THE HALSTEAD-REITAN NEUROPSYCHOLOGICAL TEST BATTERY FOR ADULTS: THEORETICAL, METHODOLOGICAL AND VALIDATIONAL BASES

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I. Background and Development of the Halstead-Reitan Battery (HRB)

After earning his PhD in physiological and comparative psychology at Northwestern University in 1935, Ward Halstead moved to the University of Chicago, established a working relationship with two neurosurgeons, Percival Bailey and Paul Bucy, and started the first full-time laboratory for the examination and evaluation of brain-behavior relationships in human beings.

Halstead's first step in evaluating patients was to observe them in their everyday living situations and attempt to discern which aspects of their behavior were different from the behavior of normal individuals. Fortunately, Halstead was relatively unencumbered by knowledge of the routine approach that existed in this era concerning the effects of brain damage. In fact, at this time and for quite a number of years previously, the principal approach of psychologists was to develop a single test that would diagnose brain damage.

Halstead's observations of persons with cerebral lesions made it apparent at the very beginning that brain-damaged individuals had a wide range of deficits and that a single test would not be able adequately to identify and evaluate the severity of their deficits. Some patients demonstrated motor and sensory-perceptual disorders, often involving one side of the body more than the other. Some patients had specific language deficits representing dysphasia. Other individuals were confused in a more general yet pervasive way (even though in casual contact they often appeared to be quite intact).

As Halstead studied brain-damaged persons in their routine everyday living situations, he observed that most of them seemed to have difficulties in understanding the essential nature of complex problem-situations, in analyzing the circumstances that they had observed, and in reaching meaningful conclusions about the situations they faced in everyday life.

The initial orientation and approach to research and evaluation may have long-term implications, and Halstead's approach was of significance in the eventual clinical use of his tests. Binet and Simon (1916), for example, began developing intelligence tests using academic competence as the criterion. IQ tests, though used to assess cerebral damage, are probably still best known for their relationship to school success. It was important and fortuitous that Halstead decided to observe the adaptive processes and difficulties that brain-damaged persons demonstrated in everyday life. If he had focused only upon academic achievement or classroom activities, it is probable that he would have developed tests that are quite different from the ones he did produce. The tests that are included in the Halstead-Reitan Battery emanated from a general consideration of neuropsychological impairment, and as a result, have much more relevance than IQ measures to practical aspects of rehabilitation and adaptive abilities.

Halstead devised and experimented with numerous psychological testing procedures. The design of his instruments placed them more in the context of standardized experiments than of conventional psychometric tests. Many of the procedures developed by Halstead contrasted sharply with conventional psychometric testing procedures of that time, inasmuch as they required the subject not only to solve the problem, but to observe the nature of the problem, analyze the essential elements, and after having defined the problem, proceed to solve it.

Halstead developed a series of 10 tests that ultimately formed the principal basis for his concept of biological intelligence. He described these tests and presented his theory in his book, *Brain and Intelligence: A Quantitative Study of the Frontal Lobes* (Halstead, 1947). Only seven of the original ten tests have withstood the rigors of both clinical and experimental evaluation. These seven tests constitute a substantial component of the Halstead-Reitan Battery, and are the seven tests used to compute the Halstead Impairment Index.

It became apparent that Halstead's seven tests had to be supplemented with an extensive array of additional procedures for the battery to attain clinical usefulness. The General Neuropsychological Deficit Scale (GNDS), a measure that provides an overall characterization of an individual's neuropsychological abilities and has proved to be highly sensitive to the effects of brain damage as well as clinically useful as a method of comparing areas of deficit, is based upon a total of 42 variables derived from measures in the Halstead-Reitan Battery (including the original seven tests developed by Halstead) (Reitan & Wolfson, 1988, 1993).

Another significant feature of the Halstead-Reitan Battery is that it was developed and validated not only by formal research, but also by evaluating thousands of patients with brain lesions and control subjects. This procedure involved administering the tests, evaluating the results, preparing a written report about their significance for brain functions, and only then turning to the independent data produced by complete and independent evaluations based on clinical tests and diagnostic studies by neurologists, neurological surgeons, and neuropathologists.

After the two sets of data had been collected, conferences were held to correlate the neuropsychological findings with the independently obtained history and neurological, neurosurgical, and neuropathological data (concerning location, type, duration, etc. of the lesion). In this way each subject served as an independent experiment. Using this procedure, Reitan studied over 8,000 patients. The Halstead-Reitan Battery (HRB) served as a focus for research in the area of human brain-behavior relationships long before the area of clinical neuropsychology emerged as a discipline, and in this sense the Halstead-Reitan Battery has played a significant role in the development of the field of neuropsychology.

During the 1950's and early 1960's published research from the Reitan Neuropsychology Laboratory stimulated much interest; however, it also generated a considerable degree of skepticism and criticism from psychologists as well as neurologists and neurological surgeons. There was a general reluctance toward accepting findings that proposed that the higher-level aspects of brain functions (which had been elusive for so many years) could actually be measured, quantified, and even used as a basis for predicting "blindly" the location and type of brain lesions (Reitan, 1964). However, the HRB was used with increasing frequency in many hospitals and clinics in the United States and other countries, and the apparent validity of the findings among researchers and clinicians gradually overcame this kind of skepticism.

Hartlage and DeFilippis (1983) reported the results of a survey conducted in 1980 of all neuropsychologists in the National Academy of Neuropsychologists and all members of the Division of

Clinical Neuropsychology of the American Psychological Association. The results indicated that 89% of the respondents used the Wechsler scales in their neuropsychological assessments, 56% included portions of the Halstead-Reitan Battery, 49% used the Bender-Gestalt Test, 38% used the entire Halstead-Reitan Battery, 32% employed the Benton Visual Retention Test, and 31% used the Luria-Nebraska Battery. McCaffrey and Isaac (1984) reported that in 1982, 65% of their respondents used the HRB; in the later survey by McCaffrey and Lynch (1996) found that this percentage had risen to 77%.

Dean (1985) reviewed the Halstead-Reitan Neuropsychological Test Battery in the *Ninth Mental Measurements Yearbook*. In his review, he indicated that, "neuropsychological assessment in North America has focused on the development of test batteries that would predict the presence of brain damage while offering a comprehensive view of a patient's individual functions. Numerous batteries have been offered as wide-band measures of the integrity and functioning of the brain. However, the HRB remains the most researched and widely utilized measure in the United States" (p. 642).

Meier (1985) also reviewed the Halstead-Reitan Neuropsychological Test Battery and had the following introductory comment:

> "This comprehensive neuropsychological test battery has a long and illustrious history of clinical research and application in American clinical neuropsychology. Following its inaugural presentation to the psychological community (Halstead, 1947), and the careful nurturance of concept and application by Reitan (1974), the battery has had perhaps the most widespread impact of any approach in clinical neuropsychology. It seems reasonable to state that in the first half of the period since World War II, during which neuropsychology expanded so remarkably, this approach was the primary force in stimulating clinical research and application in this country" (p. 646).

II. Practical Considerations in the Development of a Neuropsychological Test Battery

A valid neuropsychological test battery cannot be developed without meeting a number of criteria that relate to relationships with extensively derived indicators of brain damage as well as complementary approaches in assessment.

A. Relation to Specialized Neurological Diagnostic Procedures

The relationship between neuropsychological testing and the many excellent specialized medical diagnostic procedures (especially computerized tomography (CT) and magnetic resonance imaging (MRI) must be evaluated. Comparisons of test data with the results of brain imaging procedures is important in validating neuropsychological tests. However, it has also been a cause of concern regarding the independent value of neuropsychological testing to those psychologists and physicians who consider the principal purpose of neuropsychological examination to be the diagnosis of brain damage rather than evaluation of brain-behavior relationships.

It is important to recognize that neuropsychological evaluation draws on a different domain of evidence, to a major extent, than the diagnostic methods used by neurologists and neurological surgeons do. The Halstead-Reitan Battery focuses on higher-level aspects of brain functions (and more specifically on central processing), whereas the neurological diagnostic procedures relate principally to lower-level aspects of brain functioning or non-behavioral variables, such as electrophysiological manifestations or brain imaging procedures. Neuropsychological evaluation provides the *only* rigorous and objective method of assessing higher-level aspects of brain functions.

CT and MRI scans are highly accurate diagnostic techniques. Both procedures identify structural abnormalities in the brain, such as space-occupying lesions and the types of tissue abnormalities characteristic of diseases, such as multiple sclerosis. However, in cases of closed head injury, in which small vascular lesions or shearing of neurons may occur on a widespread basis, CT and MRI scans are frequently within normal limits. Despite their sensitivity to structural lesions and disorders of brain functions, even functional MRI, positron emission tomography, and single photon emission spectroscopy are often not able to identify deficits in higher-level aspects of brain functions. An important need, therefore, has arisen for detailed studies of the correlation between these imaging procedures and neuropsychological test results, because imaging procedures cannot evaluate an individual's general intelligence or other adaptive abilities. (The usefulness of the clinical neurological examination and specialized neurological diagnostic procedures is discussed in detail in Reitan & Wolfson, 1992a).

The fact that results from the Halstead-Reitan Battery have been shown to correlate closely with the findings of the overall neurological examination validates the neuropsychological data as indicators of the biological condition of the brain. However, it is important to recognize that these various procedures complement rather than compete with each other in providing information about the patient. If an individual's higher-level brain functions need to be evaluated, a neuropsychological examination must be performed to obtain the relevant information.

B. "Fixed" versus "Flexible" Neuropsychological Testing Procedures

The comparative advantages of fixed (or standard) versus flexible (or composed to meet the immediate assessment needs) batteries have received a considerable amount of attention (Incagnoli, Goldstein, & Golden, 1986).

The terms "fixed battery" and "flexible battery" are misleading, insofar as fixed may be taken to mean inflexible and not able to be supplemented with other tests. Flexible, on the other hand, may imply that adaptations are possible to meet the requirements of the individual situation without a loss of validity in evaluation. In practice, fixed batteries could be equated with a standard set of instruments that has been validated through extensive research with thousands of patients, with resulting consensus among thousands of psychologists around the world.

In contrast, the psychologist evaluating the patient, usually according to the history and complaints of each patient, decides upon the composition of flexible batteries. To the degree that they differ from standard batteries, these individualized series of tests have never been evaluated as a battery in research studies or assessed by consensus of other psychologists.

Flexible batteries tend to deny the concept of a battery of tests that has been designed to assess human brain functions. In this sense, fixed batteries might be better labeled as "validated" batteries, and flexible batteries as "casually composed" batteries that have never been rigorously validated or, in most instances, evaluated with regard to accuracy in diagnosing a single pathological condition (such as traumatic brain injury, cerebrovascular disease, and so on). To the extent that they are composed to assess specific referral complaints or the subjective complaints of the patient (Christensen, 1975), flexible batteries may be referred to as "symptom-oriented" batteries, with the validity and range of the battery depending on the accuracy and completeness of complaints offered by each subject examined.

Supposed advantages of the flexible battery include the prerogative to select tests to evaluate specific areas of function that accord with the patient's complaints. Of course, such a procedure might be circular in nature if the end result were only to confirm through psychological testing the patient's own initial self-evaluation (self-diagnosis).

Further, if the patient's subjective complaints are not sufficiently comprehensive, or if the patient is not able to offer an adequate and complete self-diagnosis, the resulting test battery may fail to recognize and evaluate significant areas of cerebral dysfunction. In any case, the series of tests selected by the psychologist will demonstrate a range of scores. Consequently, using this approach, the tests with low scores are usually selected as indicators of cognitive impairment.

In contrast, the fixed battery approach uses a constant group of tests. In this sense, the Halstead-Reitan Battery can be thought of as a comprehensive battery, and validated on thousands of patients to ensure that all relevant areas of brain functions are included in the assessment, thereby providing a balanced representation of the various neuropsychological functions subserved by the brain.

Finally, each test in the Halstead-Reitan Battery has been subjected to the rigorous research that is necessary to validate it as a neuropsychological test. In addition, the tests in the HRB have also been validated for their complementary significance and interpretation for assessment of the individual.

Results obtained on the Halstead-Reitan Battery regularly demonstrate the advantage of using a standard and comprehensive battery of tests. As shown in formal studies (Reitan, 1964), it is often possible, using only the HRB test results, to determine that cerebral damage has been sustained, to identify the area or location of principal involvement, and to assess whether the injury is recent or the brain has had an opportunity to stabilize. Further, from the point of view of rehabilitation, it is imperative to have a balanced representation of the nature and degree of neuropsychological deficit.

Considering the importance of assessing all neuropsychological aspects of brain function in a balanced and comparative manner, and the advantages of determining the complementary nature of results on various tests (thus achieving a battery effect in which the sum is greater than the individual components), and considering the obvious facilitation of validational research, Halstead and Reitan decided at the beginning develop a standardized battery rather than use a variable selection of individual tests.

C. Differing Approaches to Neuropsychological Interpretation

Neuropsychologists have developed differing attitudes toward neuropsychological testing and the use of supplemental information to obtain valid results. The problem appears to arise from an attempt to emulate the medical model, or more specifically, the procedures used in neurology. In the field of neurology, it is routinely recommended that the results of the EEG, CT, MRI, and other specialized diagnostic procedures be evaluated only in the context of the patient's clinical history. This approach represents a double-edged sword inasmuch as history information may influence the interpretation of the diagnostic procedure or the diagnostic procedure may be used to controvert the history information.

Some neuropsychologists contend that neuropsychological evaluation is of value only if the test results are interpreted with full knowledge of the patient and his/her usual behavior. In some instances, the neuropsychologist requires personal observation of the patient at considerable length and in various types of settings in order to obtain enough information to be able to interpret the test results. In other instances, the neuropsychologist requires the findings of other professionals, knowledge of the subject's demographic and personal behavior characteristics, detailed academic and occupational histories, and interaction with family members and other persons in the environment as a basis for interpreting the neuropsychological test results. Psychologists who adopt this approach obviously feel that neuropsychological test data does not constitute a significant source of independent information and needs to be interpreted in the framework of complementary sources of information to achieve validity.

Other neuropsychologists believe that neuropsychological testing is of value, but that a score or index cannot adequately reflect a subject's performances. This contention derives historically from the insistence by Kurt Goldstein (1942a, 1942b) that the procedures used by brain-damaged individuals to solve problems differ from the methods utilized by persons with normal brain functions, and that the principal value of the testing has been lost if the procedures used by the patient are not observed and recorded. Goldstein believed that a final score, representing the adequacy of the subject's performances, was entirely inadequate, and that the process by which the individual achieved the end result was of critical importance. This contention has been carried forward by a number of other investigators (most notably Edith Kaplan), who have differentiated performances on the same task in accordance with the types of errors made by the subject, and related such information to neuropsychological interpretations of brain functions.

A final approach to this problem, represented principally by Reitan and others, recommends that the neuropsychological examination evaluate brain functions generally for every subject, and that a “blind” interpretation of the test findings be prepared before referring to any history information, conclusions reached by other professionals, or the results of additional diagnostic procedures. If the psychologist administers the tests personally, it is inescapable that he/she will observe the subject's performances and will formulate opinions based on the process the subject used to perform a task rather than on the test scores alone. The important point in this procedure, however, is related to the *sequence* the neuropsychologist follows to evaluate the subject. We recommend the sequential steps described below.

First, the neuropsychological test data is evaluated, including notations about any deviations from standard testing procedures, and perhaps even the process the subject uses to reach a solution. This first step should be completed before referring to any additional information, such as the history, findings of other examinations, or conclusions of other professionals. This procedure allows the neuropsychologist to evaluate the relevance of the test data and determine the extent to which it can make an independent contribution to understanding the patient's brain functions and cognitive structure.

After interpreting the neuropsychological test data “blindly,” all additional information should be evaluated, including the complete history, the results of examinations by other professionals, the findings of neurological diagnostic procedures, the individual's behavior in everyday living situations, his/her interaction with family members and other significant persons in the environment, and the academic, employment, military, and professional records. Wolfson (1985) has systematized our history-gathering procedures by preparing a formal guide that explores an extensive range of relevant areas. The reader will notice that our method differs from the other approaches mentioned above only in terms of the sequence in which information is reviewed. In our system, the final interpretation of the data depends (as it does in the other approaches) upon an integration and evaluation of the consistency of all available information relating to the patient.

We prefer to avoid the risk of prejudicing the interpretation of the neuropsychological test results with supplemental information. We therefore perform an initial “blind” interpretation of the test data, and then relate these findings to any other available information. It is important to recognize that much of the history information and personal observations of the patient's behavior are obtained under inadequately standardized and uncontrolled conditions, which certainly impair interjudge reliability and the potential for unprejudiced interpretation of the test data.

A number of neuropsychologists have emphasized the importance of supplementing the information provided by the quantitative testing with observations of qualitative behavior. Such qualitative observations can be useful, but it must be recognized that some psychologists are more adept than others in reaching valid conclusions on the basis of their behavioral observations. In fact, if conclusions are based on impressions of qualitative aspects of behavioral manifestations, a considerable degree of interjudge unreliability is likely to result.

Many studies have shown that behavioral ratings among psychologists and/or psychiatrists tend to be quite variable, even when the judges are thoroughly experienced. However, these kinds of problems of reliability do not necessarily detract from the valid observations that may be made by some judges. In our own practice we have observed many subjects experiencing the stress involved with neuropsychological testing. The Tactual Performance Test, for example, is often more stressful for brain-damaged persons than individuals with normal brain functions. Thus, the difficulty-level of the task and the subject's reactions during the testing almost certainly contribute information over and beyond the quantitative score for the test.

Halstead and Reitan, having observed the various approaches to problem-solving utilized by normal and brain-damaged persons, were keenly aware of the potential implicit in assessing a subject's qualitative performances during neuropsychological testing. They were interested, nevertheless, in exploring the potential value of standardized procedures that produced quantitative scores as a basis for evaluating brain-behavior relationships. It is generally accepted that a standardized procedure that produces a quantitative score is more replicable and reproducible – and thus has greater reliability – than judgments about the qualitative aspects of behavior.

In discussing the strategy that they wished to employ in neuropsychological examination, Halstead and Reitan believed that it would be desirable to differentiate and separate the quantitative scores (which more closely meet the hallmark in science of replicability) from the observations of the patient's behavior. This decision was not intended to either deny the potential value of behavioral observations or to rule out the use of behavioral observations to supplement and complement the quantitative data produced by neuropsychological testing. However, if neuropsychology was to be established as a science rather than an art, it was critical to define the standardized testing procedures that would produce quantitative scores separate from the clinician's insightful observations of the subject's behavior.

It is not surprising that many investigators continue to emphasize the importance of qualitative observations. In fact, it appears that neuropsychologists who depend upon these procedures have a clinical orientation, and through their training have developed skills in understanding impaired brain functions through the subject's behavioral manifestations. Proponents of this approach may also include psychologists who have had a lesser degree of success in validating their conclusions based upon interpretation of quantitative scores.

The debate concerning the use of qualitative versus quantitative methods for assessment of the effects of cerebral damage has a long history. Qualitative observations and analyses of behavior necessarily precede translation of such observations into standardized and quantified neuropsychological tests, which is the precise procedure used by Halstead and Reitan in developing the tests included in the HRB. Kurt Goldstein (1942a, 1942b) argued that *only* quantitative evaluations were valid, and that quantitative assessments might only confuse the issue because a brain-impaired and a normal subject might earn the same quantitative score but use different approaches to do so. Goldstein claimed that brain damage inevitably produced a “concrete” approach to problem-solving, whereas the person with normal brain functions was able to adopt an “abstract” approach. According to Goldstein, it was imperative to observe the performances of brain-damaged subjects in order to determine whether the brain damage had imposed any limitations on the individual's cognitive functioning.

Luria (personal communication, 1967) had a very similar orientation towards this question. In a letter to one of the authors (RMR), he stated quite explicitly that little, if anything, could be gained by translating neuropsychological deficits into quantitative values, and believed that it was necessary to observe the performance style of the brain-damaged individual in order to understand that person's limitations.

As we have noted, the use of a standardized and replicable procedure in neuropsychological examination in no way obviates or even interferes with the use of clinical observation by those neuropsychologists who feel that they are skilled in this respect. At the same time, clinical observation (as contrasted with quantitative measurement of performances) should not be proposed — as Goldstein and Luria have done — as the *only* method that can validly identify the deficits of brain-injured persons.

D. The Development and Incorporation of Multiple and Complementary Methods of Inferring Cerebral Damage into a Single Battery

A critical incident that led to the development of the HRB as a battery that describes the uniqueness of brain impairment of individual subjects occurred in 1945. One of the authors (RMR) had examined an extremely competent physician who had sustained a depressed skull fracture and complained of various significant deficits following the injury. Despite his complaints, this physician consistently performed well above average on the tests he had been given. Although the examination demonstrated that he had excellent abilities, his complaints seemed clinically valid. If this physician was indeed impaired as compared to his premorbid status, we needed to find a way to assess his deficits. Thus, the challenge was set. The problem required a methodology that described the impairment in the individual subject, regardless of whether the subject's premorbid level of functioning was high or low.

We realized that it was necessary to design the battery so that methods of inference other than level of performance would contribute to the clinical conclusions. Four approaches could be used to evaluate a subject's performances: (1) level of performance (how well the subject performed on a test compared to other subjects), (2) pathognomonic signs (specific deficits that rarely occur without cerebral damage), (3) patterns and relationships among test results (identification of score patterns that reflected localized or lateralized damage as well as relationships which compared premorbid abilities with evidence of acquired impairment), and (4) comparisons of a subject's performances on the same test on each side of the body.

A great deal of formal research and clinical evaluation was necessary to develop tests that met the above requirements and also were valid measurements of the biological integrity of the brain. It was necessary that the tests complemented each other in interpretation, were as economical as possible in the time required for administration, were consistently sensitive to cerebral damage or dysfunction across a broad range of neurological conditions, and reflected an individual's deficits in a balanced and equivalent manner.

III. Content of the Halstead-Reitan Battery and its Conceptual and Theoretical Bases

Theory-building requires basic facts on which to develop constructs, and the short lives of many of the molar theories of brain-behavior relationships can be directly attributed to their inconsistency with the facts (see Reitan & Wolfson, 1988, 1993 for a review of theories in clinical neuropsychology). Our method of developing a theory differed from those customarily used. We tried at first to generate a fairly extensive body of facts which in turn could lead us to a broader conceptualization or generalization about relationships between the brain and neuropsychological functions. Our approach was therefore “fact-driven” rather than “theory-driven.” We tried initially to meet the methodological requirements noted above and to compose a set of tests (the HRB) that was consistently valid, in both research and clinical application, as a basis for describing the ways in which the brain relates to behavior. Our empirical approach, guided by validated research findings and clinical verification in the individual case, led to the development of the Reitan-Wolfson model of neuropsychological functioning. We believe that this procedure may have more objectivity than an approach that postulates a theory and then searches for facts to support it.

The brain-based functions an individual needs in order to be efficient in his or her everyday behavior fall in several categories. The Reitan-Wolfson model of neuropsychological functioning(see Fig.

1) provides a conceptual framework for organizing the behavioral correlates of brain functions and describing the tests that measure these functions.

A neuropsychological response cycle first requires input to the brain from the external environment via one or more of the sensory avenues. Primary sensory areas are located in each cerebral hemisphere, indicating that this level of central processing is widely represented in the cerebral cortex and involves the temporal, parietal, and occipital areas particularly (see Reitan & Wolfson, 1993 for a description of the anatomical structures and systems for each of the elements of the Reitan-Wolfson model).

Once sensory information reaches the brain, the first step in central processing is the “registration phase” and represents alertness, attention, continued concentration, and the ability to screen incoming information in relation to prior experiences (immediate, intermediate, and remote memory). When evaluating this level of functioning, the neuropsychologist is concerned with answering questions such as, How well can this individual pay attention to a specified task? Can he/she utilize past experiences (memory) effectively and efficiently to reach a reasonable solution to a problem? Can the person understand and follow simple instructions?

If an individual's brain is not capable of registering incoming information, relating the new information to past experiences (memory), and establishing the relevance of the information, the subject is almost certainly seriously impaired in everyday behavior. A person who is not able to maintain alertness and a degree of concentration is likely to make very little progress as he\she attempts to solve a problem. Persons with such severe impairment have limited opportunity to effectively utilize any of the other higher level abilities that the brain subserves, and they tend to perform quite poorly on almost any task presented to them.

Because alertness and concentration are necessary for all aspects of problem-solving, a comprehensive neuropsychological test battery should include measures that evaluate the subject's attentiveness. Such tests should not be complicated and difficult, but should require the person to pay close attention over time to specific stimulus material. The Halstead-Reitan Battery evaluates this first level of central processing primarily with two measures: the Speech-sounds Perception Test (SSPT) and the Rhythm Test.

The Speech-sounds Perception Test consists of 60 spoken nonsense words that are variants of the “ee” sound. The stimuli are presented on a tape recording, and the subject responds to each stimulus by underlining one of four alternatives printed on an answer sheet.

The SSPT requires the subject to maintain attention through the 60 items, perceive the spoken stimulus through hearing, and relate the perception through vision to the correct configuration of letters on the test form.

The Rhythm Test requires the subject to differentiate between 30 pairs of rhythmic beats. The stimuli are presented by a standardized tape recording. After listening to a pair of stimuli, the subject writes “S” on the answer sheet if he/she thinks the two stimuli sounded the same, and writes “D” if they sounded different.

The Rhythm Test requires alertness to nonverbal auditory stimuli, sustained attention to the task, and the ability to perceive and compare different rhythmic sequences. Although many psychologists have presumed that the Rhythm Test is dependent upon the integrity of the right hemisphere (because the content is nonverbal), the test is actually an indicator of generalized cerebral functions and has no lateralizing significance (Reitan & Wolfson, 1989).

After an initial registration of incoming material, the brain customarily proceeds to process verbal information in the left cerebral hemisphere and visual-spatial information in the right cerebral hemisphere. At this point the specialized functions of the two hemispheres become operational.

The left cerebral hemisphere is particularly involved in speech and language functions, or the use of language symbols for communication purposes. It is important to remember that deficits may involve quite simple kinds of speech and language skills, or conversely, may involve sophisticated higher-level aspects of verbal communication. It also must be recognized that language functions may be impaired in terms of expressive capabilities, receptive functions, or both (Reitan, 1984). Thus, the neuropsychological examination must assess an individual's ability to express language as a response, to understand language through both the auditory and visual avenues, and to complete the entire response cycle, which consists of perception of language information, central processing and understanding of its content, and the development of an effective response.

The Halstead-Reitan Battery measures both simple and complex verbal functions. The Reitan-Indiana Aphasia Screening Test (AST) is used to evaluate language functions such as naming common objects, spelling simple words, reading, writing, enunciating, identifying individual numbers and letters, and performing simple arithmetic computations.

The AST is organized so that performances are evaluated in terms of the particular sensory modalities through which the stimuli are perceived. Additionally, the receptive and expressive components of the test allow the neuropsychologist to judge whether the limiting deficit for a subject is principally receptive or expressive in character. The verbal subtests of the WAIS are also used to obtain information about verbal intelligence.

Right cerebral hemisphere functions are particularly involved with spatial abilities (mediated principally by vision but also by touch and auditory function) and spatial and manipulatory skills (Reitan, 1955a; Wheeler & Reitan, 1962). It is again important to remember that an individual may be impaired in the expressive aspects or the receptive aspects of visual-spatial functioning, or both. It must also be kept in mind that we live in a world of time and space as well as in a world of verbal communication. Persons with impairment of visual-spatial abilities are often severely handicapped in terms of efficiency of functioning in a practical, everyday sense.

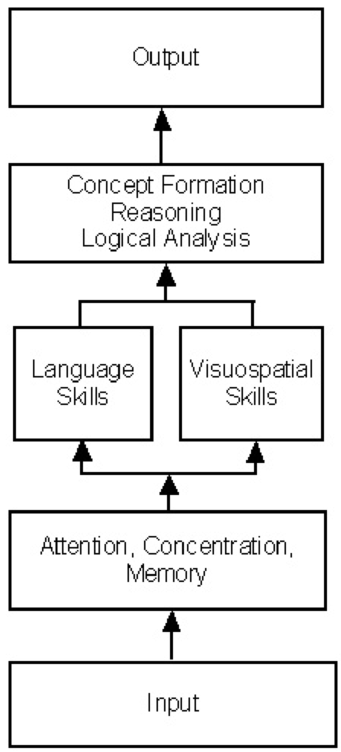
The HRB assesses visual-spatial functions with simple as well as complex tasks. Particularly important are the drawings of the square, cross, and triangle of the Aphasia Screening Test, the WAIS Performance subtests, and to an extent, Parts A and B of the Trail Making Test.

In evaluating the drawings on the AST, the criterion of brain damage relates to specific distortions of the spatial configurations rather than to artistic skill. The square and triangle are relatively simple figures, and do not usually challenge an individual's appreciation and production of spatial configurations. The cross involves many turns and a number of directions, and can provide significant information about a subject's understanding of visual-spatial form.

Comparisons of performances on the two sides of the body, using both motor and sensory-perceptual tasks, provide information about the integrity of each cerebral hemisphere, and more specifically, about areas within each hemisphere. Both finger tapping and grip strength yield information about the posterior frontal (motor) areas of each cerebral hemisphere.

The Tactual Performance Test (TPT) requires complex problem-solving skills and can provide information about the adequacy of each cerebral hemisphere. The subject is blindfolded before the test begins and is not permitted to see the form board or blocks at any time. The first task is to fit the blocks into their proper spaces on the board using only the preferred hand. After completing this task (and without having been given prior warning), the subject is asked to perform the same task using only the nonpreferred hand. Finally, and again without prior warning, the task is repeated a third time using both hands. The amount of time required to perform each of the three trials provides a comparison of the efficiency of performance of the two hands. The Total Time score of the test reflects the amount of time needed to complete all three trials.

After the subject has completed the third trial, the board and blocks are taken out of the testing area and the subject's blindfold is removed. The subject is then asked to draw a diagram of the board with the blocks in their proper spaces. The Memory score is the number of shapes correctly remembered; the Localization score is the number of blocks correctly identified by both shape and position on the board.



The Reitan-Wolfson Model of Neuropsychological Functioning

An important aspect of the Tactual Performance Test relates to the neurological model. The test's design and procedure allows the functional efficiency of the two cerebral hemispheres to be compared and provides information about the general efficiency of brain functions. During the first trial, data is being transmitted from the preferred hand to the contralateral cerebral hemisphere (usually from the right hand to the left cerebral hemisphere). Under normal circumstances, positive practice-effect results in a reduction of time of about one-third from the first trial to the second trial. A similar reduction in time occurs between the second trial and the third trial.

The TPT is undoubtedly a complex task in terms of its motor and sensory requirements, and successful performance appears to be principally dependent on the middle part of the cerebral hemispheres. Ability to correctly place the variously shaped blocks on the board depends upon tactile form discrimination, kinesthesis, coordination of movement of the upper extremities, manual dexterity, and an appreciation of the relationship between the spatial configuration of the shapes and their location on the board. Obviously, the TPT is considerably more complex in its problem-solving requirements than either finger tapping or grip strength.

The tests for bilateral simultaneous sensory stimulation include tactile, auditory, and visual stimuli. Impaired perception of stimulation occurs on the side of the body contralateral to a damaged hemisphere.

The Tactile Form Recognition Test requires the subject to identify shapes through the sense of touch and yields information about the integrity of the contralateral parietal area.

Finger localization and finger-tip number writing perception also provide information about the parietal area of the contralateral cerebral hemisphere. Finger-tip number writing requires considerably more alertness and concentration, or perhaps even more general intelligence, than finger localization (Fitzhugh, Fitzhugh, & Reitan, 1962c).

In the Reitan-Wolfson theory of neuropsychological functioning, the highest level of central processing is represented by abstraction, reasoning, concept formation, and logical analysis skills. Research evidence indicates that these abilities have a general rather than a specific representation throughout the cerebral cortex (Doehring & Reitan, 1962). The generality and importance of abstraction and reasoning skills may be suggested biologically by the fact that these skills are distributed throughout the cerebral cortex rather than being limited as a specialized function of one cerebral hemisphere or a particular area within a hemisphere. Generalized distribution of abstraction abilities throughout the cerebral cortex may also be significant in the interaction of abstraction with more specific abilities (such as language) that are represented more focally.

Impairment at the highest level of central processing has profound implications for the adequacy of neuropsychological functioning. Persons with deficits in abstraction and reasoning functions have lost a great deal of the ability to profit from their experiences in a meaningful, logical, and organized manner. However, since their deficits are general rather than specific in nature, such persons may appear to be relatively intact in casual contact. Because of the close relationship between organized behavior and memory, these subjects often complain of “memory” problems and are grossly inefficient in practical, everyday tasks. They are not able to organize their activities properly, and frequently direct a considerable amount of time and energy to elements of a situation that are not appropriate to the nature of the problem.

This nonappropriate activity, together with an eventual withdrawal from attempting to deal with problem situations, constitutes a major component of what is frequently (and imprecisely) referred to as “personality” change. Upon clinical inquiry, such changes are often found to consist of erratic and poorly planned behavior, deterioration of personal hygiene, a lack of concern and understanding for others, etc. When examined neuropsychologically, it is often discovered that these behaviors are largely represented by cognitive changes at the highest level of central processing rather than emotional deterioration *per se*.

Finally, in the solution of problems or expression of intelligent behavior, the sequential element from input to output frequently involves an interaction of the various aspects of central processing. Visual-spatial skills, for example, are closely dependent upon registration and continued attention to incoming material of a visual-spatial nature, but analysis and understanding of the problem also involves the highest element of central processing, represented by concept formation, reasoning, and logical analysis. Exactly the same kind of arrangement between areas of functioning in the Reitan-Wolfson model would relate to adequacy in using verbal and language skills. In fact, the speed and facility with which an individual carries out such interactions within the content categories of central processing probably in itself represents a significant aspect of efficiency in brain functioning.

The HRB uses several measures to evaluate abstraction skills, including the Category Test, the Trail Making Test, and the overall efficiency of performance demonstrated on the Tactual Performance Test.

The Category Test has several characteristics that make it unique compared to many other tests. The Category Test is a relatively complex test of concept formation that requires ability (1) to note recurring similarities and differences in stimulus material, (2) to postulate reasonable hypotheses about these similarities and differences, (3) to test these hypotheses by receiving positive or negative information (bell or buzzer), and (4) to adapt hypotheses based on the information received after each response.

The Category Test is not particularly difficult for most normal subjects. Since the subject is required to postulate solutions in a structured (rather than permissive) context, the Category Test appears to require particular competence in abstraction ability. The test in effect presents each subject with a learning experiment in concept formation. This is in contrast to the usual situation in psychological testing, which requires solution of an integral problem situation.

The primary purpose of the Category Test is to determine the subject's ability to use both negative and positive experiences as a basis for altering and adapting his/her performance (i.e., developing different hypotheses to determine the theme of each subtest). The precise pattern and sequence of positive and negative information (the bell or buzzer) in the Category Test is probably never exactly the same for any two subjects (or for the same subject upon repetition of the test). Since it can be presumed that every item in the test affects the subject's response to ensuing items, the usual approaches toward determination of reliability indices may be confounded. Nevertheless, the essential nature of the Category Test, as an experiment in concept formation, is clear.

The Category Test is probably the best measure in the HRB of abstraction, reasoning, and logical analysis abilities, which in turn are essential for organized planning. As noted above, subjects who perform especially poorly on the Category Test often complain of having “memory” problems. In fact, the Category Test requires organized memory (as contrasted with the simple reproduction of stimulus material required of most short-term memory tests), and is probably a more meaningful indication of memory in practical, complex, everyday situations than most so-called “memory” tests, especially considering that memory, in a purposeful behavioral context, necessarily depends on relating the various aspects of a situation to each other (see Reitan & Wolfson, 1988, 1993, for a discussion of this concept).

The Trail Making Test is composed of two Parts, A and B. Part A consists of 25 circles printed on a sheet of paper. Each circle contains a number from 1 to 25. The subject's task is to connect the circles with a pencil line as quickly as possible, beginning with the number 1 and proceeding in numerical sequence. Part B consists of 25 circles numbered from 1 to 13 and lettered from A to L. The task in Part B is to connect the circles, in sequence, alternating between numbers and letters. The scores represent the number of seconds required to complete each Part.

The Trail Making Test requires immediate recognition of the symbolic significance of numbers and letters, ability to scan the page continuously to identify the next number or letter in sequence, flexibility in integrating the numerical and alphabetical series, and completion of these requirements under the pressure of time. It is likely that the ability to deal with the numerical and language symbols (numbers and letters) is sustained by the left cerebral hemisphere, the visual scanning task necessary to perceive the spatial distribution of the stimulus material is represented by the right cerebral hemisphere, and speed and efficiency of performance may reflect the general adequacy of brain functions. It is therefore not surprising that the Trail Making Test, which requires simultaneous integration of these several abilities, is one of the best measures of general brain functions (Reitan, 1955d, 1958).

IV. Validation of the Halstead-Reitan Neuropsychological Test Battery

As noted previously, Dean (1985) cited the HRB as the “most researched” neuropsychological battery in the United States. Of even greater significance is the fact that the clinical usefulness of the HRB has been demonstrated in thousands of settings around the world, in laboratories ranging from clinical offices to major medical centers and universities.

Reitan's own research efforts began with general issues relating to brain-behavior relationships and proceeded to increasingly specific questions. Investigations were ordered in such a way that serially forthcoming information would arrive in a context of prior data.

First, the general effects of heterogeneous brain lesions were investigated; second, the differential effects of lateralized cerebral lesions without regard to type were studied; third, regional localization effects were identified; fourth, differences in effects of various pathologies and duration of lesion were researched; fifth, the neuropsychological correlates of brain lesions that were relatively chronic and static were compared with lesions that were acute and/or rapidly progressive; and sixth, the interaction among these variables and their relationship to the full range of cerebral damage, disease, and disorders was studied. Because our unit of value continually focused on the individual, the generality and specificity of application of the research results to individual subjects was routinely evaluated. No other test battery, or set of neuropsychological tests, has been evolved or studied in this organized and systematic manner.

A. General Neuropsychological Effects of Cerebral Damage

Reitan’s first study on the HRB compared results obtained with Halstead's ten tests in a group of 50 subjects with documented cerebral damage or dysfunction and a group of 50 control subjects who had no history of cerebral disease or dysfunction (Reitan, 1955c). A heterogeneous and diverse group of subjects with cerebral damage was included in order to ensure that an extensive range of conditions would be represented.

Persons with diverse medical conditions were deliberately included among the control subjects, and persons with brain damage were carefully excluded. Normally functioning individuals comprised 24% of the control group, and the remaining 76% was composed of patients hospitalized for a variety of difficulties *not* involving impaired brain functions. The control group included a substantial proportion of paraplegic and neurotic patients in order to minimize the probability that any intergroup differences could be attributed to variables such as hospitalization, chronic illness, and affective disturbances.

The two groups were matched in pairs on the basis of race and gender, and as closely as possible for chronological age and years of formal education. The difference in mean age for the two groups was .06 years, and the difference in mean education was .02 years. The two groups were obviously very closely matched for age and education, and the standard deviations for age and education in the two groups were nearly identical.

Although the two groups should have produced essentially comparable results on the basis of the controlled variables alone, the presence of brain damage in one group was responsible for a striking difference in the test results. Seven of the measures devised and described by Halstead showed differences between the mean scores for the two groups, with relation to variability estimates, which achieved striking significance from a statistical point of view. In fact, according to the most detailed tables we had been able to find, the probability estimates not only exceeded the .01 or .001 levels, but exceeded

.000000000001. However, even these tables were inadequate to express the appropriate statistical probability level.

As noted above, statistical comparisons of the two groups reached extreme probability levels on seven of the ten measures contributing to the Halstead Impairment Index, and these seven tests have been retained in the Battery. The most striking intergroup differences were shown by the Category Test and the Halstead Impairment Index (even though the Impairment Index included three of the ten measures that were not particularly sensitive to brain damage). Not one brain-damaged subject performed better than his matched control on the Impairment Index (although the Impairment Indices were equal in six of the 50 matched pairs).

The Category Test was the most sensitive of any single measure to the effects of cerebral damage. Three subjects with brain lesions performed better than their matched control, but in the remaining 47 pairs of subjects the control performed better than the brain-damaged subject.

These results indicated that Halstead demonstrated remarkable insight in developing tests that reflected the nature of neuropsychological impairment due to brain damage. On three of his ten tests the results were not statistically impressive, but this may have been due to procedural problems in administration of these tests (Reitan & Wolfson, 1993). The remaining seven tests covered a broad range of adaptive abilities, involving such diverse performances as finger tapping speed, attentional capabilities to verbal and nonverbal stimuli, psychomotor problem-solving capability, memory for stimulus material to which the subject previously had been exposed, and abstraction, reasoning, and logical analysis skills.

These results, demonstrating highly significant differences between groups with and without cerebral damage, were produced at a time when most investigations had shown relatively minimal differences. Hebb (1939, 1941) had recently reported case studies of persons who had obtained IQ values in the superior range despite having had as much as one-third of their cerebral hemispheres surgically removed. A serious question existed, therefore, about why brain-damaged persons should perform so much more poorly than controls, especially considering the findings that had been reported by other researchers in earlier investigations.

At our current stage in the development of clinical neuropsychology, a retrospective review of this apparent conflict provides an explanation. Psychologists had been using measures devised to evaluate general intelligence, presuming that these tests would also be equivalently sensitive to impaired brain functions. However, as research has clearly demonstrated over the years since that time, tests developed to predict academic success are quite different from tests that are specifically sensitive to the biological condition of the brain. In fact, the IQ measures, which relate more closely to academic success, also appear to be heavily influenced by environmental and cultural advantages. On the other hand, tests developed specifically to evaluate impairment of brain functions seem to be fairer (unbiased) in terms of cultural and environmental experiences and advantages.

The basic reason for the striking differences in the results obtained using Halstead's tests and other measures appeared therefore to stem directly from the procedures used to develop the tests. As noted above, general intelligence measures were initially designed to predict academic success. Halstead ignored factors of this type almost entirely, and instead directly observed the daily living activities of persons with cerebral damage (having had these individuals identified for him by neurological surgeons who had operated on their brains). It is not surprising that Halstead's measures appear to relate much more closely to the biological adequacy of brain functions as well as to practical aspects of everyday life.

We continued to conduct additional studies of all of the measures that eventually have been included in the Halstead-Reitan Battery, comparing groups of patients who had documented cerebral damage with groups of subjects who had no history of cerebral disease. In one study the results indicated that the Trail Making Test was extremely sensitive to the biological condition of the brain (Reitan, 1958). Although Part A showed significant results, the results for Part B were even more striking.

Similar results were obtained with the Aphasia Screening Test (Wheeler & Reitan, 1962). Most persons with cerebral damage do not show any significant evidence of dysphasia, and essentially no individuals without past or present evidence of brain damage demonstrate such signs. However, when evidence of impairment is demonstrated on the AST, it almost invariably is associated with independent (medical) evidence of brain disease or injury. Minor deficits are sometimes exhibited by control subjects, but any significant evidence of dysphasia is a valid sign of cerebral damage, particularly involving the left cerebral hemisphere (Reitan, 1984).

The Halstead-Reitan Battery customarily includes the Wechsler Adult Intelligence Scale (WAIS). Certain of the Verbal subtests of the WAIS are usually within the normal range in persons with cerebral damage, provided that no evidence of aphasia has been elicited on the Aphasia Screening Test. In addition, control subjects usually show no evidence of frank dysphasic manifestations. Scores for the Wechsler subtests are usually somewhat lower for brain-damaged subjects than controls, except for Digit Span, which is often poorly performed by controls as well as brain-damaged subjects (Reitan, 1959).

B. Lateralization Effects

The highly significant results obtained in comparing non-brain-damaged control subjects and groups with heterogeneous cerebral damage laid the foundation for more detailed studies of human brain-behavior relationships using the Halstead-Reitan Battery. One of these studies compared groups of subjects with left and right cerebral lesions in order to obtain information about the differential or specialized functions of the two cerebral hemispheres.

The initial investigation involved the Wechsler-Bellevue Intelligence Scale (Reitan, 1955a), and was one of the first studies to lay the groundwork for the “left brain versus right brain” differentiation. The findings indicated that the Verbal IQ was consistently depressed in persons with destructive lesions of the left cerebral hemisphere, whereas Performance IQ was lowered in persons with right cerebral damage.

These results were confirmed in an extensive series of studies that used various criteria for implicating the left or right cerebral hemisphere. These lateralized criteria included EEG disturbances (Kløve, 1959), homonymous visual field defects (Doehring, Reitan, & Kløve, 1961), and dysphasia versus constructional dyspraxia (Kløve & Reitan, 1958). Thus, a number of studies established the differential impairment of VIQ and PIQ to damage of the left and right cerebral hemispheres.

Throughout these investigations we continued to monitor the extent to which the generalizations applied to individual cases, and found that certain subjects did not fit the expected pattern, even though they had lateralized cerebral lesions. Other studies identified factors in addition to lateralization that influenced scores on neuropsychological tests. These factors included chronicity of the lesion, the developmental period during which the lesion occurred (childhood as compared with adulthood), the age of the adult subject when the lateralized brain damage was sustained, the education level, and even the type of cerebral damage.

For example, extrinsic tumors, which usually do not involve the brain tissue in a direct structural sense, demonstrated no evidence of differential impairment of verbal and performance intelligence, regardless of the side of the brain involved, even though other lateralizing findings were present. Traumatic head injuries showed a statistically significant but rather mild effect, correlating with the diffuse or generalized involvement (as well as lateralized damage) from a blow to the head from the outside environment.

The set of conditions that demonstrated the most profound effect on verbal or performance intelligence as a result of lateralized cerebral damage included: (1) normal prior development into adulthood of brain-behavior relationships, (2) a recent lateralized insult to a previously normal brain, and (3) a lesion that represented definite cerebral tissue damage and also structurally involved only one cerebral hemisphere. Interestingly, these conditions tend to describe persons who were normal before the lateralized cerebral damage was sustained (in contrast to a number of subjects included in split-brain studies and in evaluation of surgical excisions for epilepsy), and therefore have generalization value for normal brain functions (as contrasted with impairment of the brain sustained before neuropsychological maturation) (Reitan & Wolfson, 1993).

In their review of the historical development of clinical neuropsychology, Reitan and Wolfson (1993) have identified two historical trends — one emanating from the areas of biopsychology and clinical psychology and the other developing from the medical field of neurology. Precedents in psychology have led largely to the development of tests and procedures rated on continuous distributions that generally follow the normal probability curve. Conversely, the rather simple procedures and tests derived from the field of behavioral neurology customarily produce dichotomous distributions, with results being classified as either normal or abnormal.

The Halstead-Reitan Battery was deliberately composed to include procedures from each of these historical areas. The tradition of behavioral neurology is principally represented in the HRB by the Aphasia Screening Test and the Sensory-perceptual Examination. Control subjects almost always earn normal scores on these simple tasks, and even persons with cerebral damage often do well. (See Reitan & Wolfson, 1986, 1988, 1993 for detailed discussions of the limitations of the “sign” approach.)

When abnormal performances are demonstrated on these relatively simple tasks, the results frequently have a fairly specific significance for implicating either the left or right hemisphere, and often identify impaired regional areas within each cerebral hemisphere. Deficits elicited by the sign approach, derived from procedures in behavioral neurology, therefore have special significance. However, considering the relatively simple nature of the tasks, normal performances are expected from non-brain-damaged subjects as well as a substantial number of persons with cerebral damage.

Using these procedures, we have compared the performances of control subjects with groups having left, right, and generalized cerebral damage (Doehring & Reitan, 1961; Heimburger & Reitan, 1961; Wheeler & Reitan, 1962). In each of these studies the subjects met independent neurological criteria for the groups to which they were assigned. Subjects selected for inclusion in the study had had the advantage of normal physical growth and development without being influenced by cerebral damage early in life. The subjects for these groups permitted inferences about the organization of neuropsychological functions subserved by normal development rather than deviant neuropsychological organization influenced by the effects of early cerebral damage.

The results indicated that manifestations of dysphasia were consistently associated with left cerebral damage, whereas the presence of constructional dyspraxia (deficits in ability to deal effectively with simple spatial relationships) characterized subjects with right cerebral damage. Many deficits were nearly exclusively manifested in association with damage to either the left or right hemisphere.

For example, dysnomia occurred in 53% of subjects with left cerebral lesions, but did not appear at all among subjects with right cerebral damage. This type of deficit occurred in 1% of the controls and 17% of the subjects with diffuse cerebral involvement.

Similar results were obtained on measures included in the Sensory-perceptual Examination. For example, finger agnosia involving the right hand occurred in 36% of subjects with left cerebral damage, but in less than 2% of subjects with right cerebral damage. Impairment on a sensory-perceptual task on one side of the body had adverse implications for the contralateral cerebral hemisphere.

Wheeler and Reitan (1962) compared 104 control subjects, 47 subjects with left cerebral lesions, 45 subjects with right cerebral lesions, and 54 subjects with bilateral or diffuse damage. Four simple rules were developed to classify any subject to one of the four groups. Applying these rules gave the following conditional probabilities of correct classifications: controls, 78%; left cerebral damage, 80%; right cerebral damage, 85%; and nonlateralized cerebral damage, 84%. These findings indicate that results from the HRB not only are quite accurate in identifying and differentiating subjects with and without cerebral damage, but also in identifying which hemisphere is involved.

Similar studies have been done using discriminant function analyses to produce a single weighted score for each subject and an optimum, least-squares type of separation. Wheeler, Burke, and Reitan (1963) used a total of 24 scores for each subject (11 from the Wechsler Scales and 13 from the HRB) and analyzed them using groups of 61 control subjects, 25 subjects with left cerebral damage, 31 subjects with right cerebral damage, and 23 subjects with diffuse or bilateral involvement.

The bases for classifying subjects to these groups were derived entirely from independent neurological, neurosurgical, and neuropathological findings. Analysis of the tests results fell in the following categories of correct predictions: controls vs. all categories of cerebral damage, 90.7%; controls vs. left damage, 93.0%; controls vs. right damage, 92.4%; controls vs. diffuse damage, 98.8%; and right vs. left damage, 92.9%.

A number of studies compared persons with acute versus chronic brain lesions. Clinical observations suggested that specific deficits tend to resolve, at least partially, as the patient progresses from an acute to chronic stage. In this context, Fitzhugh, Fitzhugh, and Reitan (1961, 1962a, 1962b, 1963) studied results from the Halstead-Reitan Battery, the Wechsler Scale, and the Trail Making Test. The results generally indicated that persons who had chronic brain lesions (thus implying the possibility of some recovery of function over time) tended to perform somewhat better than subjects with recent, acutely destructive lesions.

Particularly striking were the results concerning the association between lateralized cerebral damage and differential impairment on the VIQ and PIQ. Persons with recent lateralized cerebral lesions showed consistent impairment of either VIQ or PIQ, depending upon the hemisphere involved. However, persons with chronic lateralized cerebral damage demonstrated much less consistent relationships between differential VIQ and PIQ scores and the side of the brain that was injured. These results supported our later finding that neuropsychological recovery occurs in the area of initial deficit (Reitan & Wolfson, 1988).

The Halstead-Reitan Battery has been extensively researched and studied, both in group comparisons and in application to individual persons, across essentially the full range of conditions that comprise the field of clinical neuropsychology. The characteristic results found with the HRB have been described for all of the major categories of brain disease and damage, including neoplasms, cerebral vascular disease, traumatic brain injury, degenerative and demyelinating diseases, and infectious and inflammatory diseases (see Reitan & Wolfson, 1992b , 1993 for a summary of research and clinical findings in both adults and children).

Traumatic brain injury has been an area of special emphasis (Reitan & Wolfson, 1985, 1988, 2000a). In fact, Reitan's first publications were based on brain-impaired soldiers during World War II (Aita, Armitage, Reitan, & Rabinovitz, 1947; Aita, Reitan, & Ruth, 1947; Aita & Reitan, 1948). Books by Reitan and Wolfson have reviewed the neuropathological manifestations of head injury, the neurological and neuroradiological diagnostic methods, and the neuropsychological consequences (1985); the mechanisms of repair of traumatic brain damage, prognosis and outcome, methods of rehabilitation and retraining of neuropsychological deficits, and the natural history of traumatic head injury based on an 18-month follow-up of clinical and neuropsychological examinations (1988); and a review of the pathology of mild head injury, the neuropsychological literature, and research studies that showed the sensitivity of the HRB to deficits in cases of mild head injury that met certain criteria as contrasted with the relatively routine recovery of most cases of mild head injury (2000).

Of course, many additional studies have been published in the area of head injury. Dikmen and Reitan (1976), based on the 18-month follow-up study of traumatic brain injury cases referred to above, found that a combination of neuropsychological test results, obtained at about one month following injury, permitted a 91% accuracy rate in classifying subjects who would have significant deficits 18 months after the injury as contrasted with persons who recovered much better. Rojas and Bennett (1995) used the General Neuropsychological Deficit Scale (GNDS) (based on 42 measures from the HRB) and other measures to compare subjects with mild head injury with volunteer college students. They found that the Stroop Neuropsychological Screening Test did not differentiate the groups, but the GNDS correctly identified 92% of the subjects.

The HRB has also been extended to evaluate young adults with learning disabilities, especially considering the striking sensitivity of the HRB for Older Children in differentiating groups with brain damage, learning disabilities, and no evidence of brain damage (Reitan, 1992b).

Oestreicher and O'Donnell (1995) compared the GNDS scores of three groups: learning-disabled young adults (N=60), traumatically brain-injured young adults (N=30), and non-disabled volunteers (N=30). The groups were equivalent in gender and FSIQ. The results indicated that the GNDS differentiated the three groups at highly significant levels. The non-disabled volunteers all had GNDS scores of less than 27, whereas 29 of the 30 traumatically brain-injured subjects had GNDS scores of 27 or higher. Among the learning-disabled subjects, 29 (49%) had GNDS scores of 27 or higher.

In addition to confirming the validity of the GNDS in differentiating between brain-damaged subjects and non-brain-damaged subjects, as represented by a 98% hit rate, these researchers noted that the results confirmed prior studies (O'Donnell, 1991; O'Donnell, Kurtz, & Ramanaiah, 1983) in demonstrating that learning-disabled young adults show neurobehavioral impairment which, in some instances, is surprisingly severe.

Oestreicher and O'Donnell (1995) also compared the GNDS and the Halstead Impairment Index (HII). These researchers concluded that "the Omega Squared statistic showed that the GNDS was 45% more efficient than the HII in discriminating neuropsychologically normal from neuropsychologically impaired individuals. Thus, a single measure, the GNDS, which summarizes all the data from a neuropsychological examination and incorporates multiple methods of neuropsychological inference, yields an index that is highly sensitive to brain impairment. Therefore, the present study justifies extending the GNDS to both research and clinical assessment with LD (learning-disabled) and HI (head-injured) persons" (p. 189).

C. Clinical Inferences Regarding Individual Subjects

Finally, we have been interested in applying these various research results to interpretation of test protocols for individual subjects. In order to test the validity and accuracy of the HRB, we conducted a complex study in which both location and type of cerebral damage were carefully controlled (Reitan, 1964).

The first step in the procedure was to identify subjects with criterion-quality frontal, nonfrontal, or diffuse cerebral lesions. In order to provide a rigorous test of the generality of any conclusions relating to these various groups, we designed the study so that each group had the same number of subjects with various types of lesions. Each regional localization group was therefore composed of equal numbers of subjects with intrinsic tumors, extrinsic tumors, cerebral vascular lesions, and focal traumatic lesions.

Through a review of thousands of neurological protocols, we were able to identify four individual subjects with each of these types of lesions in each of the left anterior, left posterior, right anterior, and right posterior cerebral locations. We therefore had a total of 64 subjects. When subdivided into groups of 16 subjects with different locations of damage, each group contained equal representations of four different types of lesions. When subdivided into groups of 16 subjects according to type of lesion, each group had equal representations of the four different locations. Three additional groups were included in the study: 16 subjects with diffuse cerebral damage or dysfunction due to cerebrovascular disease, 16 subjects with closed head injuries, and 16 subjects with multiple sclerosis. The inclusion of these groups resulted in a total of 112 patients.

In the first study, a form was designed to record independent judgments based on the psychological test results for each subject. This form required three general decisions: first, a judgment was made from the neuropsychological test results alone about whether the lesion was focal or diffuse; second, a lesion category was selected; finally, more detailed judgments were made within certain lesion categories. For example, if the initial decision was that the lesion was focal rather than diffuse, the next judgment required selection of the right or left cerebral hemisphere, followed by selection of an anterior or posterior location within the hemisphere.

Next, a judgment was made about whether the lesion represented cerebral vascular disease, tumor, multiple sclerosis, or trauma. If the cerebral vascular disease category was selected, the lesion was further classified as a hemorrhage or vascular insufficiency. Additional forced judgments about the underlying basis for the evidence of cerebral vascular disease were made under each of these two categories.

If the tumor category was selected, the rater had to judge whether the lesion was intrinsic or extrinsic. If the intrinsic tumor category was selected, a further classification was made concerning whether the lesion was metastatic or a primary glioma.

Under the trauma category, the lesions were classified as an open or closed head injury. All of these ratings were based solely on the neuropsychological test results.

The rating form was sufficiently complete to permit classification of all subjects according to neurological criterion information. Since the classification of subjects to their respective groups had initially been based on neurological information, judgments made on the basis of neurological information represented the criterion. The purpose was to determine the degree of concurrence between neurological criterion information and ratings made on the basis of the psychological test results alone.

Each of the 112 subjects was assigned a number before the ratings were begun, and all information other than the psychological data was concealed in order to avoid any identifying clues when the ratings were made. There was no attempt to assign an appropriate number of subjects to any particular group. For example, no running record was kept to limit assignment of only 16 subjects to the multiple sclerosis group, etc. Every effort was made to classify the test results for each subject independently, and ratings were completed without using any type of running tally.

Using the neurological ratings as the criterion, there were 64 subjects with focal cerebral lesions. Of these subjects, 57 were classified correctly on the basis of psychological testing, and 7 were judged to have diffuse damage. In the group of 48 subjects with diffuse cerebral damage, 46 were classified correctly and 2 were judged to have focal lesions.

As mentioned above, there were 16 subjects in each regional localization group. The number of correct classifications on the basis of psychological test results for each of the locations was as follows: left anterior, 9; left posterior, 11; right anterior, 7; and right posterior, 15. Thus, 42 of the 64 patients were placed in their correct groups. Adding to this the correct classification of 46 of the 48 subjects with diffuse cerebral involvement, 88 of the 112 subjects were correctly classified.

With respect to the type of lesion, the 112 subjects fell in the following neurologic diagnoses: intrinsic tumor, 16; extrinsic tumor, 16; cerebral vascular disease, 32 (16 focal, 16 diffuse); head injury, 32 (16 focal, 16 diffuse); and multiple sclerosis, 16.

The number of correct classifications on the basis of psychological inferences was as follows: intrinsic tumor, 13; extrinsic tumor, 8; cerebral vascular disease, 28; head injury, 30; and multiple sclerosis, 15. Thus, 94 of the 112 patients were correctly classified according to type of lesion.

Additionally, 13 of the 16 subjects with focal cerebral vascular disease were classified correctly, and 12 of these 13 were judged to have focal lesions. Of the 15 subjects with diffuse cerebral vascular disease who were correctly placed in this category, 14 were judged to have diffuse cerebral vascular disease. A total of 30 of the 32 head injury subjects had been placed in this category on the basis of their psychological test results, and 27 of these 30 had been correctly classified according to whether the lesion was focal or diffuse. It is particularly noteworthy that the HRB is differentially sensitive to traumatic brain injury, considering the frequency with which subjects in this category are involved in litigation. A review of the literature yields no evidence that any other neuropsychological tests or methods are able to differentiate traumatic brain injury from other conditions of brain damage.

The degree of concurrence between the neurological criteria and the neuropsychological ratings indicated above could scarcely have happened by chance. The results confirmed that neuropsychological test results are differentially influenced by (1) focal and diffuse lesions, (2) which cerebral hemisphere sustained damage, (3) frontal and nonfrontal lesions within the hemisphere involved, (4) type of lesion (intrinsic tumors, extrinsic tumors, cerebral vascular lesions, head injuries, and multiple sclerosis), (5) focal occlusion as compared with generalized insufficiency in cerebral vascular disease, and (6) focal as compared with diffuse damage from head injuries.

It is important to note that a study of this type serves a significant purpose in providing insight into the degree to which psychological test results may be determined by brain lesions. Furthermore, this study indicates the multifaceted nature of the concept of “brain damage,” and demonstrates that many neurological variables, which occur in varying combinations for individual subjects, are relevant in determining psychological measurements.

The validational studies of the Halstead-Reitan Battery leave no doubt that an individual's test results are closely dependent on his/her neurological status or diagnosis. The research findings reveal not only statistically significant intergroup differences, but also demonstrate the validity of the test results for specific neuropathological conditions which affect the individual person.

V. THE HALSTEAD-REITAN BATTERY AND CURRENT PROBLEMS IN NEUROPSYCHOLOGY

A number of recent studies have used the HRB to investigate problems of current clinical significance in neuropsychology. While the human brain subserves a broad range of abilities ranging from sensory-perceptual functions, through complex aspects of central processing, to adaptive motor responses (see the Reitan-Wolfson model described previously), a need has existed both for clinical and research purposes for an overall indicator of general neuropsychological status. The Halstead Impairment Index (Halstead, 1947; Reitan, 1955c) and the Average Impairment Rating (Russell, Neuringer, &

Goldstein, 1970) have been found to be valid and have served usefully, but these measures do not summarize fully the broad range of tests included in the HRB.

A. A Summary Index of Overall Performance on the HRB

Reitan and Wolfson (1988, 1993) addressed this deficiency by developing the General Neuropsychological Deficit Scale (GNDS), an instrument that produces a summary score based on 42 variables from the Halstead-Reitan Neuropsychological Test Battery for Adults. The field of clinical neuropsychology has identified major areas of neuropsychological functioning, and there is general recognition that a comprehensive evaluation requires assessment of these areas for clinical purposes as well as for planning a rehabilitation regimen.

The GNDS was developed for this purpose, and was devised in such a manner that four methods of evaluating data are represented. Of the 42 variables that contribute to the GNDS score, 19 are based on level of performance and reflect how well the subject performed on a broad range of neuropsychological tests. Nine variables representing motor and sensory-perceptual performances evaluate differences between the preferred and the nonpreferred sides of the body. This approach reflects the fact that brain damage often affects one side of the body more than the other side. Using the differential-score approach, two variables evaluate relationships among tests that differentiate brain-damaged subjects from control subjects. Finally, 12 variables representing dysphasia and constructional dyspraxia constitute the pathognomonic sign approach.

The GNDS was not designed to replace competent clinical interpretation of the test results (which involves characterization of the individual's deficits), but only as an overall indication of the degree of neuropsychological impairment. To achieve this purpose, each of the 42 variables contributing to the GNDS score is represented by four score ranges: 0 (a perfectly normal performance), 1 (a normal performance that is mildly deviant, but without clinical significance), 2 (a mildly to moderately impaired performance), and 3 (a severely impaired performance). These score ranges are useful when the clinician wants to assess a subject's degree of impairment on an individual test in the Halstead-Reitan Battery, and the cutoff score between 2 and 3 differentiates normal from brain-damaged subjects. Thus, in a general sense, the classifications represent normative data.

The GNDS score represents the sum of the scores for the 42 variables on which it is based. This procedure produces low GNDS scores for normal controls and high GNDS scores for persons with cerebral dysfunction. The normal range extends from 0–25; mild impairment from 26–40; moderate impairment from 41–67; and severe impairment from 68 to the maximum possible score of 168 (Reitan & Wolfson, 1988, 1993). More detailed information about the GNDS as well as computerized scoring is published in Reitan and Wolfson (1993).

Using control groups and brain-damaged groups, Reitan and Wolfson (1988, 1993) presented the results of several validational studies indicating that the GNDS was adversely affected by (1) left, right, or generalized heterogeneous cerebral damage, (2) left, right, or generalized cerebral vascular damage, (3) left, right, or diffuse cerebral damage due to trauma, and (4) left or right cerebral damage when type of lesion was held comparable. All of the non-brain-damaged control groups had lower (better) mean GNDS scores than any of the brain-damaged groups.

The following control groups were used: (1) a normal group with a mean Full Scale IQ of 129.26 (mean GNDS, 12.48), (2) a young group (mean GNDS, 15.90), (3) a heterogeneous group (mean GNDS, 17.20), and (4) an older group (mean GNDS, 24.82). (See Reitan & Wolfson, 1988 for additional details.) A group of subjects who had sustained a cerebral concussion but had not demonstrated any objective evidence of brain damage, examined at the time of discharge from the hospital, had a mean GNDS score of 25.36, a score that was significantly poorer than the score earned by a heterogeneous control group.

The groups with definite brain damage consistently had mean GNDS scores ranging from 43.73 to 64.33 (subjects with traumatic brain injuries tended to score better than other groups, and subjects with left cerebral strokes tended to do most poorly). No significant differences were found within studies among subjects with left, right, or generalized cerebral damage, suggesting that the GNDS score, as intended, was a valid overall summary indicator. Males and females showed no significant differences on the GNDS when other variables were held constant. In a study comparing a group of subjects who had cerebral concussion with a group of traumatic brain-injured subjects who had documented tissue damage, the group with concussion had a significantly better mean GNDS score. Studies comparing older and younger control subjects demonstrated that the older groups performed more poorly.

Sherer and Adams (1993) published a cross-validation study of the GNDS and indices reported by Reitan and Wolfson (1988) to be differentially sensitive to damage of the left or right cerebral hemisphere, and concluded that their findings provided "limited support for the validity of these new scales with patients commonly seen in clinical practice" (p. 429). These investigators compared 73 brain-damaged subjects with 41 "pseudoneurologic" subjects. The pseudoneurologic group was composed of subjects who reported "neurologic" symptoms but had no biomedical evidence of brain damage and included "30 subjects who had received psychiatric diagnoses" (p. 429).

The results of Sherer and Adams agreed essentially with the findings reported by Reitan and Wolfson (1988), insofar as (1) the brain-damaged group was significantly more impaired on the GNDS than the pseudoneurologic group, (2) the subgroups with left, right, or generalized damage did not differ on the GNDS, (3) males and females showed no statistical difference, and (4) older subjects performed more poorly than younger subjects. The principal differences between results reported by Sherer and Adams (1993) and Reitan and Wolfson (1988) was that 53.6% of the pseudoneurologic group scored in the brain-damaged range as compared to only 10% of Reitan and Wolfson's controls. Sherer and Adams (1993) state that "the poor classification of our pseudoneurologic subjects may be due to a limitation with the use of pseudoneurologic control groups" (p. 434).

Wolfson and Reitan (1995) designed an additional study to further investigate the validity of the GNDS in differentiating between groups of subjects with and without evidence of cerebral damage, comparing 50 brain-damaged subjects with 50 controls that were similar in age and education.

The mean GNDS score for the brain-damaged group (55.02) was very similar to the mean of 53.22 reported by Reitan and Wolfson (1988) for 169 brain-damaged subjects. The mean GNDS score for the control subjects (19.66) was slightly higher than the mean of 17.20 found for 41 controls (Reitan & Wolfson, 1988). In each case, the brain-damaged subjects performed more poorly than the controls at a highly significant level.

In Reitan and Wolfson's 1988 study, the best cutoff score was 25/26, which resulted in a 9% rate of misclassification. The 1995 study identified 28/29 as the best cutoff score, which misclassified 12% of the subjects. An inspection of the two distributions indicated that individual cases of GNDS scores differing by one or two points were responsible for the differences in the two distributions. In the 1995 study, 80% of the controls and 96% of the brain-damaged subjects were classified correctly using the original cutoff score of 25/26, again yielding a 12% rate of misclassification. Obviously, the "best" cutoff score depends upon whether one wishes to avoid false negatives or false positives, but the best clinical conclusion would identify the "grey" area (where the groups overlap) as falling between 26 and 29 points.

Sherer and Adams (1993) stated that the value of using pseudoneurologic controls was that such patients are frequently seen in clinical practice. However, their pseudoneurologic control group had a mean GNDS score of 26.56, a value considerably higher than the means reported by Reitan and Wolfson (17.20, Reitan & Wolfson, 1988; 19.66, Wolfson & Reitan,1995). In order to obtain completely "clean" comparisons, we feel that the initial validation studies should compare groups of subjects who fall unequivocally into either a brain-damaged or non-brain-damaged group.

Following such a determination, other comparison groups, composed according to clinically relevant criteria, may be evaluated, and a pseudoneurologic comparison group would certainly be clinically relevant. The group with cerebral concussion reported by Reitan and Wolfson (1988) would be another such relevant group, and it might also qualify as a pseudoneurologic group since all members of the group had “neurologic” complaints but no biomedical evidence of brain damage. (See Reitan & Wolfson, 1988 for a review of the debate concerning whether the symptoms of concussion should be considered “psychiatric” or “neurologic.”) In Reitan and Wolfson's previous study, the group with cerebral concussion had a mean GNDS score of 25.36, a value very similar to the mean of 26.56 reported by Sherer and Adams for their pseudoneurologic group (Reitan & Wolfson, 1988).

In summary, empirical research results have established that the GNDS score is a valid general indicator of the presence or absence of cerebral damage.

B. Practical and Legal Implications in the Use of the Halstead-Reitan Battery

The United States Supreme Court identified four considerations for trial judges to use in evaluating expert testimony, or in some cases, in deciding whether to admit expert testimony. This directive requires that neuropsychologists carefully consider their testing methodology in accordance with whether or not their procedures meet these four criteria. Briefly, these include the following:

1. Has the method been tested?
2. Has the method been subjected to peer review and publication?
3. What is the error rate in applying the method?
4. To what extent has the method received general acceptance in the relevant scientific community?

In our experience, trial judges and lawyers are gradually giving increased consideration to these guidelines, and giving serious consideration to the admissibility of testimony based on whether these guidelines have been met. In the main, concerns have centered around (3) and (4) above; namely, the error rate and the question of general acceptance.

It would seem perfectly legitimate, and even necessary, to know how accurate a method is in achieving its purpose. Acceptance in the scientific community, however, would carry with it a time factor, inasmuch as newer methods would need time to be incorporated into the knowledge, experience, and practical testing that might be required for acceptance. Neuropsychological tests and procedures, which have been subject to peer review and publication in acceptable outlets, however, might well be viewed as having appropriate acceptance by the scientific community.

Our recent experiences have mainly concerned (3) above – the error rate. The error rate is quite a different matter than the statistical probability of accepting the null hypothesis (or a chance effect), which some neuropsychologists have referred to in responding to this requirement. Even supplying a probability statement for multiple tests is hardly an answer, inasmuch as the independence of the tests is unknown and, in any case, this kind of information says nothing about the rate of errors in conclusions about the individual person. In legal matters concerning personal injury, data relating to the probability that groups of subjects are, or are not, drawn from the same population are essentially irrelevant, because the matter concerns the person rather than inferential statistics based on group comparisons.

In fact, the customary models of statistical analyses – the ones we all learned in school and are usually required to meet publication standards – have limited meaning when judgments, diagnoses, and conclusions must be made about the individual person. We often offer “more probable than not” statements with little or no hard evidence to support these conclusions. If knowledge of the error rate concerning the question of brain damage or impairment was actually required to permit one to testify as an expert, not many of us would be allowed to testify. Few of our studies on individual tests, or even conclusions based on batteries of tests, even report the number of false-positives and false-negatives. Such data are published for other diagnostic methods that require conclusions about the individual person (such as computed tomography and magnetic resonance imaging), and questions of accuracy were among the first issues studied when these procedures were developed and became available.

Why have psychologists failed to produce such data, when it clearly is so necessary as a basis for giving neuropsychological methods a degree of credence? There are a number of possible answers to this question, a principal one being that a specified procedure or set of tests is required, applied to each subject in a precise and standardized manner, in order to evaluate accuracy, or concurrence with independent criterion information. In cases involving litigation, neuropsychologists appear to be shying away from such specified and standardized procedures in favor of so-called “flexible” batteries, apparently wanting (or needing) to give whatever tests they wish and to thereby gain the right to draw whatever conclusions they wish (or that may be requisite in terms of the role they have accepted and the conclusions they have committed themselves to support).

In a recent case a federal judge was asked, on the basis of the Daubert challenge, to dismiss the testimony of a prominent neuropsychologist who was testifying on behalf of a plaintiff who had sustained a head injury. In many prior instances, both in his publications and sworn testimony, this neuropsychologist had supported the use of neuropsychological tests in evaluating individual persons. In this case, however, the extensive set of tests that had been administered under his direct supervision fell essentially in the normal range. He admitted that the test findings were essentially normal, and, in fact, this conclusion was readily subject to documentation, inasmuch as they were based on the HRB. However, he insisted that the plaintiff had sustained significant and serious impairment. There was strong evidence against this conclusion, such as the plaintiff having earned a greater income the year after the injury than the year before the injury. However, this prominent neuropsychologist pointed out that he had interviewed the plaintiff, his relatives, and a few friends, all of whom cited a host of complaints and problems that they attributed to the injury.

When asked about the disparity between his conclusions and the normal neuropsychological test results, the neuropsychologist replied that neuropsychological tests contributed no more than 10% to his conclusions and that his clinical impressions were the primary basis for his testimony. The opposing attorney then appealed to the judge to exclude the neuropsychologist’s testimony on the grounds that his methodology had not been adequately tested, had not been subjected to peer review, the error rate was unknown, and the neuropsychological community would disagree that neuropsychologist tests should count for 10% and clinical impressions for 90%. The defense attorney said that, in his opinion, the judge “came very close to excluding the neuropsychologist’s testimony, but in the end felt that he did not have enough information about prevailing practices in neuropsychology to make such a decision.” Another consideration may have been that the judge was reluctant to make a ruling that would have devastated the plaintiff’s case since, aside from the neuropsychologist’s opinion, there was little additional credible evidence of brain impairment.

It seems clear that the time has come when we need to support our conclusions with hard evidence. We can hardly be proud that it is the legal processes that are forcing us in this direction rather than a feeling of clinical responsibility to our clients and patients.

The problem of testing the accuracy of neuropsychological test data must receive much more critical consideration than it has up to this point. One approach might be to make predictive judgments using whatever test data was available for each subject, and checking the accuracy of these predictions against criterion information. The problem with this approach would lie in the fact that there would be no clear definition of the test data used for making the predictions, inasmuch as the tests administered would surely vary from one subject to another.

Neuropsychologists who use so-called flexible batteries would face exactly this problem, because their test batteries, designed according to the supposed complaints or deficits of the client, necessarily vary from one client to another. In fact, a procedure that first discerns the client's area of possible deficit via history information, relatives' observations of the client, or interview information, and then seeks to confirm or refute such hypotheses through selection of a range of tests judged to be appropriate, is clearly circular and can only be considered to be relevant to the complaints initially deemed to be significant.

Under these circumstances, there can be no assurance that the battery of tests selected for each client represents a comprehensive, balanced, and validated set of measures of brain function or dysfunction. Of course, if *each* of these many symptom-oriented batteries had been checked for accuracy in correlating with and identifying brain lesions of a diffuse and/or focal nature, in varying locations of the brain, representing the full range of types of brain disease and injury in identifying both chronic and stabilized brain lesions versus acute and progressive brain conditions and effectively differentiating this entire cadre of people with brain involvement from non-brain-damaged people, there would be no problem. The field of *neuro*psychology (the discipline based on establishing brain-behavior relationships) would be secure.

It is obvious, however, that there is no likely prospect that *multiple* test batteries can be checked out in the detail necessary to establish their relationships to the broad range of conditions that, in total, represent brain damage. Yet, unless evidence is available that all the categories of brain damage are reflected by a particular neuropsychological battery (or that the battery validly differentiates between brain-damaged persons and non-brain-damaged persons regardless of all of the variations that occur under the rubric of brain damage) one cannot presume that the battery validly reflects brain pathology.

In the absence of evidence supporting this presumption, we clearly lose the claim that identifies the essential nature of our field – the area of psychology that relates behavioral measurement to the biological status of the brain. Without a firm anchor to the brain, we become clinical psychologists, school psychologists, consulting psychologists, educational psychologists, or whatever type of psychologist appropriate to our particular interest. Of course, we will also find ourselves failing to compare favorably to the experts in each of these areas.

It is apparent that we cannot have it both ways. We either have to respect the brain as the basis for behavior, and validate our measures in accordance to the many things that go wrong with the brain, or recognize that the *neuro* part of neuropsychology is added for respectability alone. If we are unable to document valid relationship to brain status, in terms of our scientific methods and procedures, as responsible professionals we should at least admit that the Supreme Court was quite reasonable and correct in requiring that the error rate in *neuro*psychology be specified with respect to individual subjects. Such an admission, of course, would also verify our inadequacy to function as expert witnesses.

One way out of this dilemma would be competently to use a neuropsychological test battery for which published evidence is available that meets the four criteria identified by the Supreme Court as necessary for admission as an expert witness. The Halstead-Reitan Neuropsychological Test Battery meets these four criteria, but competent interpretation (which can be judged by a the many published examples of test interpretation) is required over and beyond training in test administration. Fortunately, detailed information is available for both administration and interpretation of these batteries of neuropsychological tests for adults, older children, and young children (Reitan & Wolfson, 1985, 1988, 1992, 1993).

VI. Recent Research with the Halstead-Reitan Battery

The manner in which the HRB has been developed and validated, and the broad range of brain-related conditions which have been studied, make it an invaluable tool to study other issues as they arise. While it is of value to study brain-related impairment with other tests and procedures, and clinical evaluation often calls for supplementation with additional tests after the basic neuropsychological condition has been established, a balanced and comprehensive assessment of brain-behavior relationships that compares the individual's overall brain functions with a generalized concept of normal (or impaired) brain functions represents an invaluable foundation in neuropsychological assessment. The alternative, using a variable selection of tests that have not been validated as a battery, risks a focus on individual tests rather than on the individual person.

The extensive research bases of the HRB, together with its demonstrated validity in assessment of individual persons, helps to create a springboard in the investigation of additional neuropsychological problems. Space considerations prevent a full review of recent investigations, but a few areas can be mentioned.

With respect to the neuropsychological consequences of mild head injury, the prevailing view had been that recovery was routine and essentially complete in a matter of one to three months (Levin, Eisenberg, and Benton, 1989). Binder, Rohling, and Larrabee (1997) reviewed the literature and concluded, "It can be argued that the average effect of MHT (mild head trauma) on neuropsychological performances is undetectable." Evaluation over the years of such cases with the HRB indicated that this conclusion was hardly true for a number of individual cases. In fact, some persons, with apparently very mild head injuries, showed evidence of significant neuropsychological impairment on the HRB.

This observation was possible because the HRB produces data not only on tests, but also provides a basis for evaluation of the individual. As a result of these observations of HRB findings, a formal study was designed which led to a paper entitled, "The Two Faces of Mild Head Injury" (Reitan & Wolfson, 1999) in which it was shown that persons who returned weeks or months after a mild head injury, with significant complaints of the type that could be attributed to brain damage, actually performed much more poorly on the HRB than did similarly injured persons whose recovery was routine. Thus, the neuropsychological of a mild head injury can hardly routinely be considered as relatively innocuous, subject to prompt recovery, but in some cases constitute a significant clinical problem.

Another study in the area of mild head injury, also arising from clinical evaluation of individual persons using the HRB, concerned the nature of any resulting neuropsychological deficits, even though presumed to be brief in duration (Reitan & Wolfson, 2000). The literature (Levin, Eisenberg, & Benton, 1989) had concluded that initial deficits (before recovery) might include impairment of attention and concentration, speed of information processing, and immediate memory (see Reitan & Wolfson, 2000 for a review of this literature).

Clinical evaluation using the HRB had indeed indicated that most persons with mild head injuries performed better than persons with more serious structural damage of the brain. However, when considering a range of neuropsychological tests, the deficits did not appear to be restricted to the areas of attention and concentration, speed of information processing, and immediate memory. In fact, considering the deficits as a whole, they appeared to be rather generally distributed.

Another formal study was then designed, based on 19 tests from the HRB, using a group with mild head injuries for comparison with diagnosed structural damage of the brain resulting from physical trauma (Reitan & Wolfson, 2000). Comparisons of these two groups showed a strikingly similar pattern of test scores across the 19 tests, with a rank-difference correlation of 0.87 between the two groups. In a study of correlations across an extensive set of tests, as included in the HRB, as contrasted with prior studies that were largely limited to pre-selected areas of function, the findings showed that neuropsychological test findings were remarkably similar (rather than unique or distinct in mild head injury) for both mild and more severe head injury. These findings were clearly a result of using a comprehensive, validated test battery in contrast to using individual, selected tests.

It is important to negate incorrect conclusions that have pervaded the field, and the HRB provides a vehicle for this purpose also. As noted earlier in this chapter, the Seashore Rhythm Test was presumed by many neuropsychologists to reflect the status of the right temporal lobe (presumably because it was a nonverbal auditory test). Clinical use with the HRB clearly indicated that many brain-damaged persons, without specific right temporal lesions, performed poorly on this test. A study was designed to explore the question formally and the results showed that impairment was equivalently present with either left, right, or generalized brain lesions (Reitan & Wolfson, 1989). Apparently, the requirement for paying close attention to repeated stimuli for a period of time, which is dependent on cerebral functions generally, overrode any effects of the specific content of the Rhythm Test in determining the results.

Exactly the same type of study was done to test the oft-repeated hypothesis that the Speech-sounds Perception Test reflected the status of the left temporal lobe. Again, the results failed to support the hypothesis, but showed the test to be generally sensitive to brain damage regardless of location (Reitan & Wolfson, 1990).

Perhaps an even more pervasive belief has been that both the Category Test and Part B of the Trail Making Test reflect frontal lobe functions. This question was tested empirically by comparing four groups of persons who had lesions in the following areas: left frontal, right frontal, left posterior, and right posterior. The results failed to show significant differences on either test among the four groups (Reitan & Wolfson, 1995a).

It is, of course, quite possible to achieve accuracy levels that far exceed chance, both with respect to localization and type of brain lesions, using the complete HRB, as shown in an earlier part of this paper. The complexity of brain functions, however, clearly requires an extensive set of tests as we learned, patient by patient, in the development of the HRB, including both higher-level and lower-level brain-related tests designed to implement the various methods of inference described above. Simplistic generalizations, based on single tests or concepts, whether stated as principles or applied in clinical evaluation, cannot be expected to do justice to the human brain.

The availability of a brain-sensitive general measure such as the General Neuropsychological Deficit Scale (GNDS) has facilitated an economical and organized approach to the important question of the relation of attribute variables, such as age and education, to results obtained with neuropsychological testing. Among children, the influence of these variables is obvious during the developmental years. Older adults, without clinical evidence of brain damage, have demonstrated deterioration on neuropsychological tests (Reitan, 1955b, 1967) and better educated people would be presumed, on an overall basis, to have the brain-related abilities to achieve higher levels of education. Thus, it seems only reasonable that age and education must be considered, and variables for which test scores must be adjusted, in clinical evaluation regarding possible brain damage.

In fact, studies have shown that both age and education are variables of influence among non-brain-damaged persons (Reitan & Wolfson, 1995b). Better educated people tend to perform better on brain-sensitive tests and older people tend to show some degree of deterioration. However, the clinically relevant question in most evaluations concerns subjects who have, or are suspected of having, some type of brain disease or damage.

Do the effects of age and education have equivalent influence when brain damage has already affected the test results, to one degree or another? If the tests are brain-sensitive, and thus reflect the clinical condition of the brain, does it not seem likely that brain damage has already determined the deficits shown by the test results and that the effects of ate and education, as shown in normal subjects, has been disrupted, if not overruled? Is there anything about being relatively young and having an advanced educational degree that immunizes one against the devastating impairment that can be caused by severe brain damage? In such cases, age and education are negatively correlated with neuropsychological test performance.

This question was put to an empirical test initially by Reitan and Wolfson (1995b). Although significant correlations were found among the control subjects between age and education and the GNDS, the correlations were not significant for the brain-damaged subjects. Brain damage had apparently been a third factor which negated the usual influence of age and education. The same effect is often cited in statistics books regarding, for example, the correlation between crop yield and rainfall, which may be entirely negated by low rather than normal temperatures.

Recently, many neuropsychologists have been influenced to adjust raw scores on HRB measures as well as other tests, for brain-damaged persons on the basis of age and education, using tables established on a normal rather than brain-damaged sample (Heaton, Grant, & Matthews, 1991). Obviously, if there is no relationship of age and education to test performances among brain-damaged people, the adjustment based on normals can do nothing but change or alter the brain-sensitive results.

The effect of adjusting scores on brain-sensitive tests earned by brain-damaged subjects, using data derived solely from non-brain-damaged subjects, has yet to be determined empirically in any detail. As a first step in this direction, in the course of preparing this manuscript, the Heaton, Grant, and Matthews (1991) tables were used to adjust the HRB scores for a sample of 26 patients with clinically-established diffuse cerebral vascular disease whose HRB findings had been previously published (Reitan, 1970). We deliberately selected a group with diffuse cerebral involvement rather than a group with focal lesions, since it is well-known that focal lesions more seriously disrupt specific functions (producing deficits such as dysphasia and greater deviations from scores of normals. Nevertheless, when the age and education adjustments were made, 37% of the adjusted scores, based on overall results using nine brain-sensitive tests from the HRB, fell in the normal range. While the question obviously needs more study, in this particular instance the adjustment of raw test scores earned by brain-damaged subjects tended to transpose evidence of neuropsychological impairment with normal performances.

The studies reviewed above concerning adjustment of raw neuropsychological test scores stimulated additional investigations based on the Wechsler Adult Intelligence Scale (WAIS) (Reitan & Wolfson, 1996). Educational level, as expected, had significant correlations with Verbal, Performance, and Full Scale IQ values for the control group, but were significantly lower in each instance for the brain-damaged group. Within the age range of the groups studied, the effects of age were less clear. In general, the findings of differences between the control and brain-damaged groups were not as clear as they were in studies with the GNDS, very possibly reflecting a differential sensitivity to brain damage of the WAIS and GNDS. Investigation of age and education correlates of the WAIS subtest scores suggested a general trend toward lower correlations among the subtests that were dependent upon immediate problem-solving abilities and higher correlations for tests requiring stored information, which also reflected the pattern of results with subtests that were more sensitive to brain damage as compared with tests that are generally less sensitive (Reitan & Wolfson, 1996).

Finally, age and education correlations with the GNDS were determined in groups with mild head injuries (Reitan & Wolfson, 1999a). No significant correlations were found, as was also true for a group with definite traumatic tissue damage of the brain. The results indicated that the influence of age and education was diminished to the point of statistical insignificance in mild head injuries as well as more severe head injuries or diversified groups of brain damage. These results, of course, serve as the foundation for the initial question regarding adjusting raw neuropsychological test scores for brain-damaged subjects, using the relationships based on the study of persons with normal brain conditions.

The HRB has served as a springboard for many additional studies which go beyond the scope of the review, but which justify Meier's (1985) statement that during the period of remarkable expansion of neuropsychology the Halstead-Reitan Battery "was the primary force in stimulating clinical research and application in this country." According to McCaffrey and Isaac (1984), their initial survey showed that 65% of the respondents used the HRB. In the survey reported by McCaffrey and Lynch in 1996, the percentage had risen to 77%, a 12% increase.

For example, findings suggest that emotional problems have little influence on neuropsychological test results – provided that the tests have established validity as brain-sensitive measures (Reitan, & Wolfson, 2000).

VII. REHABIT: A Structured Program for Retraining Neuropsychological Abilities Based on the Halstead-Reitan Battery

Before retraining of the damaged brain can begin, the nature and severity of impairment must be identified. Target points for retraining must be established. The preceding parts of this chapter have been devoted to elucidation of the basic aspects of neuropsychological impairment and methods for valid measurement of these deficits. Considering the range of adaptive abilities represented by brain functions, unless the deficits are known for the individual person, attempts to devise a specifically appropriate retraining program are almost like shooting in the dark.

Thus, the final step in the neuropsychological sequence involves remediation. After the deficits have been identified, what can be done to remediate them? The neuropsychologist must (1) identify neuropsychological deficits, (2) conclude validly that these deficits are due to brain damage rather than other possible causes, and (3) define and select training procedures that are pertinent to the needs of the individual. If a remediation program is to be of value, the behavioral deficits must be evaluated in terms of their comparative severity for the individual, and rehabilitation must be appropriate to the subject's ability level and needs.

These requirements presume that the neuropsychological evaluation has assessed the full range of brain-related functions. Evidence indicates that results on the HRB provide this kind of information by identifying an individual's neuropsychological impairment in the framework of a comprehensive model of brain-behavior relationships. Thus, evaluation with the HRB provides a diagnosis that serves as the basis for developing a rehabilitation program capable of remediating an individual's particular deficits.

Training of both children and adults is viewed within this same framework. Differences in neuropsychological evaluation of children and adults must be recognized, largely due to the fact that children are in a developmental phase of achieving brain-related abilities. However, children and adults who sustain impairment in a particular area may demonstrate many of the same types of neuropsychological deficits. The training program materials for children and adults are essentially similar, except that in many instances the training begins at a more simple level for the child.

As noted above, verbal and language functions are customarily related to the integrity of the left cerebral hemisphere, and visual-spatial and manipulatory skills are dependent on the status of the right cerebral hemisphere. Recent investigations have emphasized the specialization of brain functions in association with the cerebral hemisphere involved; however, the nonspecialized types of abilities, which are dependent upon the brain *generally*, have been relatively neglected. Because the abilities that characterize generalized brain functions involve all cerebral tissue rather than representing specialized capabilities, it might be reasonable to postulate that these abilities are of special significance in a cognitive retraining program.

Our research has shown that the broad range of abstraction abilities represents cerebral cortical functioning generally and may be more fundamental than the specialized skills. A cognitive retraining program that emphasizes abstraction and reasoning abilities would seem to provide the most appropriate basis for rehabilitation, especially considering both the research and clinical findings that demonstrate the pervasive and limiting effects of impairment in this area.

Based on many years of prior work with individual patients, REHABIT (Reitan Evaluation of Hemispheric Abilities and Brain Improvement Training) was formalized by Reitan in 1979 to provide tasks that reflected the specific as well as the generalized functions of the brain. The REHABIT training program does not use a “shotgun” approach to brain retraining; instead, it has specifically been organized to remediate an individual's neuropsychological deficits, as determined by an evaluation with the Halstead-Reitan Battery.

Considering the importance of abstraction abilities and their central role in brain training, five tracks of training materials have been established in REHABIT:

1. *Track A* contains equipment and procedures specifically designed for developing expressive and receptive language and verbal skills and related academic abilities.

2. *Track B* also specializes in language and verbal materials, but deliberately includes an element of abstraction reasoning, logical analysis, and organization.

3. *Track C* includes various tasks that do not depend upon particular content as much as reasoning, organization, planning, and abstraction skills.

4. *Track D* also emphasizes abstraction, but its content focuses on material that requires the subject to use visual-spatial, sequential, and manipulatory skills.

5. *Track E* specializes in tasks and materials that require the subject to exercise fundamental aspects of visual-spatial and manipulatory abilities.

Regardless of the content of the training materials being used for the individual subject, every effort is made to emphasize the basic neuropsychological functions of attention, concentration, and memory.

With many children and adults it is necessary to provide training in each of the five tracks. In some instances, one area should be emphasized more than the other areas. The decision for prescribing training should be based upon the results of testing with the HRB. The REHABIT program, which includes over 600 items, provides extensive training in all areas of neuropsychological functioning.

Formal research regarding the effectiveness of REHABIT has been developing slowly, but this is to be expected, considering the difficulties inherent in evaluating a procedure which, for each individual subject, is extended over a substantial period of time. The first study was possible only through the occurrence of fortuitous circumstances that resulted in collaboration by Reitan and Sena (1983). Sena had collected neuropsychological test results on subjects before and after 12 months' training with REHABIT.

In order to study the effects of practice and spontaneous recovery, it was necessary to compose two control groups: (1) normal subjects who had been tested initially and retested 12 months later (to evaluate positive practice-effects), and (2) brain-injured subjects who had been tested initially and retested 12 months later but had not received any training with REHABIT or any other cognitive rehabilitation program (to study spontaneous recovery of neuropsychological functions). Fortunately, one of the authors (RMR) did have data on such groups, and a preliminary study was devised (Reitan & Sena, 1983).

The findings indicated that the subjects who had been trained with REHABIT demonstrated substantial improvement on neuropsychological tests compared with the other two groups. The results reached levels of statistical significance on a number of variables (even considering the small number of subjects). This investigation suggested that cognitive brain retraining using REHABIT was a definite advantage in terms of facilitating the recovery process.

Sena and his associates have continued investigating the efficacy of REHABIT. One study conducted by Sena (1985) evaluated a group of 12 subjects who had sustained brain injury an average of 18.4 months before the initial evaluation. Spontaneous recovery should have been largely completed before the subjects were enrolled in the study. In addition, retesting 12 months after the initial examination may well have represented a long enough interval to minimize positive practice-effects.

The retest results indicated that statistically significant improvement occurred on 31 of 39 measures, covering a broad range of neuropsychological functions. However, additional evaluation was necessary to make direct comparisons of persons who had undergone treatment with REHABIT as compared with those who had not received such treatment.

Sena and Sena (1986) retrained 13 subjects with two to three sessions of REHABIT per week for at least one year and compared their initial and retest results with a group of 8 subjects who had similar brain injuries but had received no cognitive retraining. The initial testing indicated that the neuropsychological functions of the two groups were essentially similar before training with REHABIT was begun. The subjects were also similar with respect to age, education, and gender distribution, and the only known difference between the groups related to cognitive training.

Neuropsychological retesting was done for both groups 12 months after the initial examination. The group that had received no treatment showed little change in their test results, earning scores essentially similar to those that were obtained initially. However, the group receiving training with REHABIT demonstrated significant improvement on 18 of 30 measures.

These studies also included six subjects who had continued cognitive rehabilitation over a second year. Improvement in neuropsychological test scores from year one to year two continued on 42% of the measures, yielding evidence of statistically significant improvement on 90% of the tests in the Battery used for assessment over the two-year period.

Sena, Sena, and Sunde (1986a) administered an extensive range of neuropsychological tests to family members of the brain-injured sample in order to assess changes at a 12-month interval. They found that the family members who had not sustained brain damage or disease showed minimal changes on the test results obtained 12 months later.

Another study by Sena, Sena, and Sunde (1986b) compared test results of brain-injured subjects and those of the family members, and found that the brain-injured subjects who had received cognitive retraining showed substantially more improvement than their family members.

Alfano and Meyerink (1986) and Meyerink, Pendleton, Hughes, and Thompson (1985) have also reported a great degree of improvement of neuropsychological functions in brain-injured persons who received training oriented toward remediation of deficits as compared with a match control group, most of whom had received only traditional rehabilitation therapies such as speech therapy, occupational therapy, or physical therapy. Excellent reviews of this subject have also been published by Alfano and Finlayson (1987) and Finlayson, Alfano, and Sullivan (1987). In summary, this series of studies supports a conclusion that cognitive retraining is of value in facilitating the recovery process in persons with brain injury.

VII. Summary

We have presented a brief description of the Halstead-Reitan Neuropsychological Test Battery, including information that relates the test results to the biological condition of the brain and the implications and uses of the test results for retraining neuropsychological deficits.

This paper reviewed the roots from which Halstead began his investigations, the significance of his original collaboration with neurological surgeons, and the long-term implications of his practical approach of observing the problems and limitations in everyday living experienced by brain-damaged patients. This practical approach resulted in the development of neuropsychological tests that represent standardized experiments in adaptive behavior as contrasted with more conventional psychometric instruments.

The HRB was gradually developed by adding tests, organized in accordance with complementary inferential procedures, until a battery had been developed that covered the full range of neuropsychological dysfunction as determined by evaluation of thousands of patients with brain disease and damage. The sensitivity of the HRB to neuropsychological deficit has been demonstrated by the differential relationship of the test results to a broad range of neurological variables including location, type, and status of brain lesion.

Recent research has demonstrated the value of results of the HRB with relation to a number of current clinical problems, ranging from deficits in mild head injury, the relation of attribute variables to neuropsychological test results, the possibility of specific frontal lobe deficits, to the development of an index for dissimulation or possible malingering. This comprehensive development of a set of measures sensitive to cerebral damage has also laid the groundwork for a cognitive retraining program that incorporates neuropsychological evaluation (identification of the subject's neuropsychological needs) and cognitive retraining, using an approach that can be designed to restore the individual's functional ability structure (as contrasted with approaches oriented only toward a general, nonspecific notion of “brain damage.”

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THEORETICAL, METHODOLOGICAL, AND VALIDATIONAL BASES OF THE HALSTEAD-REITAN NEUROPSYCHOLOGICAL TEST BATTERY

Ralph M. Reitan and Deborah Wolfson

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