THE UTILITY OF THE MCCARRON-DIAL SYSTEM IN
DETERMINING LOCATION OF BRAIN LESION

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Among the goals of neuropsychological assessment are to detect the presence of brain damage, localize which areas of the brain may be dysfunctional, and describe subsequent functional impairments. The sensitivity of neuropsychological instruments in carrying out these functions has long been a question of debate. The purpose of the present study was to determine the utility of various performance level indictors and lateralizing indicators from the McCarron-Dial System Neuropsychological Assessment Battery (MDS) in ascertaining the presence or absence of brain damage as well as location of lesion. Models used in the present study appear to provide increased classification accuracy compared to other studies utilizing the MDS. The MDS was also shown to be comparable to other well-known neuropsychological batteries, including the Halstead-Reitan Neuropsychological Test Battery (HRB) and the Luria-Nebraska Neuropsychological Battery (LNNB) with regard to distinguishing between those with brain damage and normal controls, and also localizing brain lesion. The results of this study offer clinicians parsimonious models to evaluate for presence of lesion and its location so this information may be used to make accurate, thorough diagnoses and appropriate treatment and rehabilitation recommendations.
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CHAPTER 1

INTRODUCTION

Purpose of Neuropsychological Testing

The traditional goals of neuropsychological assessment are to detect the presence or absence of brain damage; when present, to determine whether a given lesion is lateralized or diffuse, and to further localize which areas of the brain may be impaired. Most importantly, the goal also is to describe the functional behavioral deficits associated with specific brain impairment. More recently, other goals have emerged to include identifying mild or pre-clinical brain damage or dysfunction not otherwise diagnosed by radiologic or other medical tests. Neuropsychologists, physicians, and rehabilitation specialists have found the results from neuropsychological assessments extremely useful in formulating treatment and rehabilitation plans (Kolb & Wishaw, 1996). Definitions of terms used within this paper may be found in Appendix A.

The chief contribution of the neuropsychological assessment, in contrast to traditional neurological and radiological procedures such as magnetic resonance imaging (MRI) and computerized tomography (CT) scans, is the provision of descriptive behavioral information regarding the person’s lesion (Reitan & Wolfson, 1996). However, the determination of the presence of brain dysfunction and the nature and location of the lesion continues to be an essential goal in the interpretation of neuropsychological data because this information provides the “key” to understanding the behavioral consequences of the brain lesion. The original pathology of the brain insult often is the basis for chronic brain dysfunction that will have substantial consequence on
the recovery and eventual outcome of a person who has sustained brain damage (Bigler, 1990). Also, neuropsychological evaluation allows variables beyond test scores and medical diagnostic data to be observed and considered in the rehabilitation plan. Such variables include motivation, cooperativeness, emotional-coping skills, and psychosocial resources (Cullum, Kuck, & Ruff, 1990). All neuropsychological assessment batteries also share the common task of detecting and describing deficits in language function, verbal and non-verbal memory, learning, attention and concentration, reasoning and abstraction ability, perception and sensorimotor functions, and emotional coping (Dial et al., 1990; Umile, Plotkin, & Sandel, 1998; Hartlage, 2001). In order to understand how neuropsychological assessment attempts to reach all of these goals, it is helpful to review the basic approaches to neuropsychological testing, a brief history of neuropsychological assessment, and theories of lateralization in persons with brain damage and normal individuals.

Clinical vs. Battery Approach

Within neuropsychological assessment, there are two approaches to evaluation: the clinical approach and the battery approach. The clinical approach advocates the selection of assessments based upon the patient’s chief complaint, previous history, concerns of the referring clinician, and the evaluating clinician’s own observations and interactions with the patient (Dial et al., 1990). By using such an approach, the clinician may create a flexible battery tailored to the specific problems and suspected etiology of each patient (Kolb & Wishaw, 1996; Hartlage, 2001). Decisions about which tests to include in an evaluation may also be based upon test performance during the evaluation.
itself. In essence, the battery may be modified as needed within a single evaluation and make use of the wide array of neuropsychological tests currently available (Cullum, Kuck, & Ruff, 1990). The flexible battery may also be adapted for time constraints and physical conditions of the patient.

Conversely, supporters of the battery approach choose to administer a standardized, broad-spectrum battery of tests and integrate those results with the patient’s personal, medical, and educational history (Dial et al., 1990). Such a battery is administered in all neuropsychological evaluations regardless of the specific primary complaint or referral question (Cullum, Kuck, & Ruff, 1990). This approach presumes that anomalous brain configuration and/or composition is responsible for abnormal behavior, and irregular behavior implies brain pathology (Dial et al., 1990). A fixed battery of standardized tests provides more data on a wider range of cognitive functions (Cullum, Cuck, & Ruff, 1990; Stuss & Levine, 2002). This approach also allows for comparison across patients, as each person has been given the same tests. The effectiveness of a particular battery is dependent upon how well a person’s performance on the tests relates to changes in brain functioning and how well information gleaned from a patient’s test performance can be translated into a treatment plan (Leahy & Lam, 1998).

There are advantages and caveats to each approach. By using a standardized battery, the evaluator is assured of using a comprehensive battery in which all tests within that battery have been normed on the same group of people. However, many clinicians complain that these tests are too broad in some areas, and may subject the patient to
excessive testing in certain areas not believed to be involved in the particular patient’s problem. These batteries may also lack a means of testing certain areas in a more in-depth manner, making it difficult for the clinician to accurately and thoroughly describe a person’s relative deficits and strengths (Halperin & McKay, 1998). In these cases, the neuropsychologist may prefer to “hand select” an array of tests targeting processes which are of interest to the clinician and which are of concern to the referring party. Some neuropsychological assessment batteries, such as the McCarron–Dial Evaluation System (MDS), make available a core battery and allow for a flexibility of approach while providing a standardized set of norms for all tests within the system. This approach has been referred to as a “mixed battery” in that a standard core of tests is administered along with additional measures selected on the basis of the referral question (Cullum, Kuck, & Ruff, 1990).

History of Neuropsychological Testing

The original objective of psychological testing in neurological diagnosis was to detect deficits that were not apparent during basic mental status interviews (Hartlage, 2001). The diagnostic technology, such as CT, MRI, and positron emission tomography (PET), used to detect the presence of brain lesions has been available only relatively recently. Also, quantitative electroencephalography (QEEG), a growing alternative to the standard electroencephalography (EEG) used by neurologists, was developed by physiologists and neuropsychologists to evaluate brain dysfunction (Cantor, 1999). Prior to the development of these technologies, the most sensitive measure of brain functioning available was behavioral observation (Kolb & Wishaw, 1996; Bigler, Lowry, & Porter,
1997). During the early part of the 20th century, efforts to create standardized methods of observing and measuring behavior intensified. Interest in developing a standardized means of comparing a particular patient’s behavioral pattern to other brain injured patients, as well as the non-brain-injured, increased. Thus, the field of neuropsychological assessment was born.

The early years of the field of neuropsychological assessment were characterized by a focus on developing a single test that would be capable of diagnosing brain damage. In the mid-1930s, Dr. Ward Halstead’s approach differed in that he observed brain-damaged patients in their everyday life situations and tried to determine which facets of the patients’ behavior differed from the behavior of non-brain injured individuals (Reitan & Wolfson, 1996). From these observations, Halstead and his colleagues concluded that it is impossible to adequately and accurately identify brain damage and subsequent functional deficits using a single test (Kolb & Wishaw, 1996). It would be necessary to develop a battery of tests to achieve this goal, as well as the goal of providing information relevant for developing a treatment plan. Although technology is now better able to pinpoint location of brain lesions, neuropsychology has not lost its foothold in the area of brain injury diagnosis and treatment. There is still a strong need for evaluation techniques that are capable of providing information about a person’s functional strengths and weaknesses (Bigler, Lowry, & Porter, 1997). Given that neuropsychologists, more so than psychologists and other mental health professionals, are more frequently in interdisciplinary relationships with and communication with professionals such as neurologists, neurosurgeons, and rehabilitation specialists, it was necessary to create a
battery that addressed the questions and concerns of all the professionals, as well as the patient (Goldstein, 1984).

**Right Brain vs. Left Brain**

When discussing lateralization, it is important to recognize that both hemispheres are a factor in nearly every behavior; however, many important functions are primarily mediated by one or the other hemisphere (Kolb & Wishaw, 1996; Nicholls, 1996; Soper & McWhorter, 2001). The overwhelming majority of knowledge regarding specific functions of the two brain hemispheres has been obtained from studies of persons with brain injuries (Vernon, 1984; Dean, 1984; Kolb & Wishaw, 1996). It has been widely accepted that observed difficulties in language and right-sided perceptual-motor performance indicate the presence of left hemisphere damage, while problems with spatial processing and left-sided perceptual-motor abilities are pathognomonic of right-hemisphere dysfunction (Nicholls, 1996).

It has been assumed that these specialized functions are also present in persons without a history of brain injury (Vernon, 1984). The right hemisphere was once believed to be of lesser importance than the left, as it did not mediate the specialized language functions so important to everyday human life (Gall, 2001). However, research has revealed the right hemisphere to be no less important or necessary than the left hemisphere. The right hemisphere serves as the mission control center for nonverbal, holistic thinking. The right hemisphere also supplements the left hemisphere’s primary role of language functions, by encoding and decoding shades of meaning in speech through vocal tone, pitch, and speed (prosody) (Kolb & Wishaw, 1996; Nicholls, 1996).
Patients with right-hemisphere damage experience difficulty understanding jokes and sarcasm, as well as inflecting emotion into their own speech (Snow, 2000). In addition, the processing of spatial and musical information depends heavily on the right hemisphere (Ross, Thrasher, & Long, 1990). The calculation of distance between objects or parts of objects is computed in the right hemisphere (Kogure, 2001). The ability to recognize and remember complex visual patterns predominates within the right hemisphere, and this hemisphere contributes significantly to the recognition of complex patterns by touch as well as movements within spatial patterns (Gall, 2001; Kolb & Wishaw, 1996).

While the right hemisphere processes information in a holistic fashion, the left hemisphere processes information sequentially (Gall, 2001; Soper & McWhorter, 2001). The left hemisphere was once believed to be the dominant hemisphere from which all higher cognition arose. The majority of language functioning, including speech, reading and writing depends on the functional integrity of the left hemisphere, and lesions in the frontal and/or temporal lobes of this hemisphere often interfere with language production and comprehension: Verbal memory is also significantly mediated by the left hemisphere (Ross et al., 1990; Dean & Anderson, 1997). Just as the right hemisphere has a role in language functioning, the left hemisphere plays a role in processing some spatial information. Since the left hemisphere processes information in a sequential fashion, it is able to compute categorical spatial associations such as above/below and left/right (Kogure, 2001). In addition, contralateral complex voluntary movement and sensory functions are organized and mediated by the left hemisphere (Kolb & Wishaw, 1996).
is also believed that tasks requiring time-dependent qualities of movement such as catching a ball may also be managed by a specialized center within the left hemisphere (Nicholls, 1996).

Relatively recently there has been more interest in lateralized functions in normal brains. Electroencephalographic studies have demonstrated relatively greater slow brain wave activity in the right as contrasted to the left hemisphere during verbal tasks and, conversely, greater slow brain wave activity in the left hemisphere during tasks of a spatial nature (Dean, 1984). These findings imply that while one hemisphere may be idling, the opposite hemisphere is actively involved in processing the information. In a study using auditory and visual evoked potentials to assess laterality of brain function, auditory event related potentials revealed more coherence of the waves in the left hemisphere while visual event related potentials were more coherent in the right hemisphere (Nicholls, 1996). On the basis of the study, it was concluded that the left hemisphere was predominantly involved in the processing of auditory stimuli, while the right hemisphere was chiefly involved in the processing of spatial stimuli. Positron emission tomography (PET) studies have noted left parietal activation during tasks of motor attention, while right hemisphere activation was observed during tasks of visuospatial orienting attention (Rushworth, Krams, & Passingham, 2001). Thus, it seems that both hemispheres mediate general attention processes.

Anatomical correlates of lateralized functioning have also been observed. The temporal areas of the brain are specialized for language functions. Damage to the left temporal lobe of the brain results in more language deficits than damage to the right
temporal lobe. In normally developing fetuses, the left temporal lobe is slightly larger than the right temporal lobe (Vernon, 1984). Other studies have observed microanatomical and psychophysiological differences between the hemispheres as early as 30 weeks gestation (Dean & Anderson, 1997). These findings suggest that the human brain is biologically primed for lateralized functioning.

**Lateralized Brain Damage vs. Diffuse Brain Damage**

For many patients with head injury, the location of the damage is not so clear-cut. An impact to a particular area of the brain may produce functional deficits corresponding to that specific area, but may also produce *contrecoup* injury resulting in deficits associated with the opposite area of the brain (Reitan & Wolfson, 1993). Such an injury produces multiple deficits of varying degrees of severity, superimposed upon each other (Bigler, 2001). Accidents resulting in brain injuries may cause axonal shearing and stretching and subsequent microlesions across multiple areas of the neocortex and paleocortex (Bigler, 2001). The amount of axonal damage is generally proportional to the severity of the injury (Umile, Rosette, & Sandel, 1998). This type of damage frequently is undetected by radiologic tests (Reitan & Wolfson, 1996). A lesion in one area of the brain may disrupt functioning in another neuropsychological realm by disturbing pathways from one brain area to another (Stringer, 1996). Therefore, it is important that neuropsychological assessment procedures be sensitive enough to detect all types of brain damage that can affect behavior, cognition, and emotion, and that such assessment methods provide accurate and timely data that can significantly contribute to rehabilitation recommendations for the examinee.
The Use of Neuropsychological Testing in Determining the Presence of Lateralized Brain Damage

The sensitivity of neuropsychological instruments in carrying out their intended functions has been a question of some debate. Nevertheless, all standardized battery approaches and most clinical assessments incorporate a variety of inferential methods simultaneously to interpret the results of the neuropsychological assessment. These methods include levels of performance, patterns and relationships among scores, pathognomic signs, and a comparison of sensory and motor functions between the two sides of the body. In the first method, levels of performance, each patient’s test scores are compared with a set of norms and interpreted in reference to a normal distribution to determine that particular person’s performance level relative to the population. Based upon this comparison, a person’s score on each test may increase or decrease the likelihood that dysfunction exists. A person with lower scores compared to the general population norms is more likely (but not necessarily) to have an overall battery profile that suggests damage. A person with average or above average scores is less likely to (but still may) have an overall profile suggesting neuropsychological impairment (Reitan & Wolfson, 1993).

Pathognomic signs refer to certain behaviors that are characteristic of a particular condition and that can be used to make a diagnosis (Reitan & Wolfson, 1993). These signs may or may not impact the performance levels on neuropsychological tests. Examples of such left hemisphere signs include dysfunction in calculation, expressive speech, reading and right-handed tactile-integration, and anomia (Vernon, 1984).
Constructional dyspraxia, difficulty in understanding holistic relationships, and spatial disorganization are examples of right hemisphere pathognomic signs (Vernon, 1984).

While comparing a patient’s score to the norms may be helpful in identifying the presence of brain damage, the patterns and relationships among the patient’s own scores may be even more revealing. While a person’s overall profile may be within average range, certain dips and peaks among scores on different tests may suggest an abnormality in particular brain systems. Depending upon the nature of the test (spatial vs. verbal), the pattern may be indicative of right, left, or diffuse brain damage (Dial, Chan, Tunick, Gray, & Marmé, 1991).

Comparing the sensory motor functions of the two sides of the body is a relatively simple yet effective method of inferring brain damage. The individual serves as his/her own control for this comparison. Divergence in right vs. left sensorimotor functioning is compared to expected ratios, and certain deviations may suggest brain damage contralateral to the impaired side of the body (Dial & McCarron, 1986).

Comparing Wechsler Adult Intelligence Scale (WAIS) verbal and performance indices has been a popular, though often controversial, means of screening for neuropsychological deficits. It has been accepted that a significantly lower verbal intelligence (VIQ) score relative to performance intelligence (PIQ) score indicates left hemisphere damage, and a significantly lower PIQ score relative to VIQ score indicates right hemisphere damage. A meta-analysis conducted by Hawkins, Plehn, and Borgaro (2000) found that this assumption was borne out in the research. More specifically, it was observed that PIQ was more sensitive to right hemisphere damage than VIQ was to left
hemisphere lesions. While the WAIS is not a strong and precise lateralizing instrument, it is useful in drawing the clinician’s attention to potential neurological deficits that would merit further assessment (Hawkins et al., 2000).

Many neuropsychological test batteries, such as the Luria-Nebraska Neuropsychological Battery and the Halstead-Reitan Neuropsychological Test Battery (HRB) include tasks that allow the examiner to compare right-side versus left-side performance (Vernon, 1984). These comparisons include grip strength and motor speed and coordination. It is assumed that a significantly lower score on one side of the body compared to the other side indicates a lesion in the contralateral hemisphere (Heilbronner, Henry, Buck, Adams, & Fogle, 1991). However, these data are often supplemented by other methods of inference, such as patterns and relationships among scores. For example, within the HRB, a clinician would not rely on one test within the battery to determine if a lesion exists in one hemisphere or the other. A depressed score on one test of right vs. left cerebral functioning, such as Finger Tapping, is not enough to make a clear determination of lateralized dysfunction. However, a depressed right side score on Finger Tapping, Grip Strength, and impaired scores on portions of the Aphasia Test, such as Dysnomia and Spelling Dysgraphia, would likely indicate damage to the left hemisphere (Reitan & Wolfson, 1993). Some tests of the HRB, such as the Category Test and the Tactual Performance Test (Time, Memory, Localization), were designed to detect diffuse damage and low scores on these tests, combined with a pattern of scores on tests to detect focal lesions, would likely point toward diffuse or generalized brain damage (Reitan & Wolfson, 1993). However, the HRB was not designed to allow
clinicians to make predictions regarding a patient’s adaptive functioning within that person’s community (Sbordonne, 1997). Neuropsychologists are frequently asked to predict how well a person will recover from the injury and the likelihood the patient will be able to return to school, work, and other daily activities, thus a battery needs to yield results capable of answering these questions (Sbordonne, 1997).

The LNNB relies on configuring patterns of scores for interpreting the test results (Golden, 1984). Various scales within the LNNB assess right/left differences, as well as verbal vs. spatial abilities. Numerous studies have been executed examining the localization capabilities of the LNNB. Overall, the results were quite good, ranging from 87-98% accuracy in predicting location of a lateralized lesion (Golden, 1984). However, each study utilized small samples and most of the patients had relatively mild brain dysfunction.

A study by Vakil, Hoofien, and Blachstein (1992) examined brain injured patients’ learning ability on verbal, figural, and spatial tasks to see if patients with lateralized injury performed significantly better on one type of task than another. They found that participants with right hemisphere damage performed significantly better than the participants with left hemisphere damage on a verbal learning task, and the reverse was true on a spatial learning task. No significant differences were observed on performance on the figural learning task, and the researchers hypothesized that this was because the task used visually and verbally coded stimuli (Vakil et al., 1992).
The Need for Additional Neuropsychological Test Batteries

The number of neuropsychological measures available to clinicians has grown as the field of neuropsychology itself has grown (Sweet, 1991). The HRB is the first known complete battery to be developed. The LNNB made its appearance as a clinical instrument in 1979, and is the second most frequently used battery (Sweet, 1991). Other measures have evolved to compensate for the weaknesses in both of these batteries, such as complex reasoning and sustained attention with the LNNB, and language and academic skills in the HRB (Sweet, 1991). Some measures, such as the Cognistat and Repeatable Battery for the Assessment of Neuropsychological Status (RBANS), were developed as screening measures for clinicians to determine if more extensive neuropsychological screening was necessary. Such measures are generally designed to be easily administered in a myriad of environments, such as a private practice office or hospital bedside. Newer batteries, including the MDS, have attempted to compensate for the weaknesses of other batteries by providing a more comprehensive system.

Gender, Racial and Educational Factors in Neuropsychological Test Performance

The question of whether gender differences in neuropsychological test scores exist has been a point of interest for some researchers in the field. Historically, it has been presumed that men are superior to women on tasks of a spatial nature, while women are superior to men within the verbal domain. This finding does bear out in the literature (Fitzhugh-Bell, 1997). The HRB is one of the few neuropsychological test batteries that allow clinicians to use norms for men and women, however Reitan and Wolfson (1993) report that using norms based on demographic variables are unnecessary. A study by
Isom (1997) examining the androcentricity of some variables within the MDS, and found that the use of sex-based norms is unnecessary. With the exception of tasks of upper body muscle strength and lower body muscle power, the MDS does not utilize gender-based norms.

Another often debated but still unresolved issue is the question of whether cognitive differences related to race exist. As a group, Caucasians outperform African Americans on many cognitive tests (Lezak, 1995). However, Caucasians are generally more socioeconomically advantaged. Socioeconomic status is often related to better educational opportunities and higher educational attainment, which may also have an influence on neuropsychological test performance. This is especially evident on tests of verbal functioning (Lezak, 1995). In fact, a poorly educated, cognitively intact individual may obtain lower scores on tests of neuropsychological function than a well-educated individual who has sustained a head injury.

The value a particular culture places on a skill may influences a person’s performance on a neuropsychological test task that utilizes that skill (Dasen & Mishra, 2000). For example, speed is less valued in the Hispanic community compared to the general Caucasian community. Therefore, relative poorer performance by Hispanics compared to Caucasians on tests of psychomotor speed may be more a function of cultural factors than any group neurological differences. Hunting-gathering populations tend to demonstrate better developed spatial abilities compared to agrarian populations (Dasen & Mishra, 2000). Research has shown that demographic variables do indeed significantly influence performance on tasks tested in neuropsychological batteries.
(Mayfield & Reynolds, 1997). Most neuropsychological tests do not allow administrators to take educational attainment and race into account when using norms tables to convert raw scores into standard scores (Cimino, 2000).

Sensitivity and Specificity of Neuropsychological Tests

The sensitivity of an assessment tool refers to the tool’s ability to accurately identify the intended population (true positive rate) (Groth-Marnat, 1999). Specificity refers to the capability of a particular tool in correctly classifying those without brain damage as unimpaired (true negative rate) (Spreen & Strauss, 1998). The power of any neuropsychological test or battery lies in its sensitivity and specificity. Adequate specificity is necessary in order to accurately distinguish those with brain damage from those without brain damage, and adequate sensitivity is essential for accurately detecting type of brain damage and functional deficits so appropriate rehabilitative care can be rendered. The question then becomes: what constitutes adequate sensitivity? What level of classification accuracy is acceptable not only to neuropsychologists, but to physicians, rehabilitation specialists, and most importantly, patients and their families?

One study of the sensitivity of the HRB found that this battery correctly identified those with lesions from those without 90.7% of the time and those with right hemisphere damage from those with left hemisphere damage 92.9% of the time (Reitan & Wolfson, 1993). Other studies have examined the “hit rate” of the LNNB and have found it to be as high as 87% (Hartlage, 2001). Both batteries have been compared to each other in terms of classification accuracy, and such studies have found that both the HRB and LNNB are sensitive enough to detect presence of brain damage and lesion location at least 80% of
the time. Studies of the sensitivity of QEEG have found that it is quite good at confirming brain injury other techniques have indicated (Cantor, 1999).

Chronicity and the Detection of Brain Damage

Elapsed time since brain injury often influences performance on neuropsychological tests. Over time, symptoms of brain damage become less lateralized (Golden, 1984). Specific deficits resulting from brain damage often resolve at least partially as the patient progresses from an acute to a chronic stage (Reitan & Wolfson, 1993). Patients may have spontaneously recovered some lost function, or may have developed means for compensating for dysfunction (Kolb & Wishaw, 1996). Without appropriate evaluation and intervention, however, it is unlikely these patients made as full a recovery as possible. Ideally, all medical and neuropsychological evaluations will be performed shortly after the injury in order to accurately diagnose and describe cognitive and emotional disturbances resulting from the injury and to maximize recovery.

Purpose of the Study

Neuropsychological tests are the standard for assessing brain dysfunction and providing a foundation for treatment interventions (Leahy & Lam, 1998). While many studies have examined the use of various neuropsychological tests in determining presence or absence of a brain lesion, there is still a need for a neuropsychological battery that is capable of not only accurately pinpointing the location of the lesion, but also of providing useful information about an individual’s deficits and retained strengths for treatment and rehabilitation purposes (Ross et al., 1990). Such information is necessary to determine what services are needed to aid a person with brain damage not only in the
employment arena (i.e. vocational rehabilitation, assisted employment), but also in day-
to-day activities (Leahy & Lam, 1998). Providing this information also allows for the
timely development of appropriate rehabilitation and treatment plans that have the
potential to maximize a patient’s functioning (Leahy & Lam, 1998). The purpose of the
present study is to examine the validity and usefulness of various performance and
lateralizing indicators derived from the McCarron-Dial Evaluation System (MDS) in
identifying individuals with brain damage and determining whether the damage is
lateralized or diffuse. This study will also explore new algorithms that may increase the
discriminative power of the instrument in determining the location of brain lesion. These
algorithms consist of a priori formulae comparing spatial versus verbal skills based on
assumptions from cumulative neuropsychological research.

Finally, while portions of this study will be a replication of previous studies using
the MDS, this study will have a larger participant pool, a new sample of non-brain
damaged participants, and will use revised instrumentation and norms. It is important to
revisit the issues of validity and utility after such battery revisions in order ensure the
original purpose and integrity of the battery is maintained.

Research Questions

One question this study intends to address is whether these lateralizing indicators
improve discrimination between brain damaged individuals and the non-impaired; e.g.,
do these indicators improve the “classification accuracy” of the MDS over that obtained
from performance measures alone? Conversely, do performance levels in addition to
right/left indicators facilitate the identification of right, left, and diffuse brain damage
among patients? It is hypothesized that using a model including both performance level measures and right/left indicators will yield a higher percentage of correctly identified people than performance level measures alone. Within the brain damaged group, it is hypothesized that the lateralizing indicators will provide a higher classification accuracy rate than the performance level measures in identifying left, right, and diffuse brain damaged individuals, and that performance level measures in conjunction with lateralizing indicators will be the most accurate model in identifying type of brain damage. It is expected that the lateralizing indicators of the MDS will indeed prove useful in not only determining lateralized and diffuse brain damage, but also in improving the system’s capability to differentiate persons who have sustained brain damage from normal controls.
CHAPTER 2

METHOD

Participants

Archival data was collected from clinical files from a private neuropsychology practice to select anonymous cases with a medically documented history of acquired brain injury. Acquired brain injury was defined as any injury such as open or closed head injury, cerebrovascular accident, seizure disorder, or systemic disease with known neurological sequelae such as multiple sclerosis or AIDS, that is not due to a congenital defect or perinatal complications. Any participant who was suspected of having a cognitive disorder of unknown etiology or a primary complaint of learning disability without additional existing acquired brain injury was excluded from this study.

Archival data for non-brain damaged persons was also available for use in this study. Participants for the control group were originally obtained from students at the University of North Texas, as well as local state rehabilitation agency employees. Additional participants for the control group were obtained from students enrolled in junior- and senior-level psychology and rehabilitation services courses at the University of North Texas. Based upon an examination of all participants’ records, they were divided into one of four groups: normal, left brain damage, right brain damage, and diffuse brain damage.

A total of 151 participants were included in this study. Of these, 69 were male and 82 were female. Of the 151, 49 participants were classified as normal, 43 were classified as having left brain damage, 19 were classified as having right-hemisphere damage, and
40 were classified as having diffuse brain damage. The normal controls averaged 16 years of education, while the left brain damage group averaged 11 years. The right brain damage group and the diffuse brain damage group both averaged 12 years of education. With regards to ethnic background, 103 identified themselves as Caucasian, 28 as African-American, 12 as Hispanic, and 8 as from an ethnic background other than those listed.

Procedure

Before beginning the evaluation, each new participant read and signed a consent form describing the voluntary nature of participation and the potential benefits and risks of participating in the evaluation (see Appendix B). Each participant was asked to provide demographic information including age, handedness, race, and educational level. Participants were questioned regarding any previous history of brain injury and loss of consciousness, current or previous diagnosis of learning disability, past or current substance abuse, or uncorrected sensory impairment. Participant confidentiality was maintained by supplying each person a participant number that was used to identify participants on the testing materials and during data analysis. Each participant was administered the Wechsler Adult Intelligence Scale-III (WAIS-III), Wide Range Achievement Test 3 (WRAT3), Haptic Visual Discrimination Test (HVDIT), McCarron Assessment of Neuromuscular Development (MAND), Trail Making Test Parts A and B, Spatial Relations Test, Auditory Analysis, Language Comprehension and Memory, Letter-Number Learning, and the Bender Visual-Motor Gestalt Test (BVMGT) according to standard published procedures. The evaluations were administered by doctoral students.
in clinical health psychology and an undergraduate research assistant under the supervision of a licensed neuropsychologist. The undergraduate research assistant received training in the administration of the WRAT3, HVDT, Trail Making Parts A and B, Auditory Analysis, Language Comprehension and Memory, Letter-Number Learning, and the BVMGT by the principal investigator.

Instruments

This study utilized various scores obtained from tests used in the MDS. The scores were organized into two types of indicators: performance level and lateralizing (right/left) indicators. Within each category, the scores were further organized into two factors: verbal-spatial-cognitive factor and sensory-motor factor. The verbal-spatial-cognitive factor refers to abilities associated with learning, language, and processing verbal and spatial information (Dial & McCarron, 1986). The sensory-motor factor refers to skills involving integrating multimodal information from the environment and responding in an appropriate manner (Dial & McCarron, 1986). The following summarizes and defines each variable:

Performance Level Indicators: Verbal-Spatial-Cognitive

WAIS-III Full Scale IQ (FSIQ)—an overall measure of intellectual functioning
WRAT3 Arithmetic—a measure of basic computational skills
WRAT3 Spelling—a measure of basic word spelling and writing skills
WRAT3 Reading—a measure of word recognition and oral reading skills
Algorithm 1—WAIS-III Comprehension scaled score plus Picture Completion
scaled score divided by 2 minus Arithmetic scaled score plus Digit Span
scaled score plus Digit Symbol scaled score divided by 3 (χ₀), considered
to be an indicator of general brain damage (Russell, 1979)
((Comprehension + Picture Completion) / 2) – ((Arithmetic + Digit
Symbol + Digit Span) / 3)
Algorithm 2—WAIS-III Information scaled score plus Picture Completion scaled
score divided by 2 minus Arithmetic scaled score plus Digit Span scaled
score plus Digit Symbol scaled score divided by 3 (χ₀), believed to be an
indicator of general brain damage, based upon “hold” vs. “non-hold”
research
(((Information + Picture Completion) / 2) - ((Arithmetic + Digit Symbol +
Digit Span) / 3)
Algorithm 3—Auditory Analysis scaled score plus Language Comprehension and
Memory scaled score plus Letter-Number-Learning scaled score divided
by 3 (converted to standard score) minus Spatial Relations standard score
(χ₀), proposed as a measure of general brain dysfunction
((((Auditory Analysis + Language Comprehension + Letter-Number
Learning) / 3) – 10) / 3) * 15 + 100) – Spatial Relations
Algorithm 4—WAIS-III Picture Completion scaled score plus Comprehension
score divided by 2 (converted to standard score) minus Trails B t-score
(converted to standard score) (χ₀), proposed as a measure of general brain
dysfunction
(((((Picture Completion + Comprehension) / 2 - 10) / 3) * 15 + 100) – Trails B standard score

Performance Level Indicators: Sensory-Motor

Bender Visual-Motor Gestalt Test (BVMGT) standard score—based upon number of errors in reproducing the 9 patterns

HVDT Total Score (HVDT-total)—an average of two composite scores from each side of the body measuring haptic visual integration abilities

MAND Hand Preference Index Total Score (HPI-total)—an average of two scores from each side of the body measuring upper body muscle power, speed, and coordination

MAND Persistent Control—measure of attention and modulation of hand-arm movement

MAND Muscle Power—measure of upper and lower body muscle

MAND Kinesthetic Integration—measure of balance, body orientation in space and, gross coordination

MAND Bimanual Dexterity—measure of upper body motor speed and coordination utilizing the right and left arms and hands simultaneously

* for each of the performance indicators, any negative score produced by subtracting scores from each other will be converted to a zero (i.e., operationally defined as no evidence of pathology).

Lateraizing (Right/Left) Indicators: Verbal-Spatial-Cognitive

WAIS-III Verbal IQ score – Performance IQ score (VIQ-PIQ)—a difference
score that, positive, when significantly is believed to be a potential marker of right hemisphere impairment

WAIS-III Performance IQ score – Verbal IQ score (PIQ–VIQ)— a difference score that, when significantly positive, is believed to be a potential marker of left hemisphere impairment

Algorithm 5—Spatial Relations standard score plus BVMGT Recall standard score plus BVMGT Localization standard score divided by 3, minus Language Comprehension and Memory standard score plus Letter-Number Learning standard score divided by 2 (χ 0), proposed as an indicator of left hemisphere impairment

\[
\frac{(\text{Spatial Relations} + \text{BVMGT-recall standard score} + \text{BVMGT-localization standard score})}{3} - \left(\frac{(\text{Language Comprehension} + \text{Letter-Number Learning})}{2} - 10\right) / 3 * 15 + 100
\]

Algorithm 6—Language Comprehension and Memory standard score plus Letter-Number Learning standard score divided by 2, minus Spatial Relations standard score plus BVMGT Recall standard score divided by 2 (χ 0), proposed as an indicator of right hemisphere impairment

\[
\left(\frac{(\text{Language Comprehension} + \text{Letter-Number Learning})}{2} - 10\right) / 3 * 15 + 100) - (\text{Spatial Relations} + \text{BVMGT-recall standard score}) / 2
\]

Algorithm 7—Trails A t-score minus Trails B t-score (χ 0), proposed as a potential indicator of right hemisphere impairment

\[
\text{Trails A} - \text{Trails B}
\]
Algorithm 8—Trails B t-score minus Trails A t-score ($\chi^0$), proposed as a potential indicator of left hemisphere impairment

Trails B – Trails A

WRAT3 Reading – Arithmetic—a difference score that, when significantly positive, is believed to be a potential indicator of right hemisphere impairment

Lateralizing (Right/Left) Indicators: Sensory-Motor

HVDT-Right – HVDT-Left (HVDT-R – HVDT-L)—a difference score between the performance of the two sides of the body, higher positive scores may indicate right hemisphere damage

HVDT-Left – HVDT-Right (HVDT-L – HVDT-R)—a difference score between the performance of the two sides of the body, higher positive scores may indicate left hemisphere damage

HPI-Right – HPI-Left (HPI-R – HPI-L)—a difference score between the performance of the two sides of the body, higher positive scores are a potential marker of right hemisphere impairment

HPI-Left – HPI-Right (HPI-L – HPI-R)—a difference score between the performance of the two sides of the body, higher positive scores are a potential marker of left hemisphere impairment

MAND Beads in the Box Right – Left—a difference score between the performance of the two hands, higher positive scores are a potential marker of right hemisphere impairment
MAND Beads in the Box Left – Right—a difference score between the performance of the two hands, higher positive scores are a potential marker of left hemisphere impairment

MAND Finger Tapping Left – Right—a difference score between the performance of the two hands, higher positive scores are a potential marker of left hemisphere impairment

MAND Finger Tapping Right – Left—a difference score between the performance of the two hands, higher positive scores are a potential marker of right hemisphere impairment

MAND Hand Strength Left - Right—a difference score between the performance of the two hands, higher positive scores are a potential marker of left hemisphere impairment

MAND Hand Strength Right – Left—a difference score between the performance of the two hands, higher positive scores are a potential marker of right hemisphere impairment

* for each of the lateralizing indicators, any negative score produced by calculating the difference between the two sides of the body was converted to a zero (i.e., operationally defined as no evidence of pathology).

The WAIS-III is a standard and widely used measure of adult intellectual capacity (Wechsler, 1997; Halperin & McKay, 1998). It consists of 11 subtests (and 2 optional tests) measuring various cognitive functions and it generates three IQ scores: Verbal IQ (VIQ), Performance IQ (PIQ), and Full Scale IQ (FSIQ). The Verbal IQ score is derived
from tasks of immediate auditory recall, expressive vocabulary, verbal reasoning, mental computation, general fund of information, and practical social knowledge. The Performance IQ score is comprised of visual-sequential thinking, visual discrimination and organization, non-verbal reasoning, psychomotor speed and coordination, and visual-spatial perception tasks. The scaled scores from all subtests (verbal and performance) are added together and converted to the Full Scale IQ score (Wechsler, 1997).

The Wide Range Achievement Test 3 (WRAT3) is a commonly used test of basic academic skills for ages five through adulthood. It is often used in educational, psychological, and neuropsychological testing for the purpose of determining academic strengths and weaknesses and may aid in the determination for necessity of remedial education services. The test consists of three subtests: Spelling, Arithmetic, and Reading. The Spelling subtest involves writing letters presented visually and words presented orally by an examiner. The Arithmetic subtest consists of counting, reading number symbols, and oral and written computation. The Reading subtest requires examinees to recognize and name printed letters and pronounce written words. Each subtest yields a raw score which is converted to a standard score based on the examinee’s age (Wilkinson, 1993.)

Three subtests from the Cognitive Test for the Blind (CTB) are used as part of the MDS battery for sighted individuals. The Auditory Analysis and Sound Repetition test requires examinees to attend to and repeat word-like sounds that are presented by the examiner or by audiotape. Below average scores may be due to left hemisphere deficits in speech comprehension and/or production. Auditory Analysis has a test-retest reliability
of .90 and an interrater reliability of .85 (Dial & McCarron, 1986). The Language
Comprehension and Memory test includes the oral presentation of stories by the examiner
or audiotape. After a story is presented, the examinee responds to orally presented
questions about events in the story and the meanings of words used in the story. This test
requires receptive language, memory for verbal detail, and expressive language skills.
Below average scores on the test may indicate damage to the left temporal and/or frontal
areas. It has a test-retest reliability of .92 (Dial & McCarron, 1986). Letter-Number
Learning involves the oral presentation of letter-number pairs in series. The examinee
repeats each series, and is allowed up to 5 trials to correctly recall the series. Each series
gets progressively longer. This task requires rote recall of verbally presented information
and adequate auditory attention and concentration (Dial & McCarron, 1986). Below
average scores may be related to left hemisphere dysfunction.

The Spatial Relations Test (SRT) is a test of immediate visual recall for patterns,
two to three dimensional transformation, and constructional praxis. A card with a printed
cube pattern is presented to the examinee, who then examines the card for 10 seconds.
After this study time, the card is removed and the examinee is instructed to construct the
pattern seen on the card using the cubes. The patterns become progressively more
complex. Poor performance on this task has been associated with right hemisphere
dysfunction.

The Trail Making Test Parts A and B are part of the Halstead-Reitan
Neuropsychological Test Battery (HRB). Trails A involves connecting numbered circles
in order as quickly as possible. Trails B is more complex in that it involves connecting
numbered and lettered circles in alternating order. The Trail Making Test requires attention, concentration, and cognitive flexibility. The time taken to complete the task and the examinee’s age and educational attainment are converted to a T-score. Poor performance on the Trail Making Test is believed to be an indicator of general brain damage (Reitan & Wolfson, 1993). Early research by Reitan initially found significantly better performance on Trails A compared to Trail B to be an indicator of right hemisphere dysfunction and significantly better performance on Trails B compared to Trails A to be an indicator of left hemisphere impairment (Heilbronner et al, 1991). However, more recent research by Heilbronner et al (1991) and Reitan and Wolfson (1993) indicates both Trails A and Trails B are good general indicators of cerebral status, but not particularly useful as a means of localizing lesion.

The Haptic Visual Discrimination Test (HVDT) is part of the MDS neuropsychological battery that was developed to assess ability to integrate tactual and visual information. It was normed on normal children and adults (ages 3-90) and the adult neuropsychologically disabled (McCarron & Dial, 1996). The HVDT has a reliability of .90 and research concerning predicting work potential has ranged from .53 to .86 (McCarron & Dial, 1996). HVDT administration involves the presentation of screened objects varying in shape, size, texture and configuration. Examinees are then instructed to feel each object and visually identify that object from a choice of 5 objects represented in a set of pictures (McCarron & Dial, 1996). This process is administered to the right hand first (regardless of the person’s handedness), and, after a 30-minute interval, is
administered to the left hand. Three scores may be derived; one for each side of the body (HVDT-R and HVDT-L) and an average score (HVDT-total).

The McCarron Assessment of Neuromuscular Development (MAND) is a standardized assessment of neuromotor skills and is also part of the MDS assessment battery (McCarron & Dial, 1976). For brain-damaged groups, it has a test-retest reliability of .99, and there is also a high predictive validity between MAND scores and work performance \( (r = .70; p < .0001) \) (Chan, Lynch, Dial, Wong, & Kates, 1993). The Hand Preference Index (HPI) is made up of scores from tasks of upper body muscle power, functional speed and coordination (Dial & McCarron, 1986). Scores from the right and left side of the body are yielded (HPI-R and HPI-L). By using scaled score conversion tables, the effects of handedness and sex may be controlled (Dial & McCarron, 1986). Significant differences in right versus left HPI scores after controlling for handedness and sex are believed to be indicative of brain pathology or musculoskeletal impairments (Dial & McCarron, 1986). A total HPI score may be calculated by averaging the scores from both sides of the body.

The MAND also yields four factor scores: Persistent Control, Muscle Power, Kinesthetic Integration, and Bimanual Dexterity. The Persistent Control factor requires the integration of perceptual skills and attention with regulation of hand-arm movements while inhibiting extraneous movement (Dial & McCarron, 1986). The Muscle Power factor measures upper and lower body muscle strength (Dial & McCarron, 1986). Kinesthetic Integration is measured by tasks requiring lower-body balance and gross-motor integration (Dial & McCarron, 1986). Bimanual Dexterity measures ability to
integrate proprioceptive and kinesthetic information with fine motor coordination of both hands (Dial & McCarron, 1986). Below average performance on any of these factors is believed to be indicative of overall brain damage.

The Bender Visual-Motor Gestalt Test (BVMGT) involves the copying of nine designs presented on cards. The quality of the reproductions may vary by age, brain dysfunction, or emotional disturbance. Distortions in the reproductions due to brain damage may be caused by motor dysfunction, sensorimotor processing difficulties, or visual detection and recognition difficulties (McCarron & Dial, 1986). The number of errors is converted to a standard score. In order to assess visual-spatial memory and incidental learning, the client may be presented with a blank sheet of paper 15 minutes after completion of the copying task and asked to recall as many of the BVMGT items as possible and redraw them in approximately the same place on the paper as before.

Data Analysis

The data were analyzed using SPSS Statistical Software Package version 9.0.0. Differences in level of education and ethnicity between the normal and brain damaged groups that could obscure true differences on several neuropsychological variables required the data to be re-normalized using adjustment tables derived from previous research (Dial, 2004). These tables were constructed based on the known mean differences within normal samples for the aforementioned demographic issues. Preliminary analysis of the data involved analysis of variances (ANOVAs) to determine which composite variables were submitted to stepwise multiple discriminate function analysis. Each resulting number from the computations and algorithms was entered into a
multiple discriminant function analysis. The first set of multiple discriminate function analyses examined the performance indicators’ success in accurately classifying persons with brain damage and persons without brain damage (Model I). Next, the lateralizing indicators were submitted to analysis to determine their accuracy in distinguishing between those with brain damage and those without brain damage (Model II). Another set of analyses examined the same performance indicators and their ability to discriminate between those with right, left, and diffuse brain damage (Model IV). Afterwards, the lateralizing indicators were submitted to another analysis to determine their accuracy in classifying right, left, and diffuse brain damage (Model V). Finally, both performance and lateralizing indicators were submitted to multiple discriminate function analysis to examine if the use of both types of indicators improved the classification accuracy of brain damage vs. non-brain damage (Model III) and right vs. left vs. diffuse brain damage (Model VI).
CHAPTER 3

RESULTS

The data were first submitted to analyses of variance (ANOVA) to determine if the groups were significantly different from each other on the variables of gender, age, or years of education. There were significantly ($p < .001$) more women in the normal control group (41 female, 8 male) than in the left (17 female, 26 male), right (7 female, 12 male), or diffuse (17 female, 23 male) brain damage groups. Participants in the normal control group differed significantly in age ($p = .04$) from the participants with left hemisphere damage. Normal controls were younger ($\bar{x} = 30$) than their peers with left-sided damage ($\bar{x} = 35$). With regards to years of education, there were significant differences ($p < .001$) between the normal controls and all of the brain damage groups. The normal controls averaged 16 years of education, while the left brain damage group averaged 11 years. The right brain damage group and the diffuse brain damage group both averaged 12 years of education. Age and gender differences were controlled by using appropriate normative tables (Wechslser, 1997; McCarron & Dial, 1976), while educational and ethnicity differences were controlled by use of tables available from previous research (Dial, 2004). Scores were first adjusted for years of education, and then those scores were again adjusted for ethnicity (see Appendix B).

The data were submitted to multiple discriminant function analyses to test the hypotheses of the study. Model I examined the classification accuracy of the performance level indicators for individuals with brain damage vs. the control group. Out of the 15 variables, the model retained three: MAND Kinesthetic Integration, WAIS-III Full Scale
IQ, and WRAT3 Spelling. Table 1 lists these variables and their standardized canonical discriminant function coefficients indicating relative importance in predicting presence or absence of brain lesion.

Table 1

Variables Retained in Model I and Respective Standardized Canonical Discriminant Function Coefficients

<table>
<thead>
<tr>
<th>Function 1</th>
<th>Kinesthetic Integration</th>
<th>.748</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>WAIS-III FSIQ</td>
<td>.412</td>
</tr>
<tr>
<td></td>
<td>WRAT3 Spelling</td>
<td>.371</td>
</tr>
</tbody>
</table>

Model II examined the classification of lateralizing indicators between those with brain damage and those without brain damage. Of the 17 variables, the model retained none. No variables were qualified for further analysis. Model III examined both lateralizing indicators and performance level indicators together, and this model retained the following variables: MAND Kinesthetic Integration, WAIS-III FSIQ, WRAT3 Spelling, MAND Finger Tapping Left-Right, Verbal IQ-Performance IQ, and Algorithm 5. Table 2 lists these variables and their standardized canonical discriminant function coefficients indicating relative importance in predicting presence or absence of brain lesion.
Table 2

Variables Retained in Model III and Respective Standardized Canonical Discriminant Function Coefficients

<table>
<thead>
<tr>
<th>Function 1</th>
<th>Kinesthetic Integration</th>
<th>WAIS-III FSIQ</th>
<th>WRAT3 Spelling</th>
<th>Finger Tapping L-R</th>
<th>VIQ-PIQ</th>
<th>Algorithm 5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>.730</td>
<td>.436</td>
<td>.394</td>
<td>-.193</td>
<td>-.289</td>
<td>-.247</td>
</tr>
</tbody>
</table>

The characteristics of the standardized canonical discrimination functions for Models I, II, and III are presented in Table 3.

Table 3

Summary of Standardized Canonical Discriminant Functions for Models I, II, and III

<table>
<thead>
<tr>
<th></th>
<th>Eigenvalue</th>
<th>Canonical Correlation</th>
<th>Wilks’ Lambda</th>
<th>Chi-Square</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model I</td>
<td>1.577</td>
<td>.782</td>
<td>.388</td>
<td>121.623</td>
<td>.000</td>
</tr>
<tr>
<td>Model II</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Model III</td>
<td>1.849</td>
<td>.806</td>
<td>.351</td>
<td>132.972</td>
<td>.000</td>
</tr>
</tbody>
</table>

Table 4 presents the results of the analyses of stepwise multiple discriminant Models I, II, and III to determine the usefulness of considering right/left indicators in addition to performance levels when ascertaining presence of brain damage.
Table 4

Classification Accuracy Percentages for Multiple Discriminant Analyses (Stepwise) Between Persons with Brain Damage and Normal Controls on Performance Level Indicators and Lateralizing Indicators

<table>
<thead>
<tr>
<th></th>
<th>Performance Levels</th>
<th>Lateralizing Indicators</th>
<th>Both</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normals</td>
<td>88</td>
<td>---</td>
<td>88</td>
</tr>
<tr>
<td>Brain Damaged</td>
<td>93</td>
<td>---</td>
<td>96</td>
</tr>
<tr>
<td>Overall</td>
<td>91</td>
<td>---</td>
<td>93</td>
</tr>
</tbody>
</table>

Lateralizing indicators were neither able to classify normal controls nor those with a history of brain damage. Performance level indicators correctly classified 88% of the normal controls and 93% of those with brain damage. Utilizing both performance levels and lateralizing indicators yielded the highest rates of correctly classified individuals; 88% of normal controls, 96% of people with brain damage, and 93% overall.

Models IV, V, and VI examined the utility of performance level indicators and lateralizing indicators, alone and together, to determine which approach best predicted a person with brain damage’s inclusion in one of the three brain damaged groups (right, left, or diffuse). Model IV considered performance level indicators alone, and this model retained two of the 17 variables: MAND Kinesthetic Integration and HVDT-Total. Table 5 lists these variables and their standardized canonical discriminant function coefficients indicating relative importance in predicting area of brain lesion.
Table 5

Variables Retained in Model IV and Respective Standardized Canonical Discriminant Function Coefficients

<table>
<thead>
<tr>
<th>Function 1</th>
<th>Function 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kinesthetic Integration</td>
<td>.933</td>
</tr>
<tr>
<td>HVDT-Total</td>
<td>.181</td>
</tr>
</tbody>
</table>

Model V assessed lateralizing indicators alone, and this model retained the HVDT Right-Left, HVDT Left-Right, MAND Beads in the Box Left-Right, and WAIS-III Performance IQ-Verbal IQ. Table 6 lists these variables and their standardized canonical discriminant function coefficients indicating relative importance in predicting area of brain lesion.

Table 6

Variables Retained in Model V and Respective Standardized Canonical Discriminant Function Coefficients

<table>
<thead>
<tr>
<th>Function 1</th>
<th>Function 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>HVDT R-L</td>
<td>-.465</td>
</tr>
<tr>
<td>HVDT L-R</td>
<td>.386</td>
</tr>
<tr>
<td>Beads in Box L-R</td>
<td>.624</td>
</tr>
<tr>
<td>PIQ-VIQ</td>
<td>.541</td>
</tr>
</tbody>
</table>

Both performance levels indicators and lateralizing indicators were investigated in Model VI, and the following variables were retained: WAIS-III Performance IQ-Verbal IQ, HVDT Left-Right, HVDT Right-Left, MAND Kinesthetic Integration, MAND Beads in the Box Left-Right, and MAND Finger Tapping Right-Left. Table 7 lists these variables and their standardized canonical discriminant function coefficients indicating relative importance in predicting area of brain lesion.
Table 7

Variables Retained in Model VI and Respective Standardized Canonical Discriminant Function Coefficients

<table>
<thead>
<tr>
<th></th>
<th>Function 1</th>
<th>Function 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>PIQ-VIQ</td>
<td>.517</td>
<td>.347</td>
</tr>
<tr>
<td>HVDT L-R</td>
<td>.332</td>
<td>.661</td>
</tr>
<tr>
<td>HVDT R-L</td>
<td>-.851</td>
<td>.791</td>
</tr>
<tr>
<td>Kinesthetic Integration</td>
<td>.273</td>
<td>-.574</td>
</tr>
<tr>
<td>Beads in Box L-R</td>
<td>.606</td>
<td>.193</td>
</tr>
<tr>
<td>Finger Tapping R-L</td>
<td>.544</td>
<td>-.391</td>
</tr>
</tbody>
</table>

The characteristics of the standardized canonical discriminations functions for Models IV, V, and VI are presented in Table 8.

Table 8

Summary of Standardized Canonical Discriminant Functions for Models VI, V, and VI

<table>
<thead>
<tr>
<th></th>
<th>Eigenvalue</th>
<th>Canonical Correlation</th>
<th>Wilks’ Lambda</th>
<th>Chi-Square</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model IV</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Function 1</td>
<td>.200</td>
<td>.408</td>
<td>.745</td>
<td>24.041</td>
<td>.000</td>
</tr>
<tr>
<td>Function 2</td>
<td>.119</td>
<td>.326</td>
<td>.894</td>
<td>9.166</td>
<td>.002</td>
</tr>
<tr>
<td>Model V</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Function 1</td>
<td>1.511</td>
<td>.776</td>
<td>.297</td>
<td>101.416</td>
<td>.000</td>
</tr>
<tr>
<td>Function 2</td>
<td>.342</td>
<td>.505</td>
<td>.745</td>
<td>24.555</td>
<td>.000</td>
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<tr>
<td>Model VI</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Function 1</td>
<td>1.740</td>
<td>.797</td>
<td>.250</td>
<td>110.071</td>
<td>.000</td>
</tr>
<tr>
<td>Function 2</td>
<td>.457</td>
<td>.560</td>
<td>.686</td>
<td>29.947</td>
<td>.000</td>
</tr>
</tbody>
</table>

The results of the classification accuracy analyses were compared and are presented in Table 9.
Table 9

Classification Accuracy Percentages for Multiple Discriminant Analyses (Stepwise) Between Persons with Left, Right and Diffuse Brain Damage on Performance Level Indicators and Lateralizing Indicators

<table>
<thead>
<tr>
<th></th>
<th>Performance Levels</th>
<th>Lateralizing Indicators</th>
<th>Both</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left</td>
<td>63</td>
<td>86</td>
<td>88</td>
</tr>
<tr>
<td>Right</td>
<td>47</td>
<td>42</td>
<td>79</td>
</tr>
<tr>
<td>Diffuse</td>
<td>50</td>
<td>88</td>
<td>83</td>
</tr>
<tr>
<td>Overall</td>
<td>55</td>
<td>78</td>
<td>84</td>
</tr>
</tbody>
</table>

For persons with brain damage, performance level indicators yielded an accuracy rate of 63% for left-hemisphere impaired individuals, 47% for right-hemisphere impaired individuals, and 50% for those with diffuse brain damage. Overall, performance level indicators accurately classify people with brain damage into the three groups 55% of the time. Using lateralizing indicators to classify type of brain damage resulted in an accuracy rate of 86% for left-brain damaged, 42% for right brain damaged, and 88% for those with diffuse brain damage. Lateralizing indicators accurately classify people with brain damage into the three groups 84% of the time. Using both performance level indicators and lateralizing indicators resulted in an accuracy rate of 88% for left-hemisphere damaged individuals, 79% for right-hemisphere damaged individuals, and 83% for people with diffuse brain damage. In general, using both performance level indicators and lateralizing indicators yielded the highest number of correctly classified people into one of the three brain damage groups.

Post-hoc analyses were conducted using a cross-tabulation method, so that relationships between each model are more apparent (Vogt, 1993). A kappa statistic, which is a measure of agreement between the variables, was generated to determine if the
models were significantly different from each other; in other words, are any changes in
classification accuracy between the various models significantly different and is a
particular model a better means of predicting brain damage vs. non-brain damage or
location of lesion?

Cross-tabulations could not be calculated using Model II as a variable, as it could
not predict inclusion of participants in the brain damage or normal control groups. A
cross-tabulation between Models I and III and subsequent kappa measure indicated that
these two models are significantly similar to each other \( (p < .001) \). After adjusting for
random chance, these two models are predicting the same, 82% of the time.

Cross-tabulation between Models IV and V revealed a kappa measure statistic of
.196, indicating that the models were in agreement only 18% of the time \( (p = .01) \).
Models IV and VI were in agreement with each other 28% of the time \( (p < .001) \). Finally,
a cross-tabulation between Models V and VI and consequent kappa measure statistic
indicated these models are in agreement with each other 84% of the time \( (p < .001) \).
CHAPTER 4
DISCUSSION

Before attempting to discern the location of a brain lesion, it is important to first determine if brain damage does indeed exist. The purpose of Models I, II, and III developed in this study was to determine the utility of performance level indicators and lateralizing indicators, alone and together, in ascertaining the presence or absence of brain damage. Based upon the results of multiple discriminant analyses and post-hoc cross-tabulations, it appears that performance level indicators alone and in conjunction with lateralizing indicators do a good job of classifying those with and without brain damage. While on the surface, using lateralizing indicators in concert with performance level indicators to determine presence of brain damage (Model III) appears to have a slight edge in identifying those with brain damage over performance levels alone (Model I), post-hoc analyses determined that no significant difference existed between the two models. Any greater classification accuracy that Model III appears to have may only be evidence of a fine-tuning of classification accuracy over Model I.

Lateralizing indicators alone (Model II) do not appear to be a useful means of determining the presence or absence of brain damage. This model did not retain any of the predicted right/left indicators, nor could it predict who had brain lesion and who did not. Given that lateralizing indicators are intended to localize brain lesion when such a lesion exists, it is not surprising that these indicators are unhelpful in establishing the overall presence or absence of brain damage.
While Model II does a good job of identifying non-brain damaged individuals (88% correctly classified), this model makes an error toward identifying 12% of the normal controls as neuropsychologically impaired. A number of factors may be involved in this phenomenon. Patients may purposely or inadvertently not disclose a history of minor head injury that may not have warranted immediate medical attention, yet resulted in mild functional impairment that could affect neuropsychological test results. Common childhood injuries (i.e. playground accidents, falling off a bicycle) are often far enough in the past that patients tend to neglect reporting such incidents when appearing for a medical or neuropsychological interview. Also, unreported or commonly denied substance abuse among some of the normal participants may result in functional neuropsychological impairments, thus resulting in a relatively higher “miss rate” for this group. Chronic alcoholism may result in retrograde and anterograde amnesia, which may impair performance on memory and learning tasks (Parsons, 1996). It is further possible that a small percentage of the normal controls had subclinical learning disorders. Such disorders may not have caused significant problems to necessitate professional attention during school, but could cause a person to appear mildly impaired on neuropsychological testing (Culbertson & Edmonds, 1996). Nonetheless, the present findings suggest that a parsimonious combination of performance level and lateralizing indicators is capable of discriminating those with brain damage from those without brain damage.

Lateralizing indicators do appear to be useful in determining general location of a lesion once it has been established that brain damage does indeed exist. Overall, lateralizing indicators (Model V) correctly classified 78% of the participants into one of
the three groups (left, right, diffuse). Using performance level indicators in addition to lateralizing indicators (Model VI) resulted in the correct classification of 84% of the brain-damaged individuals into their respective categories. While it appears that using both performance and lateralizing indicators has a small advantage over the lateralizing indicators alone, there was no significant difference in these results. Again, the perceived improvement in classification accuracy for Model VI may represent only a fine-tuning of classification accuracy rather than a major improvement.

The use of performance level indicators alone (Model IV) does not seem to be as helpful in determining lesion location compared to Models V and VI. Model IV’s classification accuracy was only 55%. Both Models V and VI did a significantly better job of classifying individuals with brain damage into their respective groups. The purpose of examining functioning on performance level indicators is to compare an individual’s performance to that of the general population, while lateralizing indicators compare within-subject discrepancies on scores. Therefore, it is not surprising that performance level indicators are less able to localize brain lesion than lateralizing indicators or both performance level and lateralizing indicators.

Models IV, V, and VI were less able to accurately classify a participant as having right brain damage than left hemisphere or diffuse brain damage (see Table 4). This finding may be attributed to several possible explanations. For example, a number of factors may be involved in this classification error. It is more difficult to distinguish between right-hemisphere and diffuse damage than between left- and right-hemisphere damage and left-hemisphere and diffuse damage. Fluid (performance) intelligence is
more sensitive to a lesion in any area of the brain than crystallized (verbal) intelligence. Also, educational attainment and socioeconomic background may play a role in the misclassification of people with right-hemisphere damage (Heaton, Ryan, Grant, & Matthews, 1996). While persons with right-hemisphere damage would likely have depressed Performance IQ (PIQ) scores on the Wechsler Adult Intelligence Scale-III (WAIS-III); in selected cases with low educational attainment and/or socioeconomic background, the Verbal IQ (VIQ) scores on the WAIS-III would also be low. A person with a right-hemisphere brain injury and low education and socioeconomic background would likely score poorly on both the VIQ and PIQ and appear to have diffuse brain damage, or perhaps even normal functioning in mild cases of impairment.

Based on the results of the current study, the capability of the MDS performance and lateralizing indicators in assessing presence of brain lesion is comparable with the Halstead-Reitan Neuropsychological Test Battery (HRB) (93% vs. 91%). However, the MDS performance and lateralizing indicators are less accurate in identifying location of lesion (84% vs. 93%). This may be related to the design of the studies. Studies examining the classification accuracy of the HRB focused on distinguishing right from left hemisphere lesion (Reitan & Wolfson, 1993), while the current study attempted to distinguish left from right from diffuse lesion. Regarding the Luria-Nebraska Neuropsychological Battery (LNNB), one study found it to have a classification accuracy as high as 87% (Hartlage, 2001). This is slightly better than the current findings. Again, these findings may be related to differences in study design. Additional studies have noted that the HRB and LNNB are sensitive enough to detect the presence of brain
damage and lesion location at least 80% of the time (Hartlage, 2001), and the present study indicates that when both performance level indicators and lateralizing indicators are utilized, the MDS is comparable in classification accuracy to these well-known and well-respected neuropsychological test batteries.

Earlier studies have also examined the discriminative capabilities of the MDS. An early study by Dial (1982) investigated the discriminative power in distinguishing adults with brain damage from psychiatric controls. In this study, 97% of those with brain damage and 71% of the psychiatric control group were accurately classified using MDS variables (Dial, 1982). The current study performed comparably with regards to identifying those with brain damage (96%), and was better at identifying those without brain damage (88%). However, it should be noted that Dial’s study utilized a psychiatric population as a control group, while the current study utilized people with no known severe psychiatric illness. A study by Dial, Chan, and Norton (1990) found variables from the MDS to have 92.6% accuracy in distinguishing those with brain damage from those without brain damage. The results of the current study are comparable (93%). With regard to discriminating general location of brain lesion, Model VI from the current study accurately classified 84% of the participants into the right, left, or diffuse brain damage groups, whereas the earlier study only classified 69.6% correctly (Dial, Chan, & Norton, 1990). A more recent study by Colaluca (1998) found the MDS to distinguish between people with brain damage and normal controls 83.1% of the time. It appears that the new models incorporating more variables and permutations of variables within the MDS increases its predictive validity.
Certain variables within the MDS proved to be better and detecting and locating brain lesion than others, as evidenced by some variables being retained in the multiple discriminant function analyses while others were not. The Kinesthetic Integration subscale from the MAND was retained in both Models III and VI, indicating its usefulness not only in helping to detect brain damage, but also lesion location. Balance and proprioception, mediated by the somatosensory cortex, occipital lobe, and parietal lobe, are necessary for the appropriate execution of these tasks. These areas may be especially sensitive to lesion, and therefore good predictors of lateralized brain lesion. This subscale is also highly dependent on the integration of multiple brain systems, including the frontal and occipital lobes, and the vestibular system, thus it is highly sensitive to dysfunction in any of these areas.

MAND Finger Tapping Left-Right was useful in determining if brain lesion existed, and MAND Finger Tapping Right-Left was useful in locating general area of brain lesion. The Finger Tapping task requires controlled fine-motor movements, psychomotor speed, and inhibition of inappropriate responses. Difficulties on this task may indicate lesions to the motor and/or somatosensory cortex.

MAND Beads in the Box Left-Right was retained in Model VI, indicating its usefulness in locating brain lesion. This task also requires controlled fine-motor movements and psychomotor speed, and large discrepancies in left vs. right-sided performance appear to be indicative of lesion.

The Haptic Visual Discrimination Test (HVDT) proved useful in determining general location of brain lesion. Both HVDT Right-Left and HVDT Left-Right were
retained as variables in Model VI. The HVDT requires the ability to integrate tactual and visual information, thus involving the somatosensory cortex, parietal lobes, and occipital lobes. This test would be sensitive to lesions in any of these areas in either hemisphere, or to diffuse damage. Not only is the HVDT helpful in localizing brain lesion, it may also provide insight into a person’s ability to synthesize and integrate information from multiple sources and apply that knowledge in practical situations (i.e. vocational rehabilitation) (Chan et al, 1993).

Of the 8 proposed algorithms, only Algorithm 5 was retained in Model III. This algorithm computed a difference score between some spatial indicators (Spatial Relations Test, Bender Visual Motor Gestalt Test Recall and Localization scores) and verbal indicators (Language Comprehension and Memory, and Letter-Number Learning). It was proposed as an indicator of left hemisphere impairment, meaning that in people with left hemisphere lesions, scores on the verbal indicators would be lower relative to the spatial indicators. While Algorithm 5 did not bear out as a lateralizing indicator, it does seem to be useful in detecting presence of damage.

Scores from the WAIS-III have also shown to have some predictive value. In determining the presence or absence of brain damage, WAIS-III FSIQ and Verbal IQ-Performance IQ were among the variables retained. Full-scale IQ is generally depressed among those who have experienced brain lesion. Performance IQ scores seem to be especially sensitive to any type of lesion, thus creating a gap between PIQ scores and crystallized intelligence-laden VIQ scores (Hawkins, et al, 2002). When distinguishing between right, left, or diffuse damage, Performance IQ-Verbal IQ was retained as a
variable. When a left-hemispheric lesion occurs, VIQ is suppressed, and while PIQ may also be suppressed, the difference may be large enough to suspect left-hemisphere damage.

From the Wide Range Achievement Test 3, only the Spelling subtest proved helpful in identifying those with brain damage from those without lesion. This subtest relies heavily on educational experience and crystallized intelligence, thus decreased scores in this subtest relative to other scores may signal a serious left-hemisphere lesion. Since this score was adjusted for educational attainment and ethnic background, the fact that this variable was retained does not seem to be the result of an educational confound.

Although the results of the present study suggest the utility of using lateralizing indicators from the WAIS-III, Haptic Visual Discrimination Test (HVDT), and the McCarron Assessment of Neuromuscular Development (MAND) in localizing brain lesions, there were some limitations to this study that must be addressed. Closed head injuries (i.e. motor vehicle accidents, sports injuries) are fairly common causes of brain injuries that may cause mild diffuse damage (i.e. contrecoup injuries, axonal shearing) in addition to a focal lesion. Thus, a patient may demonstrate deficits associated with one particular area of the brain, and also milder deficits associated with diffuse brain damage. This may have resulted in misclassification of participants within the brain-damage groups. Also, the lack of clear medical documentation in some cases may have resulted in the initial misclassification of some participants with brain damage. In some cases, the clinician relied on the patient’s self-report regarding the nature of the injury, or the information may have been provided by a rehabilitation counselor relying on the patient’s
(or the patient’s family’s) report. Traumatic brain injury patients tend to underestimate their own level of impairment (Sweet, 1991). The present study would have benefited from having clearer documentation regarding the location of the brain damage; e.g. radiologic test reports from a physician would have provided more accurate information as to the nature and location of the injury.

Elapsed time since onset of injury is another factor that was not considered in the current study. Patients may not present for neuropsychological evaluation until well after an injury when it has become painfully clear that deficits interfering with school, work, and daily life exist. As mentioned in Chapter 1, deficits tend to become more global and less lateralized as time progresses (Dean, 1984). It would be interesting to examine the classification accuracy of the McCarron-Dial System (MDS) across various periods of elapsed time since injury. Many previous studies of the MDS and other neuropsychological batteries utilized data collected from patients in a rehabilitation hospital setting. These patients were evaluated approximately 6 months post-injury. However, the current study evaluated patients an estimated 2 to 6 years post injury, well after most spontaneous recovery would have occurred.

Psychiatric disorders such as major depressive disorder may have neuropsychological sequelae as part of the overall symptom presentation (King & Caine, 1996). Concentration, memory, and motivational disturbance are common features of major depressive disorder, and could potentially impact performance on neuropsychological assessment (American Psychiatric Association, 2000). Such psychiatric disorders may be premorbid, or may be related to the current injury. Further
research may wish to examine potential relationships between emotional functioning and neuropsychological test performance on the MDS.

Nevertheless, selected MDS performance levels and right/left indicators provide parsimonious models for detecting the presence of brain damage and accurately classifying individuals according to the general location of the lesion. This study attempted to examine more indicators within this battery than previous research on the MDS. Also, several algorithms were proposed as potential lateralizing and performance level indicators. While only one of these algorithms was retained in this study (Algorithm 5), they do provide alternative means of examining these variables that may be used in further research. This study added to the body of knowledge regarding the validity and versatility of the MDS and established critical variables that are particularly useful for psychologists, rehabilitation clinicians, and vocational evaluators to assess during evaluations. In this manner, evaluators may zero in on which tests would be most helpful in establishing areas of lesion and functional deficits to quickly provide treatment and rehabilitation recommendations.

The ultimate goal of any neuropsychological assessment battery, including the MDS, is to attain appropriate and useful information about an individual’s strengths and weaknesses, so that this information may be used to assist in treatment, educational, and vocational planning. It is especially important to be able to distinguish the pathognomic signs, and patterns and relationships among scores indicative of brain injury from those of other circumstances and disorders which symptoms may result in a testing profile similar to that of a person with brain damage. For example, there are a number of reasons
why a person might attain low scores on tests of verbal functioning: left hemisphere lesion, low educational attainment, impoverished background, cultural factors, and learning disability. There are also a number of reasons a person might score poorly on tests of spatial functioning, such as right hemisphere lesion, impoverished background, and visual impairment. These factors must be taken into consideration when developing a rehabilitation program. While a person with a left-hemisphere lesion might be referred to a cognitive rehabilitation program, a person with an impoverished background or low educational attainment would be encouraged to enroll in a remedial education program. Likewise, a person may display difficulties in gross motor functioning (i.e. balance, lower body muscle power), and these difficulties may be related to cerebellar damage, inner ear infections, or musculoskeletal problems associated with conditions such as obesity and osteoarthritis.

The results of this study offer clinicians information regarding pathognomic signs and patterns of scores from selected tests from the MDS which may be used to initially determine not only presence and location of brain damage, but also what other neuropsychological tests and medical procedures are necessary to make an accurate diagnosis. Lateralizing and performance level indicators from the MDS battery, along with thorough background information, medical history, and astute behavioral observations, provide information that can be used to make accurate and timely diagnoses. In this manner, appropriate recommendations may be made for treatment and rehabilitation planning in order to best assist the person with brain injury in achieving the highest level of post-injury functioning possible.
Algorithm—a procedure or formula for solving a problem (Vogt, 1993).

Androcentricity—a view of the world from an essentially masculine perspective (Isom, 1997).

Anomia—inability to name objects (Kolb & Wishaw, 1996).

Anterograde amnesia—loss of the ability to form new memories beyond a certain point in time, generally after an insult to the brain (Kolb & Wishaw, 1996).

Contrecoup—a lesion resulting from the deceleration of the brain tissue after an initial impact in another area of the cortex (Bigler, 2001).

Dysgraphia—loss or impairment of the ability to write letters, syllables, words and / or phrases (Kolb & Wishaw, 1996).

Dyspraxia—inability to perform previously learned skills (i.e. copying figures, dressing oneself) that cannot be attributed to deficits of motor or sensory function (Kolb & Wishaw, 1996).

Diffuse brain damage—multiple lesions over several areas of the brain resulting from either multiple insults, contrecoup injuries, or environmental insults (i.e. chemical exposure, anoxia) (Bigler, 2001).

Dysnomia—difficulty in naming objects and people that are correctly perceived (Kolb & Wishaw, 1996).

Lateraledized brain damage—a lesion specific to the right or left hemisphere of the brain (Dean, 1984).

Pathognomic signs—refers to a set of behaviors that are deemed to be characteristic of a particular dysfunction, problem, and /or diagnosis (Dial & McCarron, 1986).

Retrograde amnesia—loss of the ability to recall information that had been previously encoded in memory prior to a specified or approximate point in time; may be due to a brain injury or emotional trauma (Kolb & Wishaw, 1996)
APPENDIX B
INFORMED CONSENT
Title of Study: The Utility of the McCarron-Dial System in Determining Location of Brain Lesion

Principal Investigator: Erin K. Gregory, M.S.

Co-Investigators: Genie Bodenhamer-Davis, Ph.D., Jack Dial, Ph.D.

Before agreeing to participate in this research study, it is important that you read and understand the following explanation of the proposed procedures. It describes the procedures, benefits, risks, and discomforts of the study. It also describes your right to withdraw from the study at any time. It is important for you to understand that no guarantees or assurances can be made as to the results of this study.

Start Date of Study: 03/13/2003  End Date of Study: 03/12/2004

Purpose of the Study
The purpose of this study is to learn how well some neuropsychological tests can determine if someone has experienced brain damage, and if so, where in the brain damage has occurred.

Description of the Study
As a participant in this study, you will be asked to provide basic demographic information such as your age, gender, ethnicity, and years of education. You will also be asked some questions regarding history of head injury, learning difficulties in school, and current or previous substance use. If you use any aids to correct visual or hearing impairments, please use them during your testing session.

You will be completing 4-5 hours of neuropsychological testing. The tasks you will be asked to do will assess memory, language functioning, spatial reasoning ability, and academic skills. The tasks involve manipulating test materials such as blocks, solving word and arithmetic problems, and copying figures. Breaks will be allowed during testing. You are welcome to bring a snack with you to your testing session.
**Description of the Foreseeable Risks**
The potential risks associated with participating in this study include fatigue, frustration, and mild discomfort in revealing information of a personal nature.

**Benefits to Participants or Others**
By participating in this study, you will be adding to the body of knowledge regarding the use of the McCarron-Dial System in neuropsychological testing and treatment planning. You may find this experience beneficial as a future human services provider who may be referring clients for similar evaluations. You may also benefit by receiving course credit for your participation. Feedback regarding your performance on the assessment is available upon request.

**Procedures for Maintaining Confidentiality of Research Records**
Your name will not appear on any of the testing protocols or demographic information. Instead, you will be assigned a 3-digit code. Any information recorded about your testing will be done using this code. All information will be confidential and anonymous. If you will be receiving course credit for your participation, only information confirming your participation (i.e. date and duration of testing) will be released to your course instructor. No other information, such as the results of your testing, will be released to another party.

**Review for the Protection of Participants**
This research study has been reviewed and approved by the UNT Committee for the Protection of Human Subjects on March 13, 2003 (Project 03-079). UNT IRB can be contacted at (940) 565-3940 with any questions or concerns regarding this study.

**Research Participant’s Rights**
I have read or have had read to me all of the above.

The principal investigator has explained the study to me and answered all of my questions. I have been told the risks and/or discomforts as well as the possible benefits of the study.

I understand that I do not have to take part in this study and my refusal to participate or to withdraw will involve no penalty, loss of rights, loss of benefits, or legal recourse to which I am entitled. The study personnel may choose to stop my participation at any time.

In case problems or questions arise, I have been told that I can contact Erin Gregory at (940) 565-2671 or ering@unt.edu.
I understand my rights as a research participant and I voluntarily consent to participate in this study. I understand what the study is about, how the study is conducted, and why it is being performed. I have been told I will receive a signed copy of this consent form upon request.

______________________________  _________________________
Signature of Participant     Date

For the Investigator or Designee:
I certify that I have reviewed the contents of this form with the participant signing above. I have explained the known benefits and risks of the research. It is my opinion that the participant understood the explanation.

______________________________  _________________________
Signature of Principal Investigator    Date

APPROVED BY THE UNT IRB
FROM 3/1/03  TO 3/1/04
APPENDIX C
ADJUSTMENT TABLES FOR RACE AND ETHNICITY
### WAIS-III Standard Score Adjustment for Years of Education

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<thead>
<tr>
<th>(Years of Education)</th>
<th>0-8</th>
<th>9-11</th>
<th>12</th>
<th>13-15</th>
<th>16+</th>
</tr>
</thead>
<tbody>
<tr>
<td>WAIS FSIQ</td>
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<td>0</td>
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<td>-3</td>
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<tr>
<td>WAIS VIQ</td>
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<td>+1</td>
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<tr>
<td>WAIS PIQ</td>
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### WRAT-III Standard Score Adjustments for Years of Education

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<tr>
<th>(Years of Education)</th>
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<th>9-11</th>
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<th>16+</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reading</td>
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</tr>
<tr>
<td>Spelling</td>
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<td>0</td>
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<td>Arithmetic</td>
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### BVMGT Standard Score Adjustment for Years of Education

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<th>(Years of Education)</th>
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<th>12</th>
<th>13-15</th>
<th>16+</th>
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<tr>
<td>BVMGT Total</td>
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<td>____</td>
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### HVDT Standard Score Adjustments for Years of Education

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<th>9-11</th>
<th>12</th>
<th>13-15</th>
<th>16+</th>
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<tbody>
<tr>
<td>HVDT Right</td>
<td>+1</td>
<td>+1</td>
<td>____</td>
<td>____</td>
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<tr>
<td>HVDT Left</td>
<td>+2</td>
<td>+1</td>
<td>____</td>
<td>____</td>
<td>-2</td>
</tr>
<tr>
<td>HVDT Total</td>
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<td>+1</td>
<td>____</td>
<td>____</td>
<td>-3</td>
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### MAND Standard Score Adjustments for Years of Education

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<tr>
<th>(Years of Education)</th>
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<th>9-11</th>
<th>12</th>
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<td>-1</td>
<td>+1</td>
<td>-2</td>
<td>___</td>
</tr>
<tr>
<td>Fine</td>
<td>___</td>
<td>___</td>
<td>+1</td>
<td>-2</td>
<td>___</td>
</tr>
<tr>
<td>Gross</td>
<td>+1</td>
<td>-1</td>
<td>+1</td>
<td>-2</td>
<td>___</td>
</tr>
<tr>
<td>Per. Cont.</td>
<td>+3</td>
<td>+2</td>
<td>___</td>
<td>-2</td>
<td>+2</td>
</tr>
<tr>
<td>Muscle Pwr.</td>
<td>+2</td>
<td>-1</td>
<td>+1</td>
<td>-2</td>
<td>+2</td>
</tr>
<tr>
<td>Kin. Int.</td>
<td>-1</td>
<td>-2</td>
<td>+2</td>
<td>-2</td>
<td>-1</td>
</tr>
<tr>
<td>Bi. Dexterity</td>
<td>-5</td>
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<td>+2</td>
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### WAIS III Standard Score Adjustments for Ethnicity

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<th>African-Amer.</th>
<th>Hispanic</th>
<th>Other</th>
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<tbody>
<tr>
<td>WAIS FSIQ</td>
<td>-2</td>
<td>+2</td>
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<td>WAIS VIQ</td>
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WRAT-III Standard Score Adjustments for Ethnicity

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<tbody>
<tr>
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<td>+2</td>
<td>+1</td>
<td>_____</td>
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<tr>
<td>Spelling</td>
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<td>+2</td>
<td>+1</td>
<td>_____</td>
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<tr>
<td>Arithmetic</td>
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BVMGT Standard Score Adjustments for Ethnicity

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HVDT Standard Score Adjustments for Ethnicity

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<td>-1</td>
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<tr>
<td>HVDT Left</td>
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<td>-1</td>
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### MAND Standard Score Adjustments for Ethnicity

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<tr>
<td>Fine</td>
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<td>-1</td>
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</tr>
<tr>
<td>Gross</td>
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</tr>
<tr>
<td>Per. Cont.</td>
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<td>+3</td>
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<tr>
<td>Muscle Pwr.</td>
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</tr>
<tr>
<td>Kin. Int.</td>
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<td></td>
<td>+1</td>
<td></td>
</tr>
<tr>
<td>Bi. Dexterity</td>
<td>+1</td>
<td>+1</td>
<td>-2</td>
<td></td>
</tr>
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</table>

REFERENCES


Vanderploeg (Ed.), *Clinician’s guide to neuropsychological assessment* (2nd ed.).


