CONCURRENT VALIDITY OF THE WIDE RANGE ASSESSMENT OF MEMORY AND LEARNING AND THE WOODCOCK-JOHNSON TESTS OF COGNITIVE ABILITY-REVISED WITH A NEUROLOGICALLY COMPROMISED PEDIATRIC POPULATION

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The Wide Range Assessment of Memory and Learning (WRAML) is a relatively new instrument used in the assessment of memory in children. The purpose of this study was to examine the validity of the WRAML by comparing the performance of children on both the WRAML and the Woodcock-Johnson Tests of Cognitive Ability- Revised (WJTCA-R). Subjects for the study were children in treatment for a brain tumor at a regional children's medical center. Fifty children participated in the study ranging from ages 6 to 17.

A multiple regression analysis was conducted to determine which of four selected clusters from the WJTCA-R would have the highest correlation with the Verbal Memory Index (VERI) from the WRAML. The Short-Term Memory (GSM) cluster had the highest correlation ($r = .82$) as predicted. A Pearson's product-moment correlational analysis was conducted between the Visual Processing (GV) cluster from the WJTCA-R and the Visual Memory Index (VISI) from the WRAML. GV was found to have a high positive correlation ($r = .63$) with VISI. A similar analysis was conducted between the Long-Term Retrieval (GLR) cluster from the WJTCA-R and the Learning Index (LRNI) from the WRAML. GLR was found to have a high positive correlation ($r = .81$) with

LRNI. Finally, a correlational analysis was conducted between the Broad Cognitive Ability (BCA) scale from the WJTCA-R and the General Memory Index (GENI) from the WRAML. A high positive correlation ($r = .87$) was found between these most global measures from the two batteries. The observed correlation between BCA and GENI was much higher than anticipated. The author concluded that neurological impairment had affected subject memory and intellectual functioning in similar ways. The results do not generalize to children who have not had similar decrements in cognitive functioning. Future research should establish a baseline correlation between the two instruments with a non-impaired population.

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Literature Review

Psychologists began studying memory in the mid-19th century. The first rigorous experimental investigation of human memory was published by Herman Ebbinghaus (1885), who posited the forgetting function. William James (1890) observed that memory could be subdivided into primary and secondary memory, roughly equivalent to contemporary ideas of short-term and long-term memory. The 1880's have been described as a revolutionary decade for memory research, because it marked the beginnings of the description of memory disorders (Kolb & Whishaw, 1996). In recent years, there have been new advances in our understanding of this basic cognitive function. Psychologists have realized that there are many dimensions of memory, e.g., declarative vs. procedural, locale vs. taxon, verbal vs. nonverbal, cued vs. recognition, etc. New models of memory have been posited. For example, cognitive psychologists have introduced the computer model analogy of memory and brain functioning. Technological advances are increasing geometrically and the 1990's have been deemed the decade of the brain. The use of brain imaging techniques promises to dramatically increase our understanding of memory and other psychological processes. If the rate of advance is any indication, this may well be another revolutionary decade in memory research.

Theoretical Models of Memory

It is now generally accepted that memory is not a single system, and that one can find memory defects of quite diverse nature (Nadel, 1992). Earlier this century, Tolman (1949) favored the multiple systems view, and the particulars of his theory find echoes in some modern-day treatments of the problem. The debate between Hull (1943) and Tolman on this issue was part of the very fabric of experimental psychology for more than a decade. The notion that the hippocampus was responsible for the kind of cognitive learning Tolman emphasized, while the rest of the brain was responsible for the kind of noncognitive learning Hull emphasized, has been central to most of the early-postulated dichotomies in the field (Nadel and O'Keefe, 1974; Hirsh, 1974; O'Keefe and Nadel, 1978; Mishkin, Malamut and Bachevalier, 1984).

O'Keefe and Nadel (1978) postulate a model of separate memory systems, and emphasize several characteristics of these systems that make them distinct. These include the central role of spatial information, the speed with which information can be acquired or changed, the susceptibility to interference, the kinds of motivation underlying information acquisition, and the role of contextual coding. According to O'Keefe and Nadel (1978), several factors distinguish hippocampally based locale learning from non hippocampally based taxon learning. First, locale learning is assumed to be all or none and to show rapid acquisition (and extinction), while taxon learning is assumed to be incremental and to show slower acquisition (and extinction). Second, locale learning is assumed to be quite different from taxon learning with regard to the underlying systems of motivation that drive it. Much locale learning occurs during what is called exploration, or novelty-directed behavior. Taxon learning, on the other hand, is assumed to be motivated by the traditional forces emphasized by Hull, and to therefore be dependent on the standard application of reinforcements. Third, locale learning is assumed to yield memory representations that are less prone to interference effects than are those representations formed in the process of taxon learning. Finally, the locale system is assumed to be the basis for providing the context within which context-free information from the taxon systems could be situated.

Another theory of memory which has been the framework for extensive research involves the declarative vs. procedural memory dichotomy (Lezak, 1995). Procedural memory refers to well-ingrained habits. This is a form of memory that remains intact in many amnesia patients, who remember nothing of past events, but retain the ability to walk and talk, dress and eat, etc. Procedural knowledge is not generally available to conscious awareness. Three different categories of procedural memory have been recognized (Mayes, 1988; Squire, 1987). Skill memory includes motor and cognitive skill learning and perceptual “how to” learning. Priming refers to a form of cued recall in which, without the subjects awareness, prior exposure facilitates the response. The third category of procedural memory is classical conditioning.

Declarative memory refers to the ability to learn about and remember information, objects, and events. This is the kind of memory that patients refer to when complaining of memory problems, and that teachers address for most educational activities. It has been described as the mental capacity of retaining and reviewing impressions, or of recalling or recognizing previous experiences. It always involves awareness. Lezak (1995) describes a three-stage model of declarative memory, which she says provides a suitable framework for conceptualizing and understanding dysfunctional memory for clinical purposes. Two are succeeding stages of short-term memory (STM) and the third is long-term memory (LTM). Preliminary to the three stages is what Lezak (1995) calls registration or sensory memory. Registration holds large amounts of incoming information briefly, one or two seconds at most, in sensory store. This is neither strictly a memory function nor a perceptual function, but rather a selecting and recording process by which perceptions enter the memory system. Either information being registered is further processed as STM or it quickly decays.

Immediate memory, the first stage of STM storage temporarily holds information retained from the registration process. Immediate memory only handles about seven bits of information at a time (Miller, 1956), placing severe limitations on the amount of information that we are able to perceive, process, and remember. Immediate memory is of sufficient duration to enable a person to respond to ongoing events when more enduring forms of memory have been lost (Talland, 1965; Victor, Adams, and Collins,1971). It typically lasts from about 30 seconds up to several minutes. Information in immediate memory is temporarily maintained in reverberating neural circuits, which are self-contained neural networks that sustain a nerve impulse by channeling it repeatedly through the same network. If not converted into a more stable biochemical organization for longer lasting storage, the electrochemical activity that constitutes the immediate memory trace spontaneously dissipates. Rehearsal is any repetitive mental process that serves to lengthen the duration of a memory trace. With rehearsal, a memory trace may be maintained for hours.

Another kind of STM may be distinguished from immediate memory in that it lasts from an hour or so to one or two days. This is longer than a reverberating circuit could be maintained even with rehearsal, but not yet permanently fixed as learned material in LTM (Barondes, 1975; Rosenzweig and Leiman, 1968). They may involve an intermediate holding mechanism of a biological rather than electrophysiological nature (Doty, 1979; Thatcher and John, 1977).

LTM or secondary memory refers to the ability to store information (Lezak, 1995). LTM is most readily distinguishable from STM in amnesia, in which there is a relatively intact STM capacity with significant LTM impairments (Baddeley and Warrington, 1970). Consolidation, the process of storing information as LTM, may occur quickly or continue for considerable lengths of time without requiring active involvement (Mayes, 1988; Squire, 1987). Much of the information in the LTM storage system appears to be organized on the basis of meaning, whereas in the STM system it is organized in terms of contiguity or of sensory properties such as similar sounds, shapes, or colors (Broadbent, 1970; Craik and Lockhart, 1972). However, rote repetition and association built on superficial, relatively meaningless stimulus characteristics can lead to learning, too (Baddeley, 1978).

LTM storage involves a number of processes occurring at the cellular level. These include neurochemical alterations in the neuron, neurochemical alterations of the synapse, elaboration of the dendritic structures of the neuron to increase the number of contacts made with other cells (Bailey and Kandel, 1985; Mayes, 1988; Petit and Markus, 1987; Rosenzweig, 1984), and pruning of some connections with disuse (Edelman, 1989; Singer, 1990). There does not appear to be a single local storage site for stored memories; instead, memories involve neuronal contributions from many cortical and subcortical centers (Penfield, 1968; Squire, 1987; Thatcher and John, 1977), with different brain systems playing different roles in the memory system (Thompson, 1976). Storage and retrieval of information in the memory system appear to take place according to principles of association (Wickelgren, 1981).

Lezak (1995) makes other distinctions within declarative memory that have clinical significance. For example, recent and remote memory refer, respectively, to memories stored within the last few hours, days, or weeks, or even months, and to older memories dating from early childhood. Recall and recognition memory make the distinction between when remembering involves an active, complex search process vs. when a like stimulus triggers awareness. Another distinction can be made between episodic or event memory and semantic memory. The former refers to memories of one’s own experiences, whereas semantic memory is timeless, as the alphabet or historical data unrelated to a person's life. A distinction between automatic and effortful memory rests on whether learning involves active effortful processing or the information is acquired passively.

Cognitive Structures Implicated in Memory Processes

One of the first structures implicated in human memory was the temporal lobe. At the turn of the century, Bekhterev (1900) reported on a patient who had shown a severe memory impairment, and demonstrated on autopsy a bilateral softening in the region of the uncus, hippocampus, and adjoining medial temporal cortex.

In 1915, Karl Lashley began a series of experiments to identify the neural locations of learned habits, which he called engrams. He performed surgery on animals in which he either removed portions of the neocortex or made cuts of fiber pathways, hoping to prevent transcortical communication between the sensory and motor regions of the cortex. After a lifetime of research and hundreds of experiments, Lashley concluded that "...it is not possible to demonstrate the isolated localization of a memory trace anywhere in the nervous system. Limited regions may be essential for learning or retention of a particular activity, but the engram is represented throughout the region" (Lashley, 1950).

Just three years later, in 1953, a neurosurgeon named William Scoville removed the medial temporal lobes bilaterally in a patient, rendering him amnesic for almost all events following the operation. The surgery had interfered with the process of storing or retrieving new memories, but had not touched previously stored memories. Hundreds of experiments were subsequently performed on laboratory animals, but the pattern of deficits in this patient could not be duplicated. Three incorrect conclusions were derived from this case. First, it was assumed that the damage to the hippocampus was responsible for the anterograde amnesia. However, the amygdala, which is responsible for emotional memory, and the rhinal cortex, which is responsible for object-recognition memory, also contributed to the patient's impairment. Second, it was supposed that a single structure could be responsible for most if not all memory formation. But, it is now recognized that there are different classes of memory, and this patient had impairments in only one of these classes. Finally, it was supposed that short-term memories are converted into long-term memories. But, it is now recognized that short-term and long-term memories are independent (Kolb and Whishaw, 1996).

Other evidence for the role of the temporal lobes in memory comes from brain stimulation studies. Chapman and his associates (Chapman, Walter, Markham, Rand, Crandall, 1967) stimulated the hippocampus bilaterally in two epileptic patients and unilaterally in 13 others and found that bilateral stimulations produced retrograde amnesia that persisted for a few hours and reached back about 2 weeks.

Classical theories of memory supposed that there is a specific structure in the brain that houses memory (Kolb and Whishaw, 1996). But studies of even the simplest animals and simplified circuits, such as those in the spinal cord, indicate that every part of the nervous system is able to learn. The implication is that areas that process auditory information house auditory memory, areas that process visual information house visual memory, and areas of the brain involved in producing movement house motor memories, etc. Memory can be further divided within each of the major functional modalities. For example, visual memories are at least partly separated for color, form, and motion. It has also been documented that the left and right hemispheres encode memories differently as, for example, by Marsolek and coworkers (Marsolek, Kosslyn, and Squire, 1992). They found that the left hemisphere encodes abstract word-form representations that do not preserve specific features of the letters, whereas the right hemisphere encodes perceptually specific letter forms. They concluded that this division of labor represents phoneme (language) as opposed to grapheme (spatial) functions of the hemispheres.

Petri and Mishkin (1994) state that most of the neural structures involved in explicit memory are either in the limbic system or closely related to it. The four major limbic structures are the rhinal cortex, the amygdala, the hippocampus, and the prefrontal cortex. These structures have reciprocal connections with the medial thalamus, the basal forebrain, and sensory areas of the neocortex. Experimental evidence suggests that the rhinal cortex is involved in object memory, the hippocampus in spatial memory, and the amygdala in emotional memory. The medial thalamus provides one set of connections between the temporal lobe structures and the frontal lobe. The basal forebrain and other structures in the brainstem are involved in maintaining appropriate levels of activity in the limbic and cortical structures so that they can process information. The limbic structures depend on the neocortex for the information that they process.

There are relatively large numbers of patients who have undergone temporal lobectomies as a treatment for epilepsy, and who have been subject to neuropsychological study. The results of these studies suggest that, following right temporal lobe removal, patients are impaired on face-recognition, spatial position, and maze-learning tests (Milner, 1970). Following left temporal lobectomy, functional impairments are obtained in the recall of consonant trigrams, and nonspatial associations. There are also impairments on the Hebb Recurring-Digit Test.

Numerous researchers have doubly dissociated the effects of damage to the neocortex of the temporal lobe of each hemisphere on several memory tasks (Prisko, 1963; Warrington and James, 1967; Milner, 1970; and Corsi, 1972). They conclude that removal of the right temporal lobe produces deficits on nonverbal tests including recall of complex geometric figures, paired-associate learning of nonsense figures, and recognition of nonsense figures, tunes, and previously seen photographs of faces. Few deficits are seen, however, on tests of verbal memory. Removal of the left temporal lobe, on the other hand, produced deficits on verbal tests, such as the recall of previously presented stories and pairs of words and the recognition of words or numbers and recurring nonsense syllables. Such removal has little effect on the nonverbal tests.

Other neocortical areas have been associated with explicit memory functions. Injuries in the parietal, posterior temporal, and possibly occipital cortex sometimes produce specific long-term memory difficulties. Examples include prosopagnosia, object anomia, color amnesia, and topographical amnesias. Tulving and coworkers (Tulving, Kapur, Craik, Moscovitch, and Houle, 1994) used PET studies to show that the ventrolateral frontal cortex of the left hemisphere is preferentially active during memory encoding of words or series of words. The same regions are not, however, involved in retrieval of this information. Tulving et. al. (1994) also found that the dorsolateral frontal cortex in the right hemisphere and the posterior parietal cortex in both hemispheres are active during memory retrieval.

In a review of the literature, Sarter and Markowitsch (1985) have suggested that the amygdala is involved in those memory processes associated with events that have emotional significance to the subject’s life. If the amygdala makes any contribution to the amnesia of patients with medial temporal lobe lesions, it may be emotional in nature

There is now extensive literature linking the hippocampus with spatial behavior, e. g., navigating to specific locations or remembering the locations of objects. However, there is little evidence to indicate that the hippocampus is involved in other forms of memory. Studies in which the hippocampus of primates has been ablated also find spatial memory deficits, but not other memory deficits. Given that medial temporal lobe patients have impairments in spatial tasks and are amnesic for spatial information, it is likely that only this impairment is related to hippocampal loss.

Meunier and coworkers (Meunier, Bachevalier, Mishkin, and Murray, 1993) tested monkeys with damage to various areas in the temporal lobes on visual-recognition tasks. They found that those monkeys with perirhinal lesions were most impaired. These results strongly suggest that the recognition memory deficits come from the perirhinal cortex.

Evidence of diencephalic amnesia comes from two sources: patients with focal lesions of the medial thalamus, and patients with Korsakoff's syndrome. Focal lesions of the medial thalamic area most commonly result from vascular accidents, but there are few cases in which thorough behavioral and postmortem examinations have been done, so the critical lesion remains a mystery. Korsakoff's syndrome accompanies chronic alcoholism and is caused by a thiamine deficiency. The most obvious symptom is a severe loss of memory. The effect of the vitamin deficiency on the brain is thought to be damage to the medial thalamus and possibly to the mammillary bodies of the hypothalamus, as well as generalized cerebral atrophy. There are clear differences between the memory loss experienced by diencephalic and temporal lobe patients. Temporal lobe patients show normal release from proactive interference, diencephalic patients do not. Individuals with Korsakoff's syndrome have extensive loss of past memories, whereas temporal lobe patients do not. Korsakoff individuals may have two problems: a diencephalic lesion and frontal lobe deterioration.

The basal forebrain is the source of a number of pathways to the forebrain, among which are cholinergic fibers. The cholinergic cells are not involved in the storage of memory, but are thought to play a role in activating cortical cells so that they function normally. Serotonergic cells in the midbrain and noradrenergic cells in the hindbrain also project to the limbic system and cortex. These cells play a role in maintaining activation in these areas. Profound amnesia can be produced if the serotonergic cells in the midbrain and the cholinergic cells in the basal forebrain are damaged together. Animals that receive such treatments behave as if their entire neocortex were removed (Vanderwolf, 1988). They no longer display any intelligent behavior. Experiments suggest that the cholinergic projection and the serotonergic projection are jointly responsible for maintaining waking cortical activity. If one projection is removed, the other can maintain cortical activation, but if both are removed cortical activation is no longer possible.

Petri and Mishkin (1994) have also proposed a brain circuit for implicit memory. The structures involved include the neocortex, basal ganglia, substantia nigra, ventral thalamus, and premotor cortex. The basal ganglia receive projections from all regions of the neocortex and send projections via the globus pallidus and ventral thalamus to the premotor cortex. The basal ganglia also receive projections from cells in the substantia nigra, which contain the neurotransmitter dopamine. Dopamine may be indirectly involved in memory formation. The basal ganglia have traditionally been classified as motor structures. However, the circuits that they form also appear to be involved in receiving sensory information from the sensory neocortex and channeling it into cortical motor areas.

Animals with damage in the basal ganglia circuitry display preserved recognition memory, spatial memory, and emotional memory. On the other hand, they are impaired at learning motor skills, at learning to make appropriate responses to cues, and at association tasks. Patients with Huntington's chorea, which is characterized by the degeneration of cells in the basal ganglia, have demonstrated impairments in the mirror-drawing task, but are unimpaired on verbal-recognition tasks. This suggests that the circuits identified as responsible for explicit memory in monkeys and rats, may be responsible for motors skills learning and implicit memory in humans.

Imaging studies also support the idea that structures within this circuit are involved in implicit memory. Grafton and coworkers used PET scans of rCBF in normal subjects who learned to perform a pursuit motor task (Grafton, Mazziotta, Presty, Friston, Frackowiak, and Phelps, 1992). Motor execution was associated with increases in rCBF in the motor cortex, basal ganglia, and cerebellum. Acquisition of the skill was associated with a subset of these structures, i. e., the primary motor cortex, the supplementary motor cortex, and the pulvinar of the thalamus.

A study by Pascual-Leone, Grafman, and Hallett (1994) also demonstrated the role of the motor cortex in implicit learning. Subjects were required to press one of four buttons, each labeled with a digit, in response to cues provided on a TV monitor. There was a sequence of twelve cues, which were repeated for one group, but for the other group there was no order to the sequence. The implicit memory component of this task was the improvement in reaction time that occurred with practice. The explicit memory component occurred when subjects recognized the sequence and generated responses without cues. Cortical maps of the muscles involved in the task became progressively larger as the task was acquired. Once the subjects knew the sequence of the stimuli and had explicit knowledge of the task, the area of the motor cortex involved returned to baseline conditions. Acquisition of implicit knowledge involved a reorganization of the motor cortex that was not required for explicit memory performance.

Motor regions of the cortex also receive projections through the thalamus from the cerebellum. The cerebellum occupies an important position in the brain circuits involved in motor learning and plays an important role in a form of implicit learning called classical conditioning. Using a classical conditioning paradigm with rabbits, Thompson (1986) found that lesions to pathways from the cerebellum abolish the conditioned response, but not the unconditioned response. He further demonstrated the importance of the cerebellum in learning by showing that the cortex is not necessary for the development of the conditioned response. Thompson (1986) concluded that the cerebellum is involved in learning discrete, adaptive behavioral responses to noxious events.

Memory Assessment

Lezak (1995) recommends that a memory examination should cover, at a minimum, span of immediate retention; very short-term retention with interference; learning in terms of extent of recent memory, learning capacity, and how well newly learned material is retained; and efficiency of retrieval of both recently learned and long-stored information (remote memory). She states that, ideally, these memory functions would be systematically reviewed through the major receptive and expressive modalities using both recall and recognition techniques. Lezak (1995) recommends that an initial evaluation of memory for most adults start with a Wechsler intelligence test, a thorough mental status examination, a test of configural recall and retention, a paragraph for recall, and a test of learning ability that gives a learning curve and includes a recognition trial.

Numerous instruments have been developed for the assessment of verbal memory. They form a broad spectrum in terms of their purpose, complexity, and sophistication. One of the most basic is a test of verbal automatisms. Automatisms are patterns of verbal material, learned by rote in early childhood and used frequently throughout life. Loss or deterioration of these well-ingrained responses in nonaphasic patients occurs in nonacute conditions only when there is severe, usually diffuse, cerebral damage. To test for automatisms, the examiner simply asks the subject to repeat the alphabet, the days of the week, etc. More than one error usually indicates brain dysfunction.

The next level of verbal assessment involves the short-term retention of letters and digits. One popular test of this type is a distractor technique referred to as consonant trigrams. The subject upon hearing the stimulus material, is asked to count backward from a given number until signaled to stop, and then identify the stimulus items. The purpose of the distractor task is to prevent rehearsal of the material being held in STM. This task is useful for documenting very short-term memory deficits, i.e., the rapid decay of a memory trace.

There are a number of word list learning tests that measure immediate verbal memory span. Some of these tests, such as the Auditory Verbal Learning Test (AVLT), use unrelated words. In addition to immediate verbal memory span, the AVLT provides for a learning curve and reveals learning strategies. It elicits retroactive and proactive interference as well as tendencies toward confusion or confabulation on memory tasks. It measures both short-term and longer-term retention following interpolated activity, and allows for a comparison between retrieval efficiency and learning.

Other tests, such as the California Verbal Learning Test (CVLT and CVLT-C) use shopping lists of related words to enhance the task's utility and appearance of practical relevance. While similar to the AVLT in overall format and purpose, the CVLT differs in one important respect. Each of the 16 items in the CVLT list belongs to one of four categories, i.e., fruits, herbs and spices, articles of clothing, and tools. This format creates both advantages and disadvantages. It provides important information about the subject's use of learning strategies and their effectiveness. However, the CVLT does not examine rote verbal memory itself, but an interaction between verbal memory and conceptual ability.

Tests of story recall provide both a measure the amount of information that is retained when more information is presented than most people can remember on one hearing and a measure of the contribution of meaning to retention and recall. An example of a story recall test is Cowboy Story, which is often included in mental status examinations. It is simply a paragraph about a cowboy and his dog, which has been divided into 27 memory units for quantitative verbatim recall and 24 content ideas, which are credited as correctly recalled if the subject substitutes synonyms or suitable phrases for the exact wording.

Another important component in the assessment of memory are tests of visual memory. The Rey-Osterrieth Complex Figure Test is an example of a test of visual recall. There is a copy administration in which the subject is simply asked to copy the design. Both immediate and delayed recall trials are usually given, although the amount of delay varies among examiners.

Another type of assessment of visual memory is visual recognition testing, which becomes important not only for evaluating visual memory when recall is impaired, but when subjects have physical limitations as well. One example of a visual recognition instrument is the Continuous Recognition Memory Test (CRMT). This test consists of 120 line drawings of various flora and fauna organized into six blocks of 20 drawings each. The first set of blocks includes the eight target drawings plus 12 foils. Each of the subsequent blocks contain all eight target figures plus eight similar ones, plus four drawings from other-than-target categories. The subject sees each drawing for 3 seconds and must say whether the drawing is old or new.

Historically, the primary approach for the assessment of memory has been the battery of memory tests (Lezak, 1995). Memory test batteries are available, which include various combinations of the same type tests as the individual memory tests. One example of a memory test battery is the Wide Range Assessment of Memory and Learning (WRAML). The WRAML is a relatively new instrument, which promises to fill a void in the assessment of memory in children. However, additional research is needed to establish the validity of this instrument.

In a recent study, Wheaton (1994) examined the relative performance of students on the three indices of the WRAML and selected measures of the Woodcock-Johnson Tests of Cognitive Ability-Revised (WJTCA-R). She found that Short-Term Memory was the most significant contributor to the prediction of the Verbal Memory Index from the WRAML. Short-Term Memory was also found to contribute significantly to the prediction of the WRAML's General Memory Index, though the percentage of variance accounted for was small. A strong visual component to the Learning Index was noted by the contribution of Visual Processing to the prediction of this variable. None of the administered WJTCA-R variables was found to contribute significantly to the prediction of the Visual Memory Index.

Although Wheaton (1994) attempted to compare the WRAML and WJTCA-R, there were several limitations to her study. The WJTCA-R clusters are each composed of two subtests. However, Wheaton administered only one subtest from each of four WJTCA-R clusters. She acknowledged assumptions that each of these subtests provided an adequate estimate of the corresponding cognitive cluster. However, McGrew (1994) stated that the appropriate level of analysis and interpretation for the WJTCA-R is the cognitive cluster. These assumptions greatly weakened the generalizability of Wheaton's results. Also, Wheaton's use of a non-clinical population may have obscured real correlation that exists between the two instruments. That is, the non-clinical population she used may have been too homogeneous to allow for detection of an actual correlation between the two tests above the level of error.

The purpose of the current study is to examine the validity of the WRAML by comparing the concurrent performance of a neurologically impaired pediatric population on both the WRAML and WJTCA-R. The study is important, because the WRAML is currently one of the most widely used instruments for the assessment of memory in children. Despite its widespread use, there continues to be insufficient data to clearly establish which aspects of memory the WRAML is measuring. In this study, the WRAML was compared with a relatively well-established instrument, the WJTCA-R. According to Woodcock (1990), the WJTCA-R is an operational representation of the Horn-Cattell Gf-Gc theory of intellectual processing. There is well-documented empirical evidence that supports the WJTCA-R factor structure, and which indicates that the WJTCA-R provides for reliable and valid measurement of seven factors of the Gf-Gc theory (Kaufman, 1990; Reschly, 1990; Ysseldyke, 1991). If indices from the WRAML could be shown to correlate with the WJTCA-R, interpretation of a patient's performance on the WRAML could be made with greater confidence. Another value of this study was the inclusion of all 14 subtests from the WJTCA-R Broad Cognitive Ability Extended Scale. This facilitated the computation of the Broad Cognitive Ability Score, and allowed a direct comparison of the broadest measures from both the WJTCA-R and the WRAML. Scores from the WJTCA-R and WRAML will be referred to using the abbreviations given in Table 1.

Table 1

WJTCA-R and WRAML Variables and Abbreviations Used

WJTCA-R Clusters	WRAML Indices
Long-Term Retrieval (GLR)	Verbal Memory Index (VERI)
Short-Term Memory (GSM)	Visual Memory Index (VISI)
Processing Speed (GS)	Learning Index (LRNI)
Auditory Processing (GA)	General Memory Index (GEMI)
Visual Processing (GV)	
Comprehension/Knowledge (GC)	
Fluid Reasoning (GF)	
Broad Cognitive Ability (BCA)	

Hypotheses

Hypothesis 1

Of the four WJTCA-R cluster scores, Short-Term Memory will have the highest correlation with the WRAML Verbal Memory Index as well as the largest beta weight. There were two reasons for positing this hypothesis. First, Wheaton (1994) found a relationship between these variables, although she used only one of the subtests from Short-Term Memory as an estimate of that cluster. Second, both factors are purported to measure verbal memory. The WJTCA-R Short-Term Memory cluster assesses the ability to apprehend and hold verbal information in immediate awareness and then use it within a few seconds. The WRAML Verbal Memory Index assesses ability on verbal memory tasks of increasing semantic complexity.

Hypothesis 2

There will be a statistically significant, high positive Pearson product moment correlation between the WJTCA-R Visual Processing cluster and the WRAML Visual Memory Index. The hypothesis that there is a relationship between the Visual Memory Index and the Visual Processing cluster was not supported in previous research (Wheaton, 1994). However, the subtest used to estimate the Visual Processing cluster, Visual Closure, is more accurately described as a measure of gestalt closure. As Wheaton pointed out, there is also a timed component to the three subtests from the Visual Memory Index, but no timed element to Visual Closure. The subtest that represents the second half of the Visual Processing cluster, Picture Recognition, appears to be a closer representation of visual memory. Picture Recognition measures the ability to recognize a subset of previously presented pictures within a field of distracting pictures. It was held that this hypothesis would be supported in the current study, despite the failure to establish a relationship in a previous study, for several reasons. Both factors are purported to measure visual processing. The inclusion of both subtests from the Visual Processing cluster gave a more accurate representation of the construct. Finally, the use of a clinical population helped insure greater heterogeneity in performance, increasing the probability of finding an existing relationship between the variables.

Hypothesis 3

There will be a statistically significant, high positive Pearson product moment correlation between the WJTCA-R Long-Term Memory cluster and the WRAML Learning Index. Both factors purport to measure associative learning with feedback. The visual-auditory learning task in the Sound-Symbol subtest seemed especially similar to both subtests from the Long-Term Memory cluster. The relationship between these variables, although posited by Wheaton (1994), was not analyzed due to an error in administration of the Memory for Names subtest.

Hypothesis 4

There will be a statistically significant, high positive Pearson product moment correlation between the WJTCA-R Broad Cognitive Ability- Extended Scale Score and the WRAML General Memory Index. Two of the seven WJTCA-R clusters, representing nearly one-third of the battery, are devoted to the assessment of memory. Hypothesizing an empirical relationship between these two variables is a logical extension of the constructs associated with each instrument.

Statistical significance for analysis of the primary hypotheses will be set at $p < .05$. To be of importance, however, correlations would need to be not only statistically significant, but also clinically significant. For the purposes of this study, clinical significance was defined by the following three categories of positive correlation: high (.70 to 1.00), medium (.50 to .69), and low (0 to .49).

Method

Participants

Children between the ages of six and seventeen were solicited from a population who had received treatment for a brain tumor at a regional children's medical center. All participants were being followed in the neuro-oncology clinic at the medical center. A neuropsychological assessment was offered to the families of children not covered by commercial insurance, who needed, but could not otherwise afford, the evaluation. Other children were invited to participate, and did so, because the assessment provided supplementary information to the neuropsychological evaluation they had already received. Even though some children needed no additional testing, these parents allowed their children to participate simply to assist with the research project.

Of the 50 children who participated in the study, 26 (52%) were male and 24 (48%) were female. The ethnic composition of the sample consisted of 80% Caucasian, 8% Hispanic, 6% Native American, 2% African American, 2% Asian American, and 2% of Middle Eastern extraction. The average age of the participants was 11.8 years (SD = 3.3). Their ages ranged from 6.2 to 17.3 years. The average grade in school at the time of assessment was 6.2 (SD = 3.3). Grade in school ranged from .6 to 11.9. Nineteen of the children (38%) were receiving special education services at school. Eight children (16%) had repeated at least one grade. Seventeen (34%) were reported to be having difficulty in school at the time of the assessment.

The average age at diagnosis of the child's brain tumor was 7.8 years (SD = 4.3). Age at diagnosis ranged from .3 to 16.9 years. All but three of the children (6%) had a surgical resection of the tumor. The number of years post diagnosis at the time of participation in the study was four years (SD = 3.0). The range of years post diagnosis was from .3 to 13.3 years. The most frequently observed location of tumor was in the posterior fossa at 12 (24%). For a complete listing of tumor locations, refer to Table 2. In terms of lateralization, seventeen of the tumors (34%) were midline. Fifteen (30%) were located in the left hemisphere, while ten (20%) were in the right hemisphere. Six (12%) were diffuse posteriorly, and two (4%) were located bilaterally. Histological studies identified Astrocytoma as the most frequently occurring type of tumor at seventeen (34%). For a complete listing of tumor type, refer to Table 3. Twelve of the children (24%) had high grade malignancies, while 38 (76%) were considered low grade. Sixteen of the children (32%) had received radiation treatments. Ten (20%) had received chemotherapy. Twenty-one of the children (42%) had increased intra-cranial pressure of which 13 (26%) required placement of a shunt. Seven of the children (14%) had a recurrence of tumor subsequent to surgical resection, but prior to testing.

Table 2

Tumor Location (n = 50)

Tumor Location	Frequency	Percent
Posterior Fossa	12	24
Pituitary Gland	6	12
Cerebellum	6	12
Fourth Ventricle/ Brainstem	5	10
Temporal Lobe	3	6
Tectal Plate	3	6
Optic Tract	2	4
Thalamus	2	4
Frontal Lobe	2	4
Pineal Gland	2	4
Parietal Lobe	2	4
Thalamus/Basal Ganglia	1	2
Frontoparietal Lobe	1	2
Hypothalamus/Basal Ganglia	1	2
Pons	1	2
Lateral Ventricle	1	2

Table 3

Tumor Type (n = 50)

Tumor Type	Frequency	Percent
Astrocytoma	17	34
Glioma	6	12
Ependymoma	5	10
Craniopharyngioma	5	10
Medulloblastoma	4	8
Ganglioglioma	3	6
Papilloma	2	4
Lipoma	2	4
Pleomorphic Xanthoastrocytoma	1	2
Oligodendroglioma	1	2
Adenoma	1	2
Primitive Neuroectodermal (PNET)	1	2
Ganglion Cell	1	2
Chorid Plexus Paloma	1	2

Procedure

The primary purpose for the cognitive assessment of these children was to provide clinical feedback regarding their cognitive functioning. The subjects' parents were contacted by the investigator or one of his assistants and offered an appointment for the assessment. At the time of the initial contact, the child's parents were informed that, with their permission, the investigator was to also use the assessment data in a research project. They were advised that if they chose to participate in the research, the assessment results would remain confidential. They were advised that the assessment was free of charge and that there was no obligation to participate in either the assessment or the research. They were also advised that the assessment would be provided free of charge, even if they chose not to participate in the research project. Parents signed a consent form acknowledging receipt of this information. Refer to Appendix A for a copy of the consent form used in the study. The Director of Neuropsychology for the children's medical center and a staff Neuropsychologist provided supervision for the assessment process, report writing, and feedback to the family.

Subjects were administered the Woodcock Johnson Tests of Cognitive Ability-Revised (WJTCA-R) and the Wide Range Assessment of Memory and Learning (WRAML). The WRAML takes about 45 minutes to an hour to administer. The WJTCA-R takes about an hour and a half. Additional tests were administered to provide a relatively comprehensive neuropsychological battery, i.e., Conners' Continuous Performance Test, Booklet Category Test, Trail Making Test, Developmental Test of

Visual-Motor Integration, Finger Tapping Test, Behavior Assessment System for Children, and the Pediatric Oncology Quality of Life Scale. Breaks were offered to prevent fatigue. The WJTCA-R and WRAML were administered in a counterbalanced order to control for the effects of order of administration. WJTCA-R scores were computed using an IBM version of Compuscore (Riverside Publishing, 1989). The WRAML scores were calculated manually by the test administrators. Parents were given feedback regarding their child's performance through written record and personal interview. For those parents who were unable to attend the feedback session, written feedback was sent to their home and a telephone interview was conducted to clarify the interpretation.

Measures

Wide Range Assessment of Memory and Learning (WRAML)

The WRAML is a standardized psychometric instrument, which was designed to evaluate memory in children 5 through 17 years of age (Sheslow and Adams, 1990). The standardization group included 2363 individuals and was constructed using a nationally stratified sampling technique, controlling for age, gender, race, regional residence, and metropolitan vs. non-metropolitan residence.

The construction of the WRAML was guided by influences from the cognitive, neuropsychological, and developmental traditions (Sheslow and Adams, 1990). According to Sheslow and Adams (1990), the subtests comprising the WRAML were developed with the following objectives in mind: (a) to allow assessment of modality specific competencies (i.e., visual vs. verbal deficits); (b) to vary along the episodic-semantic continuum, so that some subtests require the memory of discrete, non-meaningful bits of information, while others are tasks of a meaningful nature; (c) to allow the evaluation of a child's memory strategies by including some tasks where learning could be assessed through a multiple trials procedure; (d) to allow the assessment of varied criterion performances (immediate vs. delayed recall vs. recognition); and (e) to allow for the evaluation of memory function across childhood and adolescence.

There are three Verbal, three Visual, and three Learning subtests, yielding a Verbal Memory Index, a Visual Memory Index, and a Learning Index (Sheslow and Adams, 1990). These nine subtests are combined to yield a General Memory Index. For each of the four indices, standard scores and percentiles can be derived. The entire WRAML battery was administered to the participants.

The subtests that comprise the Verbal Memory Scale allow the examiner to assess the learner's capability on a rote memory task and to compare that performance with tasks that increase in semantic complexity (Sheslow and Adams, 1990). This allows the examiner to form hypotheses about the child's ability to utilize language (semantics) as an aide or detractor in remembering. The three subtests comprising the Verbal Memory Scale are: (a) Number/Letter Memory- This task measures the child's ability to repeat number-and-letter combinations which are verbally presented. (b) Sentence Memory- This task requires the child to repeat meaningful sentences immediately after presentation. (c) Story Memory- Two short stories are read and the child is asked to recall as many parts of each story as can be remembered. The stories are developed with differing developmental levels of linguistic complexity. Both a delayed recall and a recognition task are provided.

The visual subtests are also constructed along a dimension of increasing meaningfulness, from rote memory demands to memory demands with increasingly meaningful material. The three subtest comprising the Visual Memory Scale are: (a) Finger Windows- The child indicates his/her memory of a rote visual pattern manually reproducing a demonstrated spatial sequence. (b) Design Memory- Four designs are presented and the child is asked to draw the designs remembered after a ten-second delay. (c) Picture Memory- The child is shown a complex meaningful scene. The child is then asked to look at a second, similar scene. Memory of the original picture is indicated by identifying elements which have been added or changed in the second picture.

All subtests on the Learning Scale evaluate performance over trials. One verbal, one visual, and one cross-modal task comprise this scale: (a) Verbal Learning- The child is read a list of simple words followed by immediate recall, using a free-recall paradigm. Three additional presentation/recall trials follow. A delayed recall trial is also provided. (b) Visual Learning- The child is asked to recall a fixed number of visual stimuli presented over four trials. Visual designs are presented in a particular position on a board. The child is then asked to remember which spatial location is associated with each design. A delayed recall task is also provided. (c) Sound-Symbol- This is a paired-associate task requiring the learner to recall sounds associated with various abstract figures. There are four discrete trials plus a delayed recall trial.

For each of the WRAML subtests, coefficient alpha measures of internal consistency range from .78 to .90, while the Verbal Memory, Visual Memory, and Learning Indices range from .90 to .93. The General Memory Index coefficient alpha was .96. Additional support for internal consistency was obtained by using Person Separation Indices, which were obtained through Rasch item analysis and revealed Person Separation Index values ranging from .79 to .94 for all WRAML subtests. The consistently high item and Person Separation statistics are considered by Sheslow and Adams (1990) to be supportive evidence for the WRAML's content validity. To control for carry-over effect, test-retest measures were completed across an interval not less than 60 days. Stability measures revealed a .84 stability coefficient for the General Memory Index and .82, .61, and .81 for the Verbal Memory, Visual Memory, and Learning Indices, respectively. Preliminary support for the criterion-referenced validity of the WRAML was obtained by comparing the performance of students to the McCarthy Memory Index (ages 6 and 7 years), the Memory Scale on the Stanford Binet: Fourth Edition (ages 10 and 11 years), and the Wechsler Memory Scale-Revised (WMS-R) (ages 16 and 17 years). The McCarthy study suggests that the McCarthy Memory Index and the WRAML Verbal Memory Index and General Memory Index are highly correlated (.90 and .72, respectively), while the WRAML Visual Memory Index is correlated at a much lower level (.48). The WRAML Learning Index appears to be independent of the McCarthy (r=.10). The correlational study which examined the relationship between the Stanford Binet Short-Term Memory Scale and the WRAML memory indices suggests that these two measures are generally measuring the same construct since correlational values range from .67 to .80. Though a moderately high correlational value of .54 was reported between the WRAML General Memory Index and the WMS-R General Memory Index, the remaining correlational values, which range from .32 to .63 suggest that more research is needed before it can be determined that these two measures are examining the same construct.

Comparison of the WRAML Index scores with the Wechsler Intelligence Scale for Children- Revised (WISC-R) reveals a significant, but moderate, correlation between memory and general cognitive ability.

Woodcock Johnson Tests of Cognitive Ability- Revised (WJTCA-R)

According to Woodcock (1990), the WJTCA-R is an operational representation of the Horn-Cattell (Gf-Gc) theory of intellectual processing. It consists of 21 individual tests that provide for the comprehensive assessment of simple to complex abilities in seven areas of intellectual functioning as described by the Gf-Gc theory (McGrew, 1994). Participants in this study were administered the Broad Cognitive Ability-Extended Scale, which is the broadest of the WJTCA-R Scales and represents an individual's performance on the first 14 cognitive tests. Two tests from each of the seven Gf-Gc cognitive factors are included in this broad ability score. What follows is a list of the seven areas of intellectual ability, or clusters, included in the broad ability score: (a) Long-Term Storage and Retrieval (GLR)- Refers to the ability to store information in long-term memory and to fluently retrieve it later through association. Subtests- Memory for Names, Visual-Auditory Learning. (b) Short-Term Memory (GSM)- Refers to the ability to apprehend and hold information in immediate awareness and then use it within a few seconds. Subtests- Memory for Sentences, Memory for Words. (c) Processing Speed (GS)- Refers to the ability to perform automatic cognitive tasks quickly, especially when under pressure to maintain focused attention and concentration. Subtests- Visual Matching, Cross Out. (d) Auditory Processing (GA)- Refers to the ability to comprehend, analyze, and synthesize patterns among auditory stimuli. Subtests- Incomplete Words, Sound Blending. (e) Visual Processing (GV)- Refers to the ability to perceive, analyze, synthesize, and think with visual patterns. Subtests- Visual Closure, Picture Recognition. (f) Comprehension-Knowledge (GC)- Represents the breadth and depth of a person's knowledge and the effective application of that stored knowledge. Subtests- Picture Vocabulary, Oral Vocabulary. (g) Fluid Reasoning (GF)- Refers to the broad ability to reason. Subtests- Analysis-Synthesis, Concept Formation.

Test construction and standardization of the WJTCA-R was extensive and thorough (Kamphaus, 1993; McGrew, Werder, & Woodcock, 1991). The concepts of latent-trait theory and the analysis of data by the Rasch model were employed (McGrew, 1994). The normative data were gathered from 6,359 subjects in over 100 communities selected during a three-stage stratified sample based on the 1980 U.S. Census. Representativeness of the standardization sample was achieved by controlling for 5 person variables (gender, race, Hispanic origin, and occupation and education of adults) and fifteen community variables (location, size, and 13 community socioeconomic variables) in the norming plan.

Reliability for the seven WJTCA-R cognitive clusters, as reported in the technical manual (McGrew et.al., 1991), were completed with a formula for calculating the reliability of composite scores (Mosier, 1943). Since the clusters are to be used for generating strength and weakness hypotheses, the reliability criterion of .80 or above is an appropriate yardstick for evaluating these clusters (McGrew, 1994). The median reliability for each cluster, which ranged from .816 (Visual Processing) to .946 (Fluid Reasoning), meet this criterion. The WJTCA-R cognitive clusters possess adequate reliability for generating hypotheses about intra-cognitive strengths and weaknesses. The lack of consistent reliability at or above the .90 level argues against the use of a single WJTCA-R cognitive cluster score as the sole basis for an important educational decision (McGrew, 1994).

A network of evidence supports the validity of the WJTCA-R cognitive clusters for interpretation as measures of seven unique human abilities (McGrew, 1994). Evidence is available in the form of exploratory and confirmatory factor analysis studies (McGhee, 1993; McGrew et. Al., 1991; Woodcock, 1990), comparison of cluster growth curves (McGrew et. al., 1991), correlations with measures of similar abilities in other intelligence batteries (McGhee, 1993; McGrew et. al., 1991; Woodcock, 1990), and differential patterns of correlations between the seven cognitive factors and measures of reading, mathematics, and written language (McGrew, 1993a, 1993b; McGrew and Knopik, 1993).

Results

Descriptive Analyses

Each of four WRAML Indices and eight WJTCA-R standard scores were analyzed. Reported descriptive statistics included: mean, median, mode, standard deviation, variance, and range.

Descriptive Statistics for WRAML Indices

Descriptive statistics were computed for the four WRAML Indices based on the sample of 50 subjects. Means (M) and standard deviations (SD) within the sample ranged from M = 80.14, SD = 17.63 (GENI) to M = 89.04, SD = 16.39 (LRNI). Estimates of variance (MS) ranged from MS = 268.69 (LRNI) to MS = 310.74 (GENI). Refer to Table 4 for a complete listing of descriptive statistics for each of the WRAML Indices. Histograms representing the WRAML Index scores can be found in Appendix B.

Descriptive Statistics for WJTCA-R Standard Scores

Descriptive statistics were computed for the seven WJTCA-R Cluster scores and the Broad Cognitive Ability score based on the sample of 50 subjects. Means within the sample ranged from M = 82.52 (GS) to M = 95.66 (GV). Standard deviations and estimates of variance ranged from SD = 15.14, MS = 229.27 (GA) to SD = 24.81, MS = 615.28 (GS). Refer to Table 5 for a complete listing of descriptive statistics for each of the WJTCA-R scores. Histograms representing the WJTCA-R scores can be found in Appendix C.

Table 4

Descriptive Statistics for WRAML Indices (n = 50)

Index	M	Mdn	Mode	SD	MS	Range
VERI	81.28	81.00	94.00	16.55	273.92	53-123
VISI	82.10	83.50	68.00	16.85	283.81	45-114
LRNI	89.04	92.00	109.00	16.39	268.69	51-118
GENI	80.14	80.00	72.00	17.63	310.74	45-109

Table 5

Descriptive Statistics for WJTCA-R Scores (n = 50)

Index	M	Mdn	Mode	SD	MS	Range
GLR	93.24	92.50	86.00	19.35	374.31	45-131
GSM	90.42	90.00	77.00	17.83	317.92	50-138
GS	82.52	85.00	93.00	24.81	615.28	24-134
GA	90.86	94.00	98.00	15.14	229.27	49-123
GV	95.66	100.00	112.00	22.73	516.76	5-130
GC	91.88	92.00	78.00	16.81	282.39	50-131
GF	92.62	92.50	108.00	17.19	295.34	55-127
BCA	85.88	88.00	95.00	22.21	493.46	27-128

Preliminary Analyses

An analysis of demographic data with respect to their effect on relevant WJTCA-R and WRAML scores was conducted using Pearson's product moment correlation. Family income, gender, ethnicity, and parent education were examined. Since numerous correlational pairs were studied, only those pairs which reached a $p<.01$ level of significance were reported in an effort to reduce the possibility of Type 1 errors. Order of test administration and tester were analyzed using multivariate statistical techniques and a $p<.05$ level of significance.

Family income was the first demographic variable examined. Parents were to choose one of ten discrete income brackets. Each bracket represented $10,000 of annual income from $0- $9,999 through $90,000 or more. Nine parents declined to report their income. For the 41 parents who reported income, the average was $40,000 to $49,999. When the relationship between family income and each of the WJTCA-R Standard Scores and WRAML Index Scores were examined, no significant correlations were found. A histogram for family income can be found in Appendix D.

Descriptive statistics for gender and ethnicity were reported previously. There were no significant correlations between either gender or ethnicity and variables from the WJTCA-R or the WRAML.

Highest level of parent education completed was reported by choosing one of seven discrete brackets representing grade school through graduate degree. Eleven parents declined to report level of education. Parent education was to be reported for both the child's mother and father. The average level of education completed for both fathers and mothers was some college/trade school. When the relationship between parent education and experimental variables was examined, there was a significant correlation between father's level of education and three of the relevant variables, i.e., the Comprehension/ Knowledge cluster (GC) from the WJTCA-R and the Learning Index (LRNI) and General Memory Index (GENI) from the WRAML ($p<.01$). Table 6 lists means and standard deviations for each educational category with respect to these three variables. There were no significant correlations between mother's level of education and variables from the WJTCA-R or the WRAML. Histograms for parent's education level can be found in Appendix D.

Overall, order of test administration was not found to be related to testing results ($\underline{F} = 1.04$; $\underline{df} = 1{,}48$; $\underline{p} = .437$) using a Hotelling's T^2 analysis. Table 7 contains means and standard deviations for the relevant WRAML and WJTCA-R measures by order of administration.

Table 6

Significant WJTCA-R and WRAML Means by Father's Education(N=39)

		WJTCA-R		WRAML			
		GC		LRNI		GENI	
Father Education	n	M	SD	M	SD	M	SD
Grade School	2	62.50	17.7	76.50	20.5	62.50	21.9
Some High School	4	80.25	4.6	72.25	7.2	67.25	3.7
High School/GED	10	90.50	21.0	88.20	15.7	76.90	18.5
Some College/Trade	13	95.31	14.7	89.85	16.1	83.31	19.1
College Degree	6	93.83	11.2	103.17	7.7	95.33	9.8
Some Graduate	1	131.00	-	98.00	-	89.00	-
Graduate Degree	3	97.33	14.6	106.67	12.7	92.00	8.2

Table 7

WRAML Indices and WJTCA-R Scores by Order of Administration (N = 50)

	WJTCA-R FIRST		WRAML FIRST	
	M	SD	M	SD
GA	85.70	14.2	96.91	14.2
GC	86.89	17.7	97.74	13.9
BCA	79.70	23.9	93.13	17.9
VISI	77.67	16.5	87.30	16.1

There were four individuals who administered the test batteries. Tester A administered tests to 20 children. Tester B administered tests to 22 children. The two remaining testers administered tests to six and two children respectively. For the purposes of this analysis, data from these two testers were combined and analyzed as Tester C. Overall, tester was not found to be related to testing results ($F = 1.46$; $df = 1,48$; $p = .110$) using Wilks' lambda. Table 8 contains means and standard deviations for the relevant WJTCA-R measures by test administrator.

Table 8

WJTCA-R Scores by Test Administrator (N = 50)

	GF		GSM	
	M	SD	M	SD
Tester A	84.65	16.4	83.35	14.3
Tester B	101.27	14.1	97.05	17.5
Tester C	88.75	17.7	89.88	21.6

Analyses of Hypotheses

Hypothesis 1

Performance on the Short-Term Memory (GSM) Cluster of the WJTCA-R was hypothesized to have the highest correlation with performance on the Verbal Memory Index (VERI) from the WRAML as well as to be associated with the largest beta weight. In a stepwise multiple regression analysis, Short-Term Memory (GSM), Long-Term Memory (GLR), Auditory Processing (GA), and Visual Processing (GV) were entered as independent variables with VERI as the dependent variable. The independent variables entered into the equation according to their relative contribution to the variance of VERI in the following order: (1) GSM, (2) GLR, (3) GA, (4) GV. GSM and GLR contributed significantly to the variance of VERI, while GA and GV did not. GA and GV were, therefore, dropped from the equation. There was overall significance in the relationship of

GSM and GLR with VERI (F = 58.80; df = 2,47; p<.0001). The coefficient of multiple correlation was high (R= .85). The percentage of variance accounted for by GSM and GLR (Adjusted R^2 = .70) suggests that there is a strong linear relationship between these two clusters from the WJTCA-R and the VERI. GSM did account for the greatest variance in VERI as indicated by the largest beta weight (GSM, β = .6756; GLR, β = .2423). The correlation of GSM to VERI (.82) was also larger than the correlation of GLR to VERI (.65). The first hypothesis was supported. Post hoc analyses of the correlation between GSM and the WRAML subtests that make up the VERI, i.e., Sentence Memory (.85), Number/Letter Memory (.72), and Story Memory (.51) revealed a strong positive correlation with each.

Hypothesis 2

It was hypothesized that there would be a statistically significant, high positive Pearson product moment correlation between the WJTCA-R Visual Processing (GV) Cluster and the WRAML Visual Memory Index (VISI). When GV was compared with VISI using a two-tailed test, a significant correlation was obtained (r= .6333, p<.0001). A scatterplot representing the correlation between GV and VISI can be found in Appendix E. The variance in VISI accounted for by GV was approximately 40%. The second hypothesis was supported. Post hoc analyses of the correlation between GV and the WRAML subtests that make up the VISI, i.e., Design Memory, Finger Windows, and Picture Memory resulted in the following correlations: .58, .56, and .21 respectively.

Hypothesis 3

It was hypothesized that there would be a statistically significant, high positive Pearson product moment correlation between the WJTCA-R Long-Term Retieval (GLR) Cluster and the WRAML Learning Index (LRNI). When GLR was compared with LRNI using a two-tailed test, a significant correlation was obtained ($r = .8125$, $p < .0001$). A scatterplot representing the correlation between GLR and LRNI can be found in Appendix E. The variance in LRNI accounted for by GLR was approximately 66%. The third hypothesis was supported. Post hoc analyses of the correlation between GLR and the WRAML subtests that make up the LRNI, i.e., Sound Symbol (.70), Verbal Learning (.64), and Visual Learning (.61) revealed a strong positive correlation with each.

Hypothesis 4

It was hypothesized that there would be a statistically significant, high positive Pearson product moment correlation between the WJTCA-R Broad Cognitive Ability Extended Scale (BCA) and the WRAML General Memory Index (GENI). When BCA was compared with GENI using a two-tailed test, a significant correlation was obtained ($r = .8705$, $p < .0001$). A scatterplot representing the correlation between BCA and GENI can be found in Appendix E. The variance in GENI accounted for by BCA was approximately 76%. The fourth hypothesis was supported. See Table 9 for a correlation matrix of WJTCA-R Clusters and WRAML Indices. A correlation matrix of WJTCA-R and WRAML subtests is also provided in Appendix F.

Summary

Descriptive statistics including mean, median, mode, standard deviation, variance, and range were computed for each of four WRAML Indices and eight WJTCA-R standard scores. An analysis of demographic data, including family income, gender, ethnicity, and parental education with respect to their effect on the data was also conducted. No significant correlations were found between family income, gender, ethnicity, or mother's level of education and variables from the WJTCA-R or the WRAML. There was a significant correlation, however, between father's level of education and three relevant variables, i.e., the Comprehension/Knowledge (GC) Cluster from the WJTCA-R and the Learning Index (LRNI) and General Memory Index (GENI) from the WRAML. The relationship between parental education and a child's cognitive functioning is well established in the literature and was anticipated in the data. Control for parental education was felt to be unnecessary. An analysis of order of test administration and tester with respect to their effect on the data was conducted, and no significant correlations were found. All parameters from preliminary analyses indicated that further analysis of the data was appropriate.

The results of statistical analyses are reported for each of the hypotheses. Performance on the Short-Term Memory (GSM) Cluster of the WJTCA-R was found to have the highest correlation with performance on the Verbal Memory Index (VERI) from the WRAML, as well as to be associated with the largest beta weight. The first hypothesis was supported. Post hoc analyses revealed high to moderate positive correlations between

GSM and each of the WRAML subtests that make up the VERI. A statistically significant positive correlation was found between the WJTCA-R Visual Processing (GV) Cluster and the WRAML Visual Memory Index (VISI). The second hypothesis was supported. Post hoc analyses revealed moderate to low correlations, however, between GV and the three WRAML subtests that make up the VISI. A statistically significant positive correlation was found between the WJTCA-R Long-Term Retrieval (GLR) Cluster and the WRAML Learning Index (LRNI). The third hypothesis was supported. Post hoc analyses revealed high to moderate correlations between GLR and the WRAML subtests that make up the LRNI. A statistically significant positive correlation was found between the WJTCA-R Broad Cognitive Ability- Extended Scale (BCA) and the WRAML General Memory Index (GENI). The fourth hypothesis was supported.

Table 9

Correlation Matrix for WJTCA-R Clusters and WRAML Indices

	glr	gsm	gs	ga	gv	gc
gsm	.6088					
gs	.5984	.6010				
ga	.5902	.6437	.5806			
gv	.7436	.4939	.6132	.5379		
gc	.6209	.6341	.5768	.6736	.5369	
gf	.6804	.6974	.5061	.5803	.5326	.6665
BCA	.8344	.8314	.7940	.7885	.7556	.8305
VERI	.6536	.8231	.5097	.6469	.4843	.7684
VISI	.6902	.5518	.6743	.4403	.6333	.5186
LRNI	.8125	.5884	.5484	.4613	.5623	.5779
GENI	.8332	.7548	.6527	.5965	.6466	.7220

All correlations are statistically significant at $p < .01$

Correlation Matrix for WJTCA-R Clusters and WRAML Indices (Cont.)

	gf	BCA	VERI	VISI	LRNI
BCA	.8341				
VERI	.6878	.8099			
VISI	.5557	.7205	.5582		
LRNI	.6545	.7433	.6841	.6352	
GENI	.7252	.8705	.8616	.8334	.8943

All correlations are statistically significant at $p < .01$

Discussion

The purpose of this study was to examine the validity of the WRAML by comparing the concurrent performance of children on both the WRAML and WJTCA-R. According to Woodcock (1990), the WJTCA-R is an operational representation of the Horn-Cattell Gf-Gc model of intelligence. There is well-documented empirical evidence that supports the WJTCA-R factor structure, and indicates that the WJTCA-R provides for a reliable and valid measurement of the seven factors of Gf-Gc theory (Kaufman, 1990; Reschly, 1990; Ysseldyke, 1991). Since the results of this study indicate that there is a high positive correlation between WJTCA-R clusters and indices from the WRAML, we can begin to use Gf-Gc theory to generate tentative hypotheses regarding the interpretation of WRAML profiles.

Short-term memory is defined as the ability to hold information in immediate awareness and then use it within a few seconds (Woodcock, 1990). The WJTCA-R operationalizes short-term memory with a cluster composed of two subtests, Memory for Sentences and Memory for Words. Memory for Sentences measures the ability to remember and repeat single words, phrases, and sentences. Memory for Words measures the ability to repeat lists of unrelated words in a correct sequence. Both tasks are presented auditorily via tape player. There was a high positive correlation (.82) between the Short-Term Memory (GSM) cluster from the WJTCA-R and the Verbal Memory Index (VERI) from the WRAML. The Verbal Memory Index (VERI) does appear to provide a valid measure of short-term memory.

The VERI is composed of three subtests. Story Memory is a measure assessing immediate recall of two short stories. Sentence Memory is a measure assessing immediate recall of meaningful sentences. Number/Letter Memory is a measure assessing immediate recall of a random mix of numbers and letters. These three measures certainly appear to be tasks that require the person to hold information in immediate awareness and then use it within a few seconds. The task demands on Sentence Memory, in fact, appear to be almost identical with those on Memory for Sentences. The only differences involve the actual content of the sentences and the fact that one subtest is presented verbally by the examiner and the other is presented via tape player.

Sheslow and Adams (1990) indicate that VERI is composed of three subtests that fall along a continuum from rote verbal memory to semantically complex verbal memory tasks. Story Memory, the most semantically complex task, had the lowest correlation with GSM (.51). The rote verbal memory task, Number/Letter Memory, a task loosely resembling Memory for Words, had a high positive correlation with GSM (.72). Sentence Memory, with a moderate amount of semantic complexity had the highest correlation with GSM (.85), and, therefore, appears to be the best individual measure of short-term memory on the WRAML. VERI can be interpreted as an operational representation of short-term memory from the Horn-Cattell model, roughly equivalent to GSM. The individual WRAML subtest Sentence Memory, and, to a lesser degree Number/Letter Memory, can also be interpreted as representing short-term memory in the Horn-Cattell sense.

Visual processing is defined as the ability to analyze and synthesize visual stimuli (Woodcock, 1990). There was a high positive correlation (.63) between the Visual Processing (GV) cluster from the WJTCA-R and the Visual Memory Index (VISI) from the WRAML. The Visual Memory Index (VISI) does appear to provide at least a moderate measure of visual processing. Although the tasks on VISI subtests clearly involve the analysis and synthesis of visual stimuli, there are also distinctions from the task demands in the GV subtests. The Visual Memory Index (VISI) is composed of three subtests. Finger Windows is a measure assessing immediate recall of a rote spatial sequence. Design Memory is a measure assessing the ability to reproduce designs after a 10 second delay. Picture Memory is a measure assessing immediate recall of a complex meaningful scene by identifying elements which have been altered in a similar scene. Contrast these tasks with the two subtests from the Visual Processing (GV) cluster, Visual Closure and Picture Recognition. Visual Closure is a measure assessing the ability to identify a drawing or picture that is altered in one of several ways. The picture may be distorted, have missing lines or areas, or have a superimposed pattern. Picture Recognition is a measure assessing the ability to recognize a subset of previously presented pictures within a field of distracting pictures. Given the differences in task demands associated with the GV and VISI subtests, the fact that VISI provides only a moderate measure of visual processing is reasonable. Both Design Memory (.58) and Finger Windows (.56) had moderate correlations with GV. Picture Memory on the other hand had a very weak correlation with GV (.21), and variations in performance on this subtest should typically be considered to have little bearing on visual processing abilities as defined by the Horn-Cattell model. VISI, however, can be interpreted as a moderate measure of visual processing. Interpretation of VISI in terms of the Horn-Cattell model should probably be restricted to the level of the WRAML Index, due to the moderate to low correlations of the individual VISI subtests with GV.

Long-term retrieval is defined as the ability to store information and retrieve it later through association (Woodcock, 1990). The WJTCA-R operationalizes long-term retrieval with a cluster composed of two subtests, Memory for Names and Visual-Auditory Learning. Memory for Names measures the ability to learn associations between unfamiliar auditory and visual stimuli. Visual-Auditory Learning measures the ability to associate new visual symbols with familiar words and to translate a series of those symbols into verbal sentences. The task simulates learning to read. The subject receives corrective feedback for both subtests. There was a high positive correlation (.81) between the Long-Term Retrieval (GLR) cluster from the WJTCA-R and the Learning Index (LRNI) from the WRAML. The Learning Index (LRNI) does appear to provide a valid measure of long-term retrieval.

The LRNI is composed of three subtests. Verbal Learning is a measure assessing free recall of a list of words with repeated trials. Visual Learning is a measure assessing the ability to recall the position of colorful designs on a board with repeated trials and feedback. Sound Symbol is a paired-associate task requiring recall of sounds associated with abstract line drawings with repeated trials and feedback. This is a cross-modal task (i.e., visual-verbal), and resembles important processes involved in the acquisition of the mechanics of reading or "word calling". The task demands for Sound Symbol appear to be very similar to those for Verbal-Auditory Learning. These three measures do appear to include tasks that tap the ability to store information and retrieve it later through association. Post hoc analysis revealed that there was a moderate correlation between Verbal Learning (.64) and LRNI and between Visual Learning (.61) and LRNI. There was a moderate to high correlation between Sound Symbol (.70) and LRNI. LRNI can be interpreted as an operational representation of long-term retrieval from the Horn-Cattell model, roughly equivalent to GLR. Interpretation of LRNI in terms of this model should probably be restricted to the level of the WRAML Index, due to the moderate correlations of the individual subtests with GLR.

Finally, there was a high positive correlation (.87) between the most global measures from the WJTCA-R (BCA) and the WRAML (GENI). The variance in GENI accounted for by BCA was approximately 76%. Although a high positive correlation between BCA and GENI was predicted, the observed correlation is somewhat surprising and much higher than anticipated. There are overt similarities between the nine subtests representing the three WRAML Indices and the six subtests representing three of the WJTCA-R cognitive clusters. Four cognitive clusters from the WJTCA-R, however, are not represented by specific WRAML subtests or Indices, i.e., Auditory Processing, Comprehension-Knowledge, Fluid Reasoning, and Processing Speed. The WJTCA-R is, after all, an intelligence battery purported to measure a broad range of intellectual ability, whereas, the WRAML is designed to sample behaviors from the more circumscribed domain of memory functioning. Given that the WRAML appears to coincide with approximately one-third of the domain sampled by the WJTCA-R, how can a correlation of .87 between the most global scores from the two instruments be accounted for?

A possible explanation is that the WRAML and WJTCA-R have approximately equal loadings on g, the hypothesized general intellectual factor underlying all cognitive abilities. If this were true, then a quick review of the domain sampled by the WRAML would indicate that g is much more a function of memory than previously believed. The assessment of Processing Speed, Fluid Reasoning, Comprehension-Knowledge, and Auditory Processing would be superfluous. The WRAML would be a much more efficient means of assessing intelligence than the WJTCA-R, or the WISC-III, for that matter. This explanation hardly seems likely. Countless correlational and factor analytic studies would have already established such a strong positive relationship between g and memory, if it existed.

Another possible explanation for the data is that the WJTCA-R does not sample a broad range of intellectual abilities, but is, itself, heavily loaded with memory. This explanation can be rejected out of hand. The WJTCA-R is one of the most thoroughly researched instruments on the market today. Once again, this research indicates that the WJTCA-R provides for reliable and valid measurement of seven major factors of the Gf-Gc theory (Kaufman, 1990; Reschly, 1990; Ysseldyke, 1991).

The most parsimonious explanation for the data has to do with the generalizability of the results. The children who participated in this study were solicited from a population who had received treatment for a brain tumor. Most of the children (94%) had been subjected to a neurosurgical resection of the tumor. Many had also received chemotherapy and radiation treatments. Therefore, the most reasonable explanation for the unusually high positive correlation between BCA and GENI is that the disease process, and subsequent medical intervention these children received, has impacted their memory and general intellectual functioning in similar ways.

In an attempt to test this explanation, subjects were divided into two groups, based on median length of time since diagnosis and treatment. Twenty-five subjects who were $\leq$3.2 years post diagnosis and treatment were in one group and twenty-five subjects who were $\geq$3.3 years post diagnosis were in the second group. It was hypothesized that the children who were most recently diagnosed and treated would have higher WRAML/ WJTCA-R correlations and that the children who were further out post diagnosis and treatment would have correlations closer to base levels. Data analyses for each of the original hypotheses were conducted independently for these two groups. Differences in WRAML/WJTCA-R correlations for the two groups were negligible and not in the predicted direction. Therefore, this analysis did not provide empirical support for the medical intervention explanation.

The high correlation between the WRAML and the WJTCA-R would, nevertheless, be best explained by the neurological impairment of subjects in the study.

This is not to say that the two instruments, the WRAML and WJTCA-R, do not correlate under normal conditions, but that the correlational coefficients in this study are not likely to be representative of the correlation in the unimpaired pediatric population. The results do not generalize to children who have not had similar decrements in cognitive functioning. It is interesting, nonetheless that the instruments do correlate so highly under these circumstances. The results strongly suggest future research with unimpaired pediatric populations to establish a baseline correlation between these two instruments under normal conditions.

APPENDICES

APPENDIX A

Consent Form

Cook Children's Medical Center
Psychology/neuropsychology Department

The University of North Texas- Psychology Department

Informed Consent
Concurrent Validity of the Wide Range Assessment of Memory and Learning and the Woodcock Johnson Tests of Cognitive Ability- Revised with a Neurologically Compromised Pediatric Population

This is an invitation to participate in a neuropsychology research study which is being conducted by the staff of Cook Children's Medical Center in conjunction with the Psychology Department of the University of North Texas. The following is an explanation of this research and of the rights of human research subjects:

As you know, you have had (your child has had) neurosurgery. Neurosurgery can and often does result in changes in cognitive functioning, e.g., memory, problem solving, auditory processing, etc. The purpose of neuropsychological assessment is to document patterns of cognitive functioning. Following neurosurgery, cognitive strengths and abilities that have been spared can be identified. In addition, the nature of cognitive deficits, if any, can be determined. Recommendations can then be made regarding accommodations that might be necessary at school or at home. However, the relationships between neuropsychological tests and cognitive abilities must be established through research.

The Research

1. Procedures

You (Your child) will be administered the Wide Range Assessment of Memory and Learning, the Woodcock Johnson Tests of Cognitive Ability- Revised, and other standard neuropsychological tests as deemed appropriate. Testing will last approximately three hours. In addition, your (your child's) performance will be correlated with your (his/her) existing Magnetic Resonance Imaging (MRI) data. The research study will be supervised by a Licensed Psychologist, Marsha Gabriel, Ph.D.

2. Research goals

This study seeks to establish the relationship between an older, more established neuropsychological instrument, the Woodcock Johnson Tests of Cognitive Ability- Revised, with a newer, less established instrument, the Wide Range Assessment of Memory and Learning.

Risks

The primary risk of participation in this research involves possible psychological consequences of the identification of irreversible cognitive deficits. Recommendations will be made to address any deficits that are revealed, including, for example, accommodations that should be made at your (your child's) school. In addition, a referral for counseling will be made, as necessary, to resolve psychological consequences. However, no funds are available for compensation for research-related consequences and payment for counseling will be your responsibility. Your (Your child's) participation in this research study will not involve any other reasonably foreseeable risks or discomfort.

Benefits

The primary benefit of participation in this research study is that you will receive a report and recommendations regarding your (your child's) neuropsychological performance. This valuable information will be provided to you at no cost. The information may be useful to your (your child's) school in making accommodations so that you (he/she) will receive the maximum benefit from participation in an academic environment.

An additional possible benefit of participation in this research is the psychological satisfaction of contributing to scientific knowledge that will very likely benefit patients who have neurosurgery in the future.

Confidentiality

As you have a right to expect, your (your child's) records as they pertain to this research will be treated with the strict confidentiality required by law and ethical considerations. No information that can be identified with you (your child) will be released to anyone other than the physicians and staff at Cook-Fort Worth Children's Medical Center and University of North Texas investigators. The results of this study may be published in scientific journals without identifying you (your child) by name.

Contact Persons

You may contact the following individuals for further information regarding psychological aspects of this research:

Cook Children's Medical Center

Name: Gary Rochelle, M.S., L.P.A., PRN Staff, Psychology/Neuropsychology Department
Marsha Gabriel, Ph. D., Director, Psychology/Neuropsychology Department
Telephone: (817) 885-1480 or 885-1481

The University of North Texas

Name: Ernest Harrell, Ph. D., Psychology Department, The University of North Texas
Telephone: (940) 565-2671

You may contact the following individual for information regarding your child's rights as a research subject:

Name: Larry Tubb (or current IRB Chairperson)
Institutional Review Board
Cook Children's Medical Center
Telephone: (817) 885-4341

VOLUNTARY PARTICIPATION

Participation in this research is voluntary. You are free to decline to participate without fear that your refusal will in any way compromise your (your child's) medical care. In addition, should you choose (allow your child) to participate now, you will continue to have the right to withdraw your consent at any time in the future. Even if you choose not to participate in the research project or to withdraw consent at any time, you can choose to continue with the evaluation and receive feedback regarding your (your child's) performance without charge.

I ACKNOWLEDGE THAT I UNDERSTAND THAT MY PARTICIPATION IN THIS RESEARCH STUDY IS VOLUNTARY. MY SIGNATURE BELOW INDICATES THAT I HAVE DECIDED TO PARTICIPATE, HAVING READ (OR BEEN READ) THE INFORMATION PROVIDED ABOVE AND THAT I HAVE RECEIVED A COPY OF THIS INFORMED CONSENT.

______________________________ ________________________

Signature of Parent or Legally Authorized Representative | Signature of Patient (Optional)

______________________________ ________________________

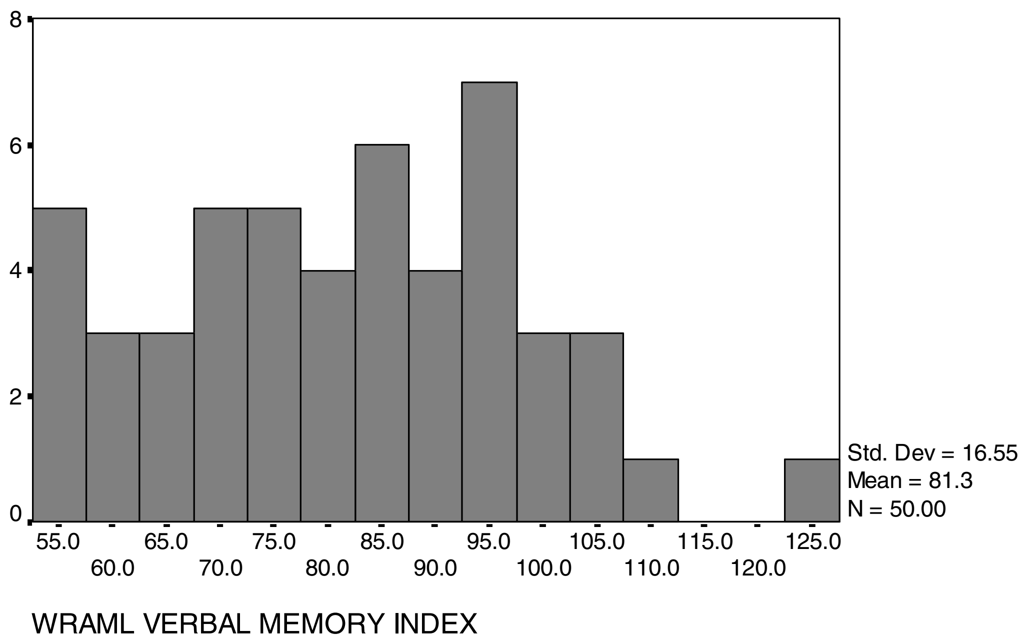
Relationship to Patient | Date Time

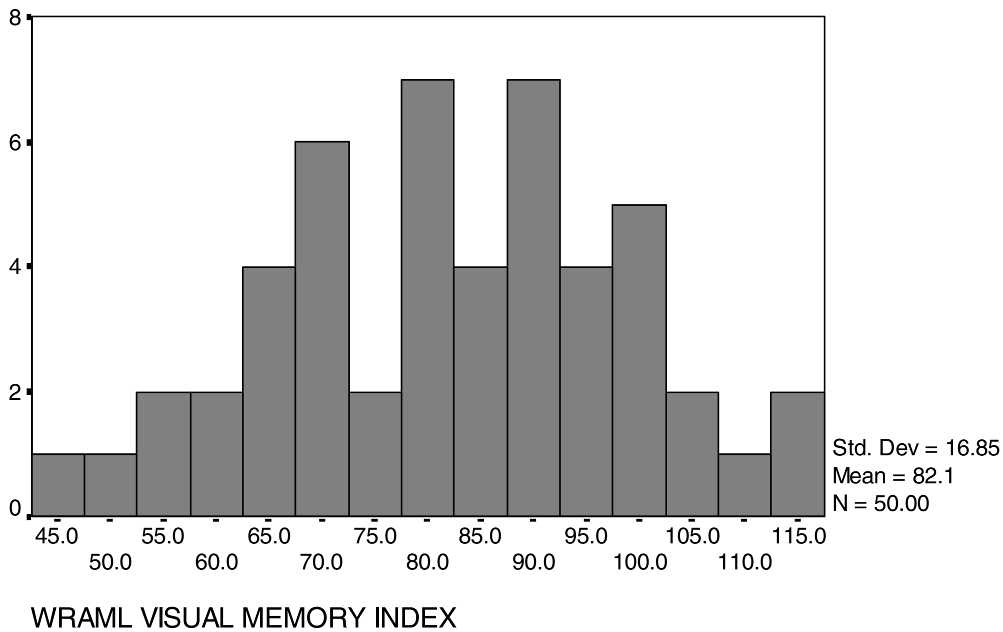
______________________________ ________________________

Investigator | Witness

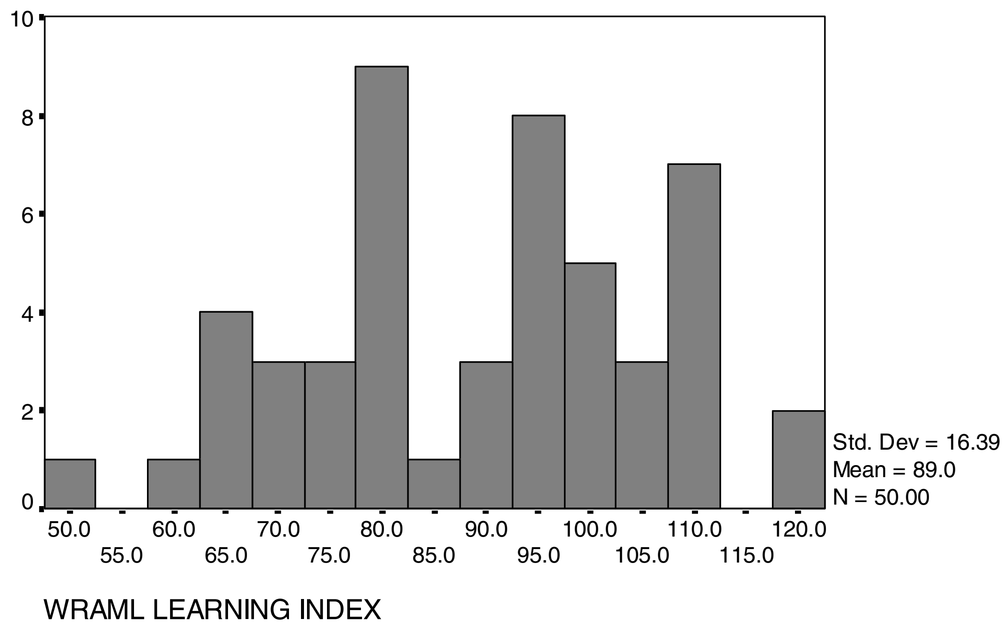
APPENDIX B

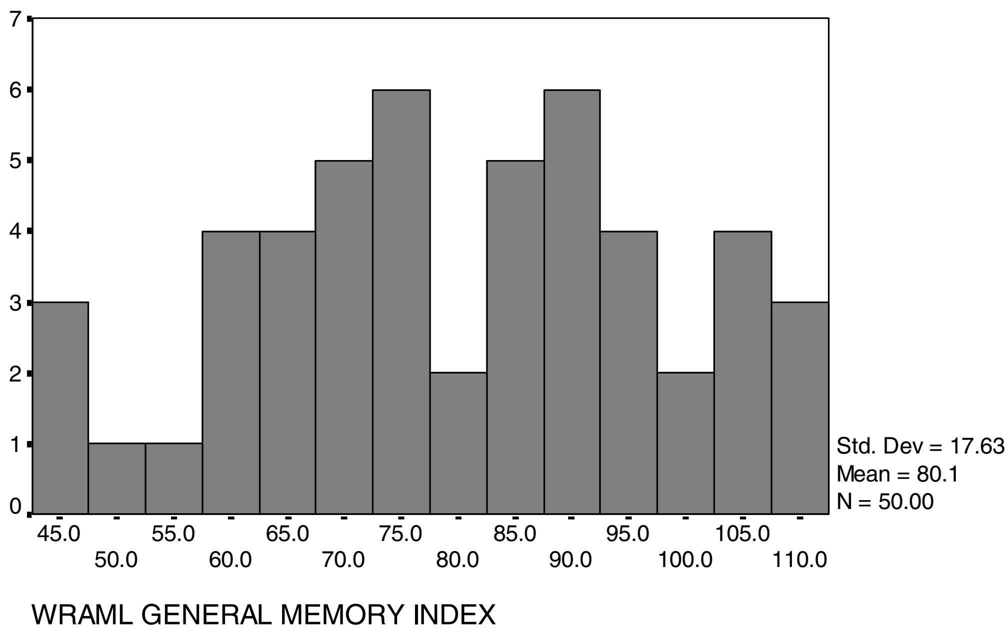
Histograms of WRAML Indices


8
6
4
2
0
Std. Dev = 16.55
Mean = 81.3
N = 50.00
55.0
60.0
65.0
70.0
75.0
80.0
85.0
90.0
95.0
100.0
105.0
110.0
115.0
120.0
125.0
WRAML VERBAL MEMORY INDEX



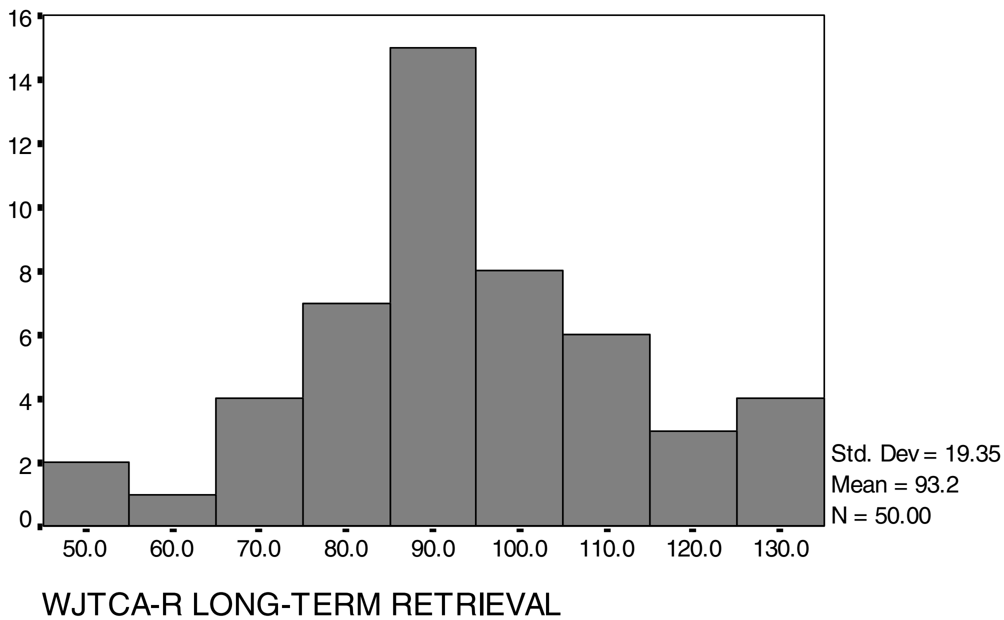
8
6
4
2
0
Std. Dev = 16.85
Mean = 82.1
N = 50.00
45.0
50.0
55.0
60.0
65.0
70.0
75.0
80.0
85.0
90.0
95.0
100.0
105.0
110.0
115.0
WRAML VISUAL MEMORY INDEX

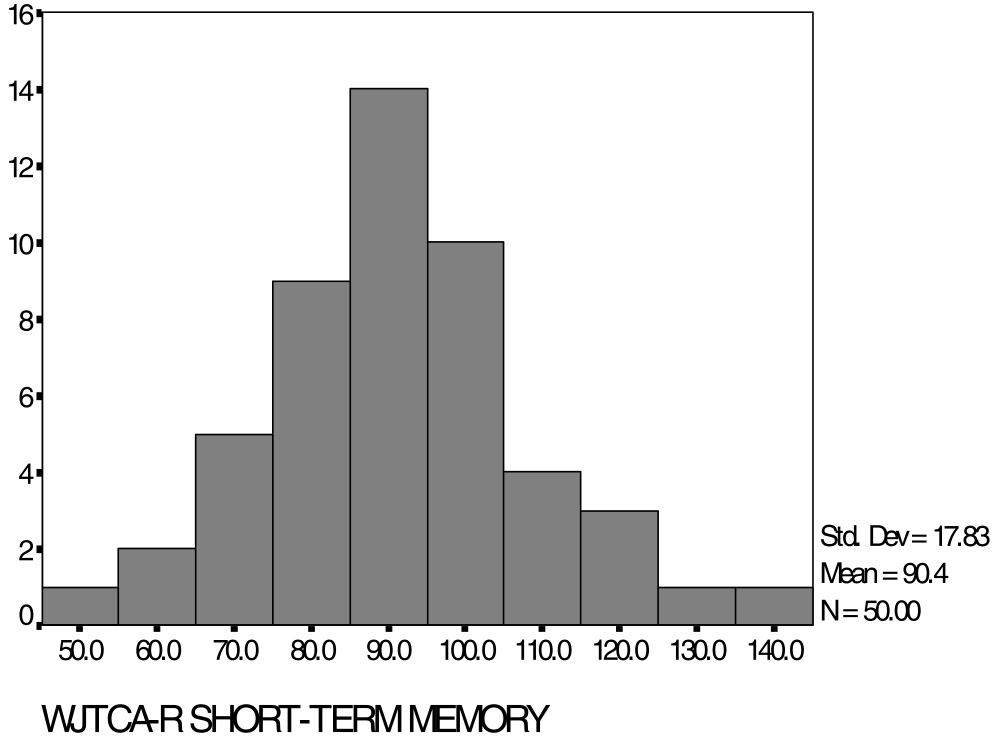

10
8
6
4
2
0
Std. Dev = 16.39
Mean = 89.0
N = 50.00
50.0
55.0
60.0
65.0
70.0
75.0
80.0
85.0
90.0
95.0
100.0
105.0
110.0
115.0
120.0
WRAML LEARNING INDEX

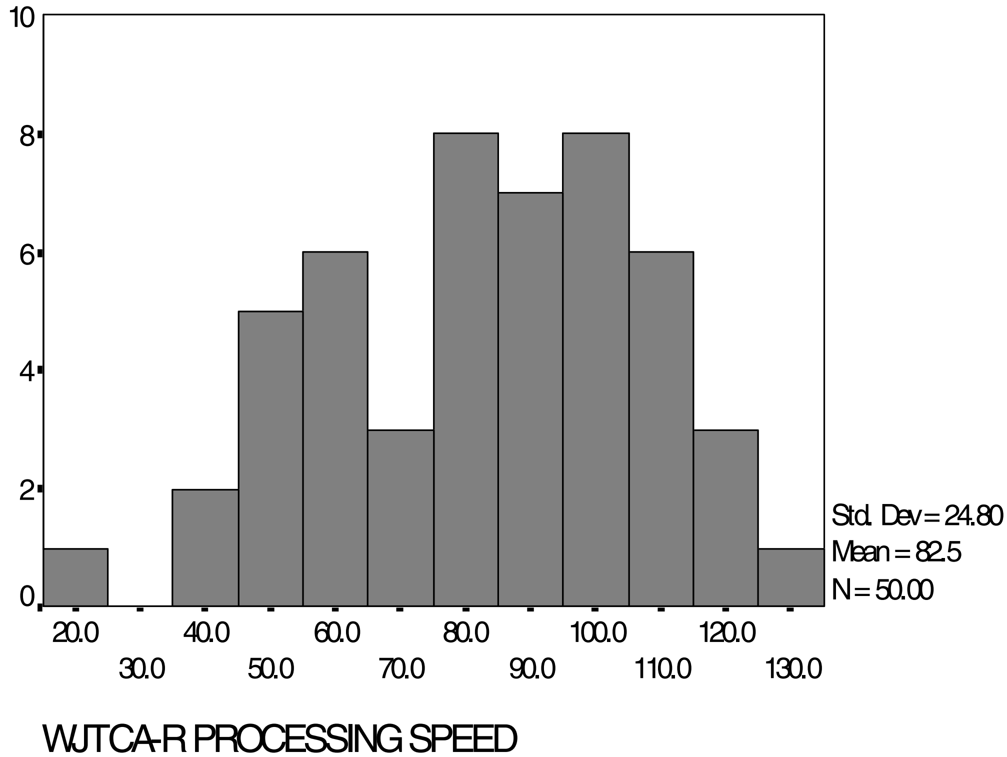

7
6
5
4
3
2
1
0
45.0
50.0
55.0
60.0
65.0
70.0
75.0
80.0
85.0
90.0
95.0
100.0
105.0
110.0
Std. Dev = 17.63
Mean = 80.1
N = 50.00
WRAML GENERAL MEMORY INDEX

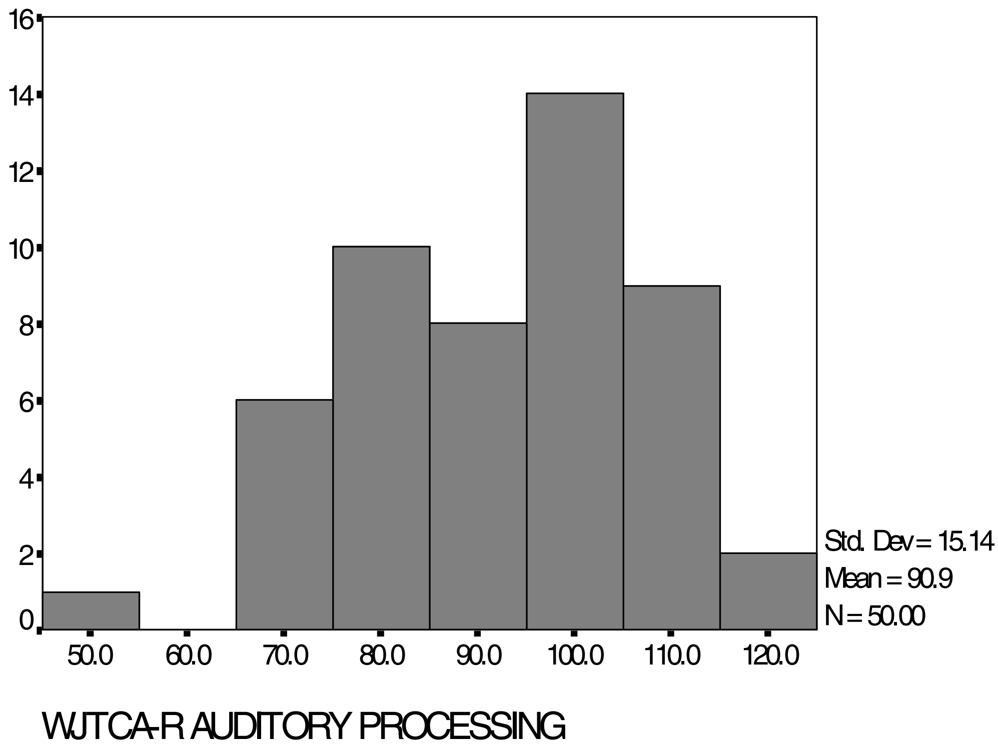
APPENDIX C

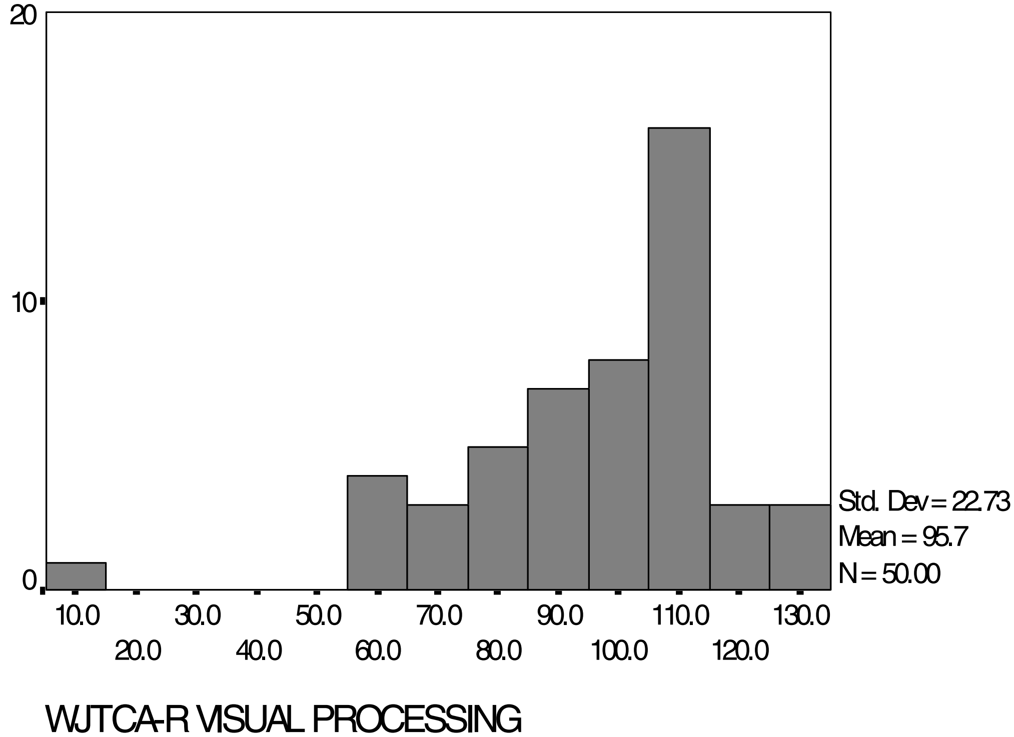
Histograms of WJTCA-R Standard Scores

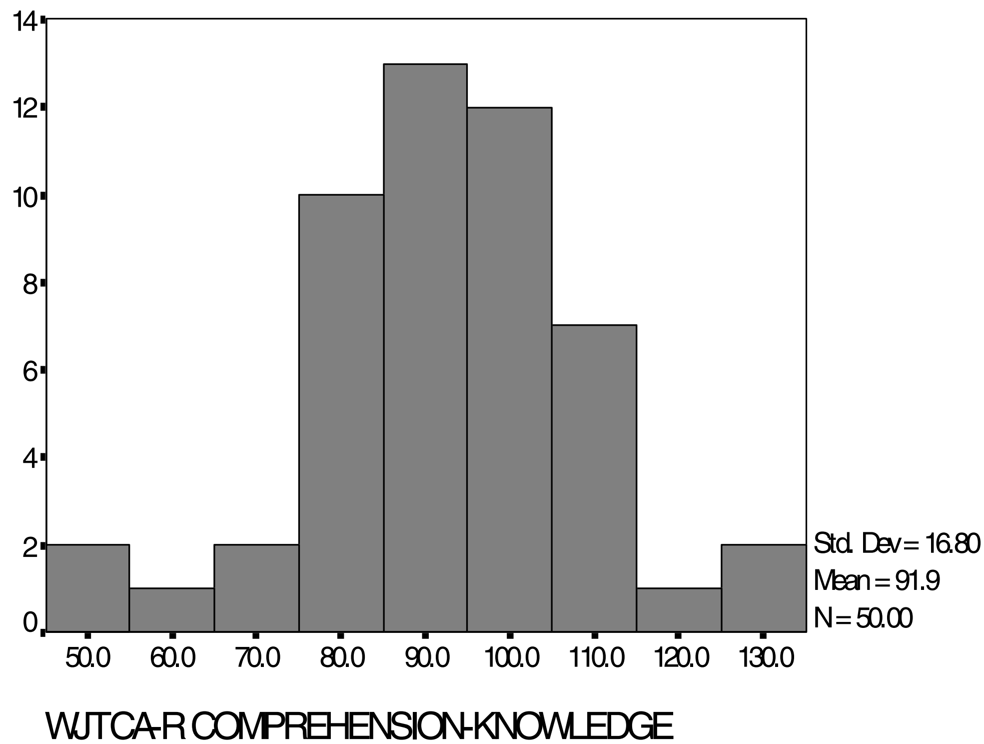

16
14
12
10
8
6
4
2
0
50.0
60.0
70.0
80.0
90.0
100.0
110.0
120.0
130.0
Std. Dev = 19.35
Mean = 93.2
N = 50.00
WJTCA-R LONG-TERM RETRIEVAL

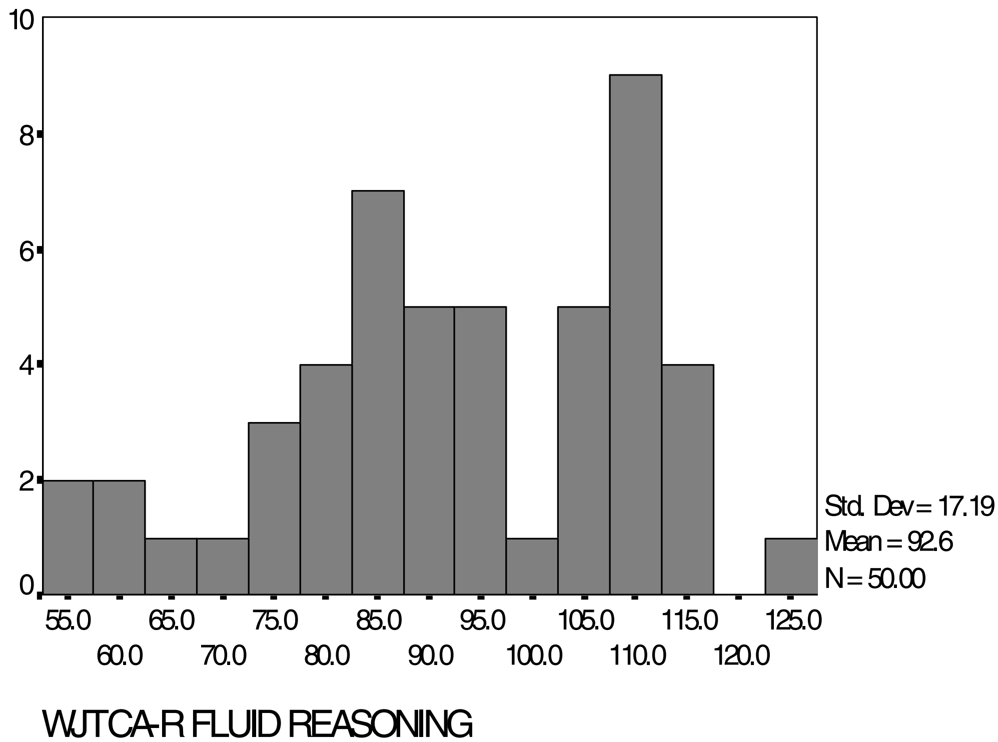

16
14
12
10
8
6
4
2
0
50.0
60.0
70.0
80.0
90.0
100.0
110.0
120.0
130.0
140.0
Std. Dev = 17.83
Mean = 90.4
N = 50.00
WJTCA-R SHORT-TERM MEMORY

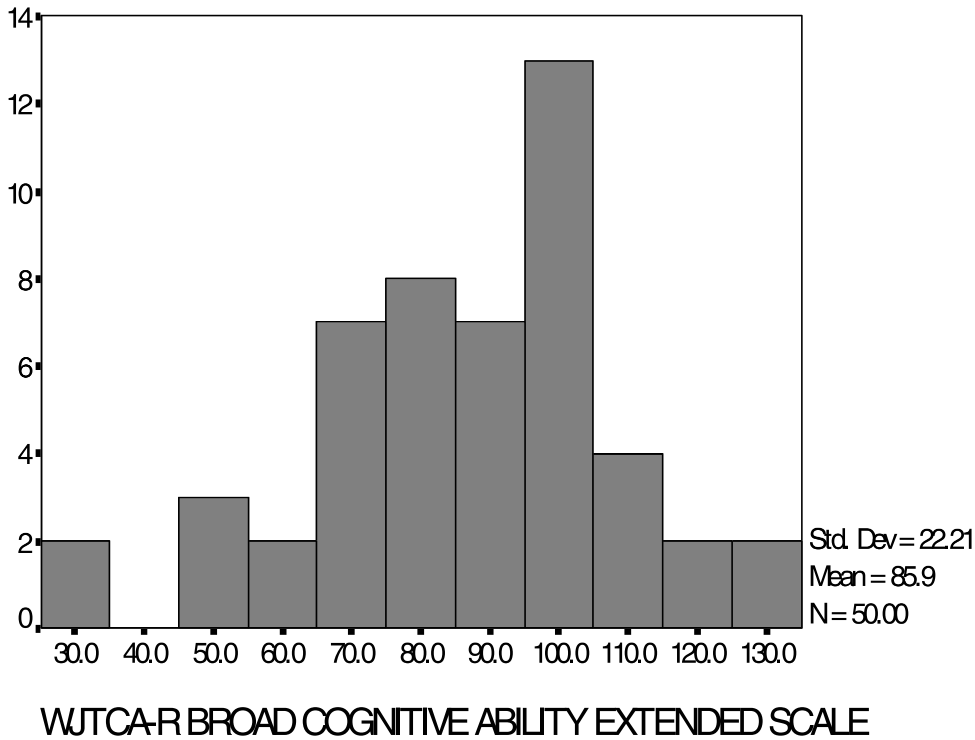

10
8
6
4
2
0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
110.0
120.0
130.0
Std. Dev = 24.80
Mean = 82.5
N = 50.00
WJTCA-R PROCESSING SPEED


16
14
12
10
8
6
4
2
0
50.0
60.0
70.0
80.0
90.0
100.0
110.0
120.0
Std. Dev = 15.14
Mean = 90.9
N = 50.00
WJTCA-R AUDITORY PROCESSING


20
10
0
Std. Dev = 22.73
Mean = 95.7
N = 50.00
10.0
30.0
50.0
70.0
90.0
110.0
130.0
20.0
40.0
60.0
80.0
100.0
120.0
WJTCA-R VISUAL PROCESSING

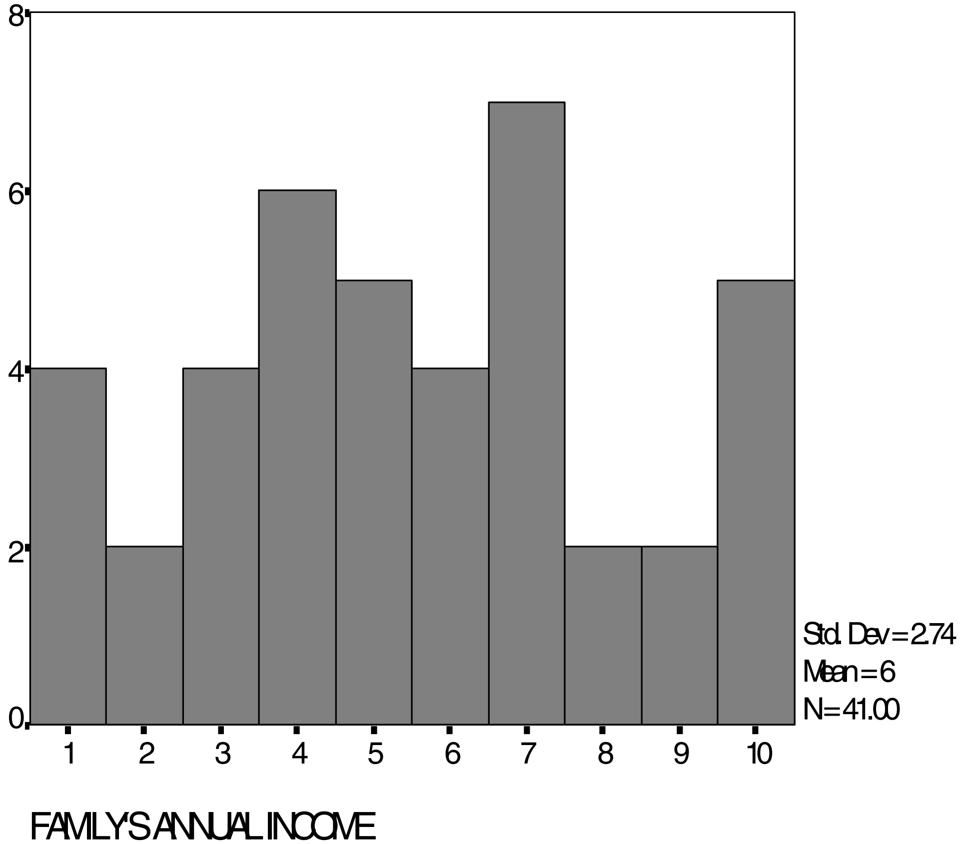

14
12
10
8
6
4
2
0
50.0
60.0
70.0
80.0
90.0
100.0
110.0
120.0
130.0
WJTCA-R COMPREHENSION-KNOWLEDGE
Std. Dev = 16.80
Mean = 91.9
N = 50.00


10
8
6
4
2
0
Std. Dev = 17.19
Mean = 92.6
N = 50.00
55.0
60.0
65.0
70.0
75.0
80.0
85.0
90.0
95.0
100.0
105.0
110.0
115.0
120.0
125.0
WJTCA-R FLUID REASONING


14
12
10
8
6
4
2
0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
110.0
120.0
130.0
Std. Dev = 22.21
Mean = 85.9
N = 50.00
WJTCA-R BROAD COGNITIVE ABILITY EXTENDED SCALE

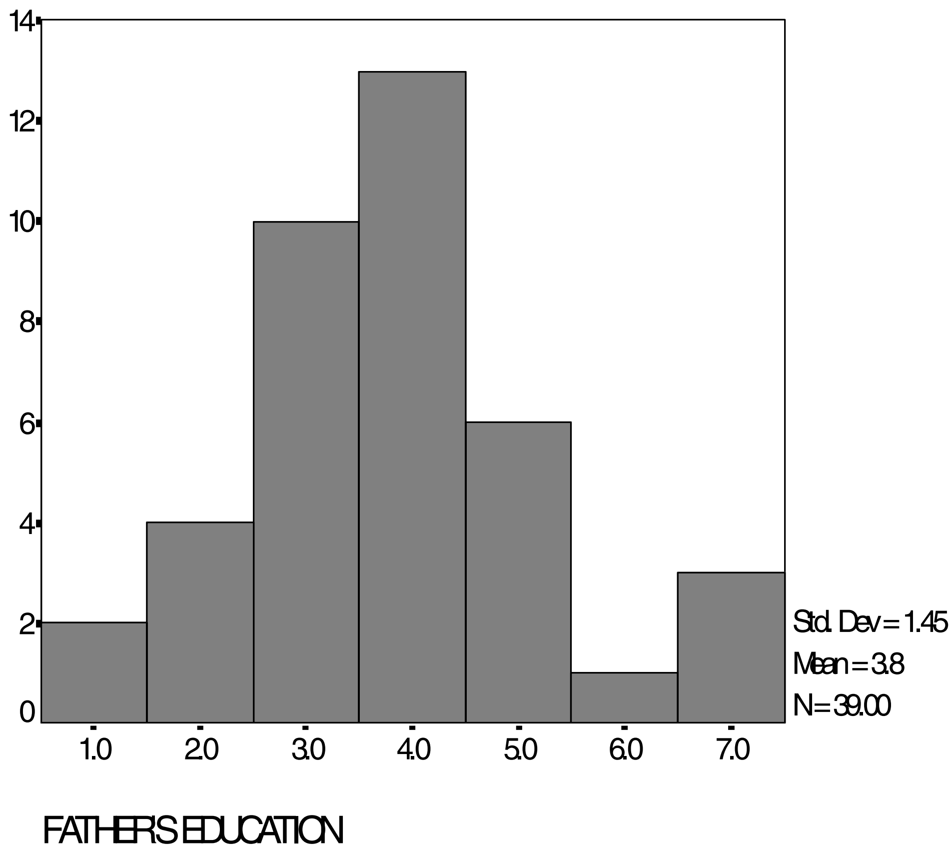
APPENDIX D

Histograms of Demographic Variables



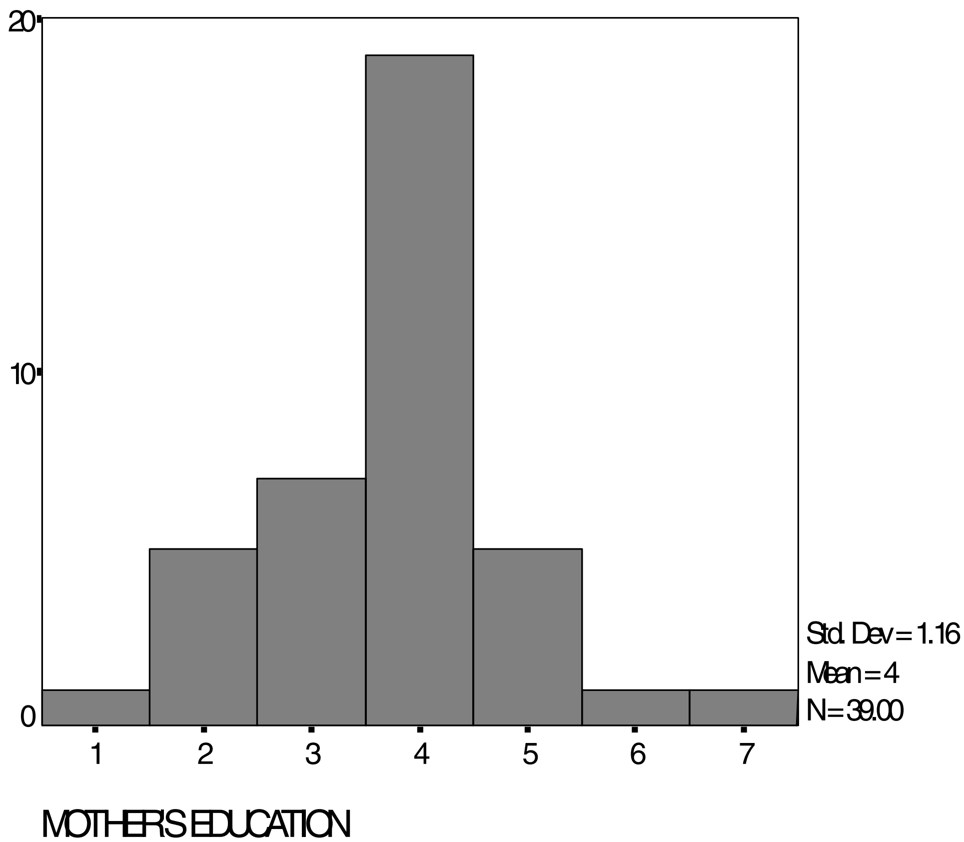
Le
ge
nd
1
=

$0 - $9,999
2 = $10,000 - $19,999
3 = $20,000 - $29,999
4 = $30,000 - $39,999
5 = $40,000 - $49,999
6 = $50,000 - $59,999
7 = $60,000 - $69,999
8 = $70,000 - $79,999
9 = $80,000 - $89,999
10 = $90,000 or more



Le
ge
nd

1 = Grade School
2 = Some High School
3 = High School/ GED Diploma
4 = Some College/Trade School
5 = Four Year College Degree
6 = Some Graduate School
7 = Graduate Degree



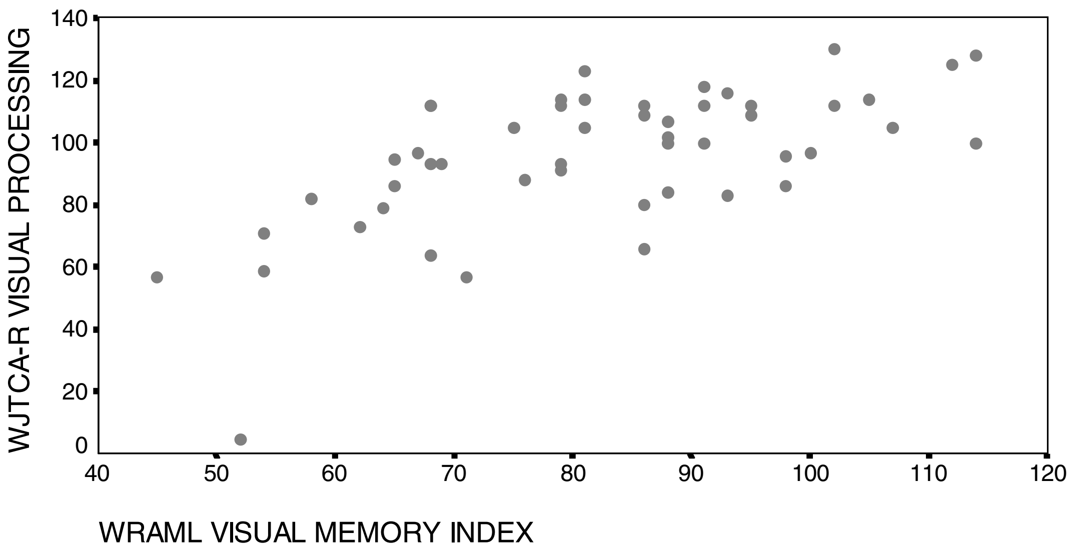
Legend
1 = Grade School
2 = Some High School
3 = High School/ GED Diploma
4 = Some College/Trade School
5 = Four Year College Degree
6 = Some Graduate School
7 = Graduate Degree

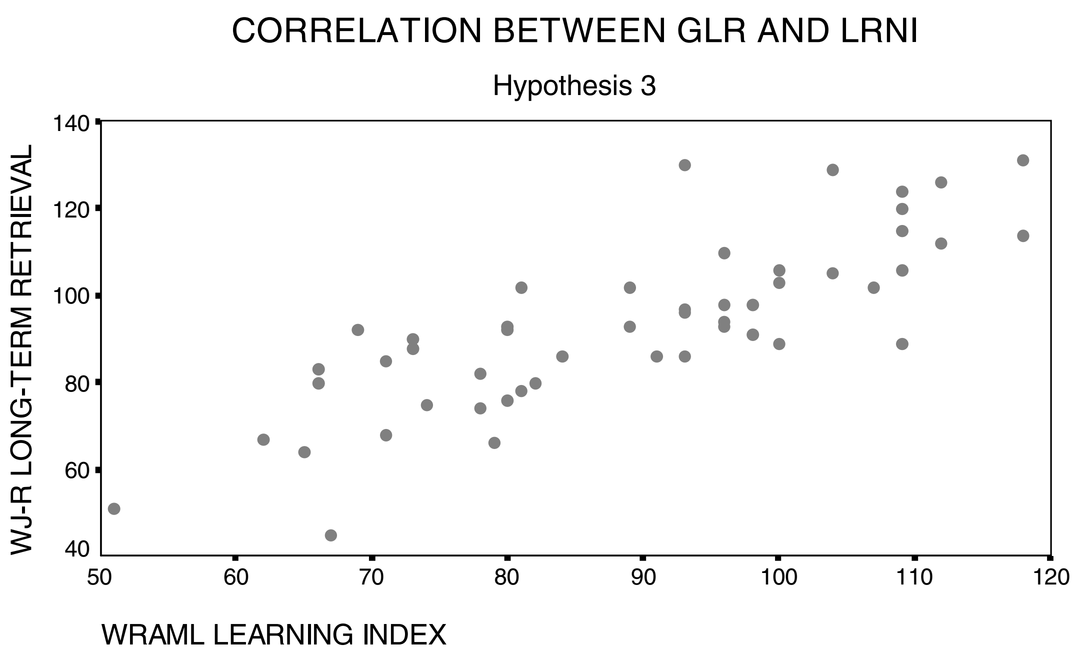
APPENDIX E

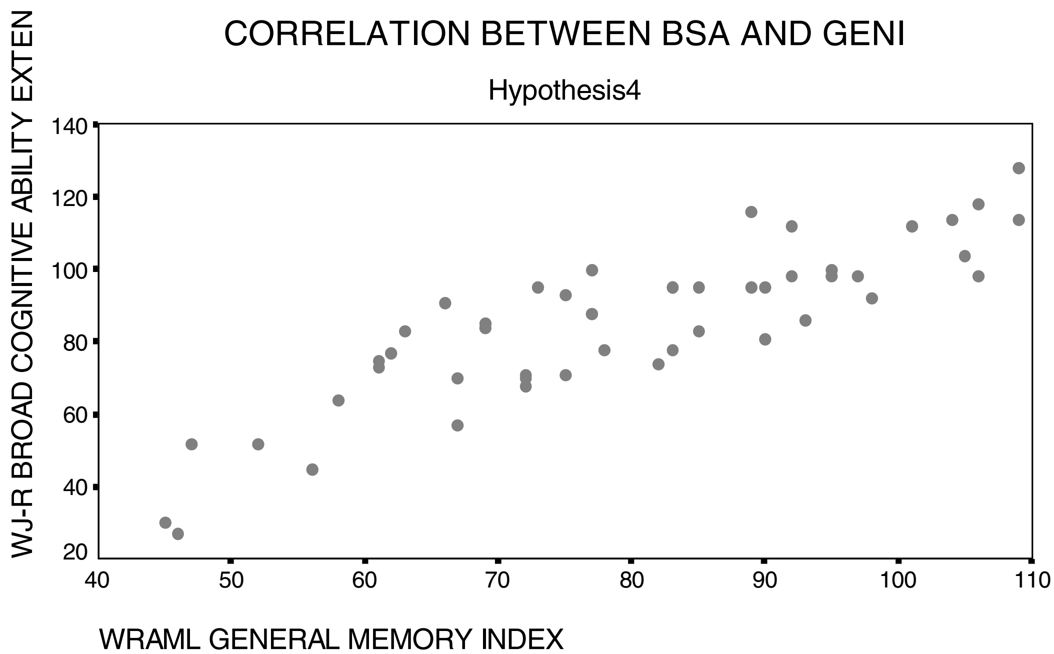
Scatterplots for Hypotheses 1-4

CORRELATION BETWEEN GV AND VISI

Hypothesis 2




CORRELATION BETWEEN GLR AND LRNI
Hypothesis 3
WJ-R LONG-TERM RETRIEVAL
140
120
100
80
60
40
50
60
70
80
90
100
110
120
WRAML LEARNING INDEX


CORRELATION BETWEEN BSA AND GENI
Hypothesis4
WJ-R BROAD COGNITIVE ABILITY EXTEN
140
120
100
80
60
40
20
40
50
60
70
80
90
100
110
WRAML GENERAL MEMORY INDEX

APPENDIX F

Correlation Matrix for WJTCA-R and WRAML Subtests

Appendix F

WJTCA-R and WRAML Subtest Abbreviations Used

WJTCA-R Subtests	WRAML Subtests
Memory for Names (WJMN)	Story Memory (WRST)
Memory for Sentences (WJMS)	Sentence Memory (WRSE)
Visual Matching (WJVM)	Number-Letter Memory (WRNL)
Incomplete Words (WJIW)	Picture Memory (WRPM)
Visual Closure (WJVC)	Design Memory (WRDM)
Picture Vocabulary (WJPV)	Finger Windows (WRFW)
Analysis-Synthesis (WJAS)	Verbal Learning (WRVE)
Visual-Auditory Learning (WJVL)	Sound-Symbol (WRSS)
Memory for Words (WJMW)	Visual Learning (WRVL)
Cross Out (WJCO)	
Sound Blending (WJSB)	
Picture Recognition (WJPR)	
Oral Vocabulary (WJOV)	
Concept Formation (WJCF)	

Appendix F (Cont.)

Correlation Matrix for WJTCA-R and WRAML Subtests

	WJMN	WJMS	WJVM	WJIW	WJVC	WJPV
WJMN	1.000					
WJMS	.4803	1.000				
WJVM	.4641	.6055	1.000			
WJIW	.6211	.5311	.4438	1.000		
WJVC	.5537	.3929	.4929	.4616	1.000	
WJPV	.5093	.5856	.4693	.5462	.5579	1.000
WJAS	.5471	.5502	.2914*	.4103	.2197*	.4397
WJVL	.6452	.7114	.6070	.4466	.6258	.5431
WJMW	.4346	.7405	.4335	.6074	.3503*	.3951
WJCO	.4665	.6372	.8627	.4716	.5349	.4530
WJSB	.3735	.5486	.5087	.5058	.4057	.4718
WJPR	.5243	.5773	.4763	.2752*	.4323	.4379
WJOV	.4898	.7157	.5911	.6432	.4305	.7244
WJCF	.4448	.7357	.5364	.3631*	.4582	.5806
WRST	.4805	.5823	.3659	.5087	.2737*	.6396
WRSE	.5112	.8484	.4029	.6386	.3823	.6264
WRNL	.3486*	.6528	.4090	.4888	.3326*	.4803
WRPM	.2629*	.2082*	.1736*	.2948*	.2286*	.1928*

* Correlations not statistically significant at p< .01

Appendix F (Cont.)

Correlation Matrix for WJTCA-R and WRAML Subtests

	WJMN	WJMS	WJVM	WJIW	WJVC	WJPV
WRDM	.3615*	.4903	.5384	.1742*	.5102	.3438*
WRFW	.4713	.6044	.7308	.4489	.5176	.4213
WRVE	.5138	.6422	.6200	.3784	.3908	.5019
WRSS	.5001	.5250	.3474*	.3476*	.2976*	.4713
WRVL	.5623	.2684*	.2885*	.2244*	.2860*	.2085*

* Correlations not statistically significant at p< .01

Appendix F (Cont.)

Correlation Matrix for WJTCA-R and WRAML Subtests

	WJAS	WJVL	WJMW	WJCO	WJSB	WJPR
WJAS	1.000					
WJVL	.5838	1.000				
WJMW	.4439	.5300	1.000			
WJCO	.3184*	.5578	.5026	1.000		
WJSB	.4461	.4982	.4635	.4845	1.000	
WJPR	.4426	.6595	.3886	.5168	.3802	1.000
WJOV	.4876	.6551	.5838	.5622	.5987	.3689
WJCF	.6162	.7167	.6248	.5264	.5444	.5370
WRST	.4765	.4941	.4010	.3813	.2328*	.4232
WRSE	.6047	.6644	.7401	.4622	.5204	.4300
WRNL	.3846	.5188	.6892	.4918	.5542	.3475*
WRPM	.2295*	.3154*	.1775*	.1167*	.2001*	.1188*
WRDM	.3155*	.6638	.2829*	.4064	.2732*	.4923
WRFW	.3251*	.6845	.5013	.7086	.3483*	.4269
WRVE	.4462	.6771	.5758	.5996	.4425	.5811
WRSS	.5138	.7562	.4117	.3036*	.4353	.4713
WRVL	.2735*	.5371	.2328*	.3290*	.0634*	.4245

* Correlations not statistically significant at $p < .01$

Appendix F (Cont.)

Correlation Matrix for WJTCA-R and WRAML Subtests

	WJOV	WJCF	WJST	WJSE	WJNL	WJPM
WJOV	1.000					
WJCF	.6887	1.000				
WRST	.4736	.4005	1.000			
WRSE	.7531	.6727	.6036	1.000		
WRNL	.6522	.5548	.3756	.7191	1.000	
WRPM	.2066*	.2248*	.3469*	.2616*	.2171*	1.000
WRDM	.4111	.4337	.3833	.3184*	.2879*	.2634*
WRFW	.5718	.6155	.3478*	.4729	.5116	.2688*
WRVE	.5891	.6422	.5418	.5812	.5367	.3370*
WRSS	.5955	.5712	.4308	.6049	.5885	.0709*
WRVL	.1962*	.3144*	.4149	.1908*	.1813*	.3800

* Correlations not statistically significant at p< .01

Correlation Matrix for WJTCA-R and WRAML Subtests (Cont.)

	WJDM	WJFW	WJVE	WJSS
WJDM	1.000			
WRFW	.4855	1.000		
WRVE	.5547	.5253	1.000	
WRSS	.3445*	.4099	.5547	1.000
WRVL	.4061	.3446*	.4829	.3508*

* Correlations not statistically significant at p< .01

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