17.000	77.000	53.000	24.000
15	8.000	105.000	103.000	17.000	87.000	57.000	30.000
16	9.000	123.000	115.000	13.000	110.000	98.000	12.000
17	6.000	118.000	122.000	7.000	112.000	58.000	54.000
18	7.000	131.000	128.000	5.000	126.000	120.000	6.000
19	6.000	118.000	117.000	8.000	102.000	82.000	20.000
20	3.000	80.000	73.000	29.000	50.000	7.000	43.000
21	6.000	105.000	109.000	14.000	91.000	47.000	44.000
22	6.000	113.000	102.000	18.000	95.000	56.000	39.000
23	4.000	62.000	54.000	29.000	33.000	0	33.000
24	5.000	113.000	108.000	14.000	102.000	77.000	25.000
25	3.000	50.000	21.000	38.000	12.000	0	12.000
26	6.000	108.000	92.000	20.000	87.000	71.000	16.000
27	3.000	41.000	32.000	23.000	19.000	0	19.000
28	6.000	110.000	98.000	20.000	90.000	67.000	23.000
29	5.000	90.000	81.000	17.000	73.000	45.000	28.000
30	4.000	46.000	30.000	26.000	20.000	2.000	18.000
31	4.000	79.000	50.000	35.000	44.000	30.000	14.000
32	4.000	92.000	73.000	31.000	61.000	32.000	29.000
33	4.000	73.000	35.000	45.000	28.000	7.000	21.000
34	1.000	59.000	54.000	19.000	41.000	12.000	29.000
35	4.000	61.000	30.000	41.000	19.000	4.000	15.000
36	6.000	84.000	45.000	46.000	41.000	25.000	16.000
37	3.000	63.000	23.000	49.000	10.000	0	10.000
38	3.000	79.000	66.000	25.000	54.000	27.000	27.000
39	5.000	107.000	81.000	28.000	79.000	67.000	12.000
40	6.000	89.000	83.000	22.000	72.000	43.000	29.000

	BSRT remi...	BSRT Intru...	BSRT Cued ...	BSRT Multiple...
1	15.000	0	12.000	12.000
2	30.000	0	12.000	12.000
3	57.000	4.000	8.000	12.000
4	17.000	0	12.000	12.000
5	59.000	4.000	9.000	11.000
6	38.000	6.000	12.000	12.000
7	58.000	8.000	10.000	12.000
8	70.000	5.000	5.000	12.000
9	13.000	0	12.000	12.000
10	24.000	1.000	12.000	12.000
11	34.000	4.000	10.000	12.000
12	46.000	11.000	10.000	12.000
13	27.000	5.000	11.000	12.000
14	58.000	8.000	8.000	12.000
15	49.000	3.000	8.000	12.000
16	32.000	8.000	11.000	12.000
17	38.000	0	10.000	12.000
18	25.000	1.000	11.000	12.000
19	38.000	4.000	12.000	12.000
20	71.000	8.000	3.000	9.000
21	49.000	17.000	10.000	11.000
22	43.000	9.000	9.000	11.000
23	87.000	5.000	7.000	12.000
24	43.000	23.000	11.000	12.000
25	99.000	5.000	5.000	9.000
26	47.000	2.000	11.000	12.000
27	106.000	0	2.000	2.000
28	45.000	0	10.000	12.000
29	63.000	12.000	6.000	12.000
30	104.000	4.000	3.000	12.000
31	73.000	1.000	3.000	11.000
32	61.000	0	10.000	12.000
33	78.000	0	3.000	12.000
34	92.000	11.000	3.000	9.000
35	89.000	2.000	6.000	12.000
36	67.000	8.000	7.000	12.000
37	87.000	0	10.000	12.000
38	74.000	11.000	10.000	12.000
39	46.000	16.000	2.000	10.000
40	65.000	19.000	8.000	12.000