USE OF BEHAVIORAL MEASURES IN DISCRIMINATING NEUROLOGICAL STATUS

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CURRICULUM STUDIORUM

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INTRODUCTION

Psychologists have as their very general aim the study of the behavior of man. One sub-discipline within psychology, neuropsychology, has as its theoretical goal the understanding of the organismic basis of man's behavior. More practically, it aims at using behavioral measures which tap the functioning of the central nervous system for differential diagnosis.

Specific problems have arisen from this general goal. The basic question has been the validity of the inferences made from these measures of external behavior to central nervous system functioning in the classification of patients with cerebral pathology. Closely connected with this problem is the practical question of the use of these measures, if the results are merely a redundant formulation of that which is medically known.

A particular question which has arisen from this milieu is the use of behavioral measures in discriminating neurological status. In this research, behavioral measures are compared to the physical neurological exam, which also taps external behavior, to ascertain how they both reflect central nervous system functioning. For the comparison to be valid, it is essential that there be adequate external criteria of the true state of the central nervous system.

INTRODUCTION

The first chapter of this research is concerned with a selective review of the literature concerning the validity of the neuropsychological measures in discriminating cerebral pathology, with some stress on the relationship of the battery as compared to various neurological measures.

The formulation of the general purpose of the study is followed by a chapter describing the experimental design of the project. Emphasis here is placed on the description of the tests used in the analysis, plus an understanding of the statistical methods to be employed. This portion concludes in a statement of the specific hypotheses and secondary aims.

The results obtained in the experimentation are presented and discussed in the final chapter. This is followed by the concluding remarks, and implications for subsequent research.

CHAPTER I

REVIEW OF THE LITERATURE

In this first chapter, the way neuropsychology has moved from the theoretical to the practical and clinical will be reviewed, emphasizing its complementary role in elucidating that which neurology has difficulty discriminating. This methodological history clarified, the present-day approach within the area of neuropsychology will be discussed as an introduction to a review of relevant validity studies. The culmination of the validity review will consider the relationship of psychological tests of brain functioning as compared to various neurological tests, leading specifically to a formulation of the relationship of behavioral measures to a diagnosis of neurological status based on the physical neurological exam.

The earnest search for behavioral indices of central nervous system functioning began with Ward Halstead's renewed and different approach to the quest for a "man on horseback," Sigmund Freud's analogy for the relationship of the ego to the id. "What is the basic plan or structure of the ego, and whence come its forces?" Halstead queried. "Thus it has been left to others to provide a neuropsychological description of the ego and to elucidate its mechanisms."[1] Framed in another setting, Halstead was asking what was the difference, if any, in the manner and accuracy with which a psychologist looks at central nervous system functioning and brain pathology as compared to a neurologist. Both, indeed, are looking at behavior.

Using twenty-seven behavioral measures on a sample of 237 brain-damaged subjects, Halstead phrased his question in a different manner than Freud did, searching for the relationship of human intelligence to brain functions. Factor analyzing the tests resulted in four basic factors: C - a Central Integrative Field factor, which is a memory factor, against which new experience is evaluated; A - an Abstraction factor, a general human property, maximized in the prefrontal lobes; P - the Power factor, apparently related to cerebral metabolism, and is the energy source behind intellectual functioning; D - the Directional factor, the means by which intelligence is exteriorized.

These four factors are the basic components of biological intelligence, Halstead's concept of the normal outcome of the functioning of a healthy nervous system.[2]

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1 Ward C. Halstead, <u>Brain and Intelligence, A Quantitative Study of the Frontal Lobes</u>, Chicago, University of Chicago Press, 1947, p. 3.

2 --------, "Biological Intelligence," <u>Journal of Personality</u>, Vol. 20, No. 1, 1951, p. 118-130.

By unveiling this, Halstead believed he had arrived at a conception of the nuclear structure of the ego, a meeting point in the organismic substratum of all personal acts, where psychology and the biological sciences (and possibly biochemistry) could join hands, where hard-boiled classificationists and interpretive students of the individual could meet on common ground, and where all human problems could be brought within the folds of general psychology.[3]

Although Halstead believed more factors were likely,[4] he studied this model of the nuclear structure of the ego to see if the factors were differentially localized in the brain. It is from here that the application of formal psychological tests to clinical neurology started.

The significance of the four-factor theory itself is uncertain. Russell,[5] in a re-examination of biological intelligence, found only one factor that was similar to Halstead's division of biological intelligence. Although Russell states possible reasons for the differences, he suggests that his four factors of nonverbal, tapping, verbal, and auditory tests question Halstead's division.

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3 Halstead, Brain and Intelligence, p. 91.

4 *Ibid*., p. 96.

5 Elbert W. Russell, "A Reexamination of Halstead's Biological Intelligence Factors," Proceedings of the 79th Annual Convention of the American Psychological Association, Vol. 6, 1971, p. 461-462.

This study, a lonely figure in the study of Halstead's conceptualization, is indicative of the trend neuropsychology has taken, abandoning the theoretical in favor of the practical. Kløve summarizes this trend, pointing out that, although the theoretical framework is uncertain,

> [...] it cannot be disputed that the tests themselves have provided the methodological impetus for a large amount of research which has increased our knowledge of brain-behavior relationships and which has led to significant advances in clinical human neuropsychology.[6]

This is based upon the assumption that a standardized battery of intellectual, motor and sensory functions will enable inferences to be made regarding the organic integrity of the brain. Halstead, in attempting to show that the four factors are related to brain function, already had moved from the theoretical to the clinical by showing that persons with cerebral dysfunction were disturbed on his measures as compared to normals.

Various authors have discussed approaches and methodological issues in the psychological assessment of organic brain functioning. Heilbrun saw the main issue as the study of brain-behavior functional relationships, and clearly pointed out the dichotomy in the two different

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6 Hallgrim Kløve, "Validation Studies in Adult Clinical Neuropsychology," based on a paper entitled "Current Status of Adult Clinical Neuropsychology," read at a symposium entitled "Human Neuropsychology: The Significance of Brain Damage for Human Behavior," American Psychological Association Annual Meeting, 1970.

approaches. The first is the clinical approach, whose purpose is to maximize diagnostic predictions of the presence or absence, site and extent of lesion, and nature of pathology. In trying to perfect "the proportion of times diagnostic predictions correspond to neurological verdict,"[7] the problem is not to find out why the cerebrally impaired do poorer or better, for the cause might not even be neurological in nature, but to find measures, regardless of what is measured, that do disciminate.

Among the different clinical issues, a pressing problem is outlined as follows:

> The major clinical contribution which the psychologist could make would be to make valid inferences regarding brain status in persons where the symptoms are much more subtle and the ability of neurologists to agree considerably less than the standard research methodology has required. A crucial study would be one in which the neurological group is made up entirely of Ss for whom neurologists disagree as to diagnosis or are unable to make a diagnostic statement at all <u>at the time the psychological measure is obtained</u> and for whom retrospective diagnosis is possible. To validly infer brain damage when the neurologist is scratching his head is a contribution; to do so when even the patient's family can reach the same conclusion is not.[8]

The second approach is the theoretical one, in which the goal is to increase knowledge of the way the brain functions. Since both the changed behavior and the

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7 Alfred B. Heilbrun, "Issues in the Assessment of Organic Brain Damage," <u>Psychological Reports</u>, Vol. 10, 1962, p. 511.

8 <u>Ibid</u>., p. 513.

nature of the pathology are of importance, it would be necessary, for example, to define the behavior which is impaired.

Yates[9] discusses other problems by attacking three common assumptions in cerebral integrity research. The first is that brain dysfunction may be treated as unitary phenomena. He states, rather, that there are general and specific effects which must be winnowed out, and which may depend on lesion localization. Secondly, it is often assumed that if a test, or tests, has been validated, and then cross-validated, it can be used diagnostically. The problem here is that often, in research, clear-cut cases are used, and a test of brain pathology is required precisely when the neurological or psychiatric evidence is equivocal.

> If, in the clinical situation, the test can identify from routine neurological or behavioral observations only those Ss whose brain damage is obvious, then the test serves no useful purpose, since it confirms what needs no confirmation. Validation and cross-validation are essential preliminary steps in the construction of a test of brain damage, but the crucial reference point is the test's predictive validity, that is, given an unselected intake group of psychiatric patients, can the test successfully predict which of the patients will ultimately be diagnosed as brain-damaged?[10]

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9 Aubrey J. Yates, "Psychological Deficit," Annual Review of Psychology, Vol. 17, 1966, p. 111-144.

10 Ibid., p. 113.

Yates is thus reaffirming Heilbrun's demand for a study which will validate a test of definite brain pathology precisely when the diagnosis from other sources is ambiguous. He underlines this in his attack on the third assumption--the often naive belief that neurological criteria are per se more valid than psychological criteria.

Heilbrun, in his binary approach to brain pathology, had revealed a basic problem in the validation of tests of brain dysfunction. Yates, in another article,[11] argued in favor of the theoretical approach by stressing the need for a theory exclusive to brain dysfunction which must first be developed, and then tested experimentally. S. Goldstein[12] reversed the order. If the problem is approached primarily from a theoretical viewpoint by means of construct validity, both the criteria and the predictor fail the test of objective observability since it is virtually impossible to agree on a theoretical definition. A more realistic approach is by means of empirical validity in which the behavioral results are measured against a directly observable

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11 Aubrey J. Yates, "The Validity of Some Psychological Tests of Brain Damage," Psychological Bulletin, Vol. 51, No. 4, 1954, p. 359-379.

12 Steven G. Goldstein, "Strategies of Research in Human Neuropsychology," Journal of Learning Disabilities, Vol. 2, No. 8, 1969, p. 403.

phenomena on which almost all experts concur. The criterion groups must be well defined empirically.

This empirical approach is the way tests based on Halstead's battery have advanced, pioneered by Ralph M. Reitan. Reitan stated that the search for tests of brain lesions is self-limiting.[13] It is better to hold the test battery constant, and accumulate neurological material to validate these tests. What the battery of tests must have are the following criteria. It must sample the major abilities, such as the motor, sensory-perceptive, psycho-motor, and higher level psychological functioning. It must have pragmatic rather than supposed theoretical validity, that is, it must be able to discriminate. Finally, the battery should allow the use of various principles of inference, such as comparison to normal groups and analysis of patterns of response. To do this, a basic procedure must be followed. There must be an accurate and independent definition of the neurological independent criteria, and the administration and scoring of the tests must be unbiased.

This present study follows Reitan's plan in accumulating evidence on an already formed battery of tests. The following section will review relevant research, stressing the increasing number of validity studies on this basic

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13 Ralph M. Reitan, "Diagnostic Inferences of Brain Lesions Based on Psychological Test Results," Canadian Psychologist, Vol. 7a, No. 4, 1966, p. 368-383.

Halstead-Reitan[14] (H-R) neuropsychological battery, concluding with the relation of the battery to various neurological variables. Unless otherwise stated, all validity studies will refer to research on an adult population. Research which concerns both the H-R battery and the Wechsler scales will also be discussed.

This review and critical analysis will lead to the formulation of the purpose of this research which will attempt to study whether valid inferences of true cerebral dysfunction can be made from this battery as compared to the diagnosis from a physical neurological exam.

1. General Validity Studies.

Reitan was well aware that, in the search for special tests of the relationship between brain functions and behavior potentials, the accumulation of validity studies was of prime importance. The first step in his plan of research was to verify Halstead's basic results, using the same tests administered in the same way, with entirely different patients, and in a different geographic locale. In this and subsequent studies where the general purpose

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14 The basis of the battery was established by Halstead, with later modifications made by Reitan, and then others. In different studies, the battery is labelled the Halstead battery, or the Halstead-Reitan battery. This review will use the terms interchangeably, with the understanding that the core of tests is the same.

was to see if the battery could differentiate brain-damaged from normal controls in a clinical setting. Reitan used heterogeneous groups, not controlling for location and extent of lesion and other variables, although groups were generally matched for age, education, sex and color. A quote from Heilbrun indicates why, at least in the early stages of different areas of research, this approach was purposeful:

> From a clinical viewpoint [...] there is some merit in assessing our diagnostic instruments with a heterogeneous criterion group, since this apprises us of the clinical value of any instrument where the neurological symptoms and the underlying pathology are highly varied. Thus, one advantage of a diverse research sample of brain-damaged Ss is that we are given an estimate of the clinical utility of the predictor in a setting where diversity is the clinician's lot, e.g., in a screening situation. If, on the other hand, one is interested in the relationship between localized brain pathology and specified sensory or motor functions, as might be the case if the interest were theoretical, it goes without saying that maximal similarity in the nature of lesion would be a methodological advantage.[15]

On a sample of fifty subjects with verified brain pathology, and fifty control subjects with no neurological or anamnestic evidence of brain pathology or disease, with both groups matched for color, sex, age and years of formal education, Reitan[16] discovered that, on ten tests of the

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15 Heilbrun, op. cit., p. 512-513.

16 R. M. Reitan, "Investigation of the Validity of Halstead's Measures of Biological Intelligence," AMA Archives of Neurology and Psychiatry, Vol. 73, 1955, p. 28-35.

battery and the Impairment Index, there were significant mean differences on all results except on the two Critical Flicker Frequency (CFF) scores. The battery, in addition to the CFF scores consisted of the following eight tests: Category test, Rhythm subtest of the Seashore tests of Musical Talent, Speech Sounds Perception test, Finger Oscillation test, Time Sense test-Memory component, Tactual Performance test-Time, Memory, Location components. The differences were larger and more consistent than Halstead's original results. The Impairment Index differentiated the groups the best, followed closely by the Category test.

From this Reitan concluded that this battery was sufficiently sensitive to the effects of organic brain damage and could be used to systematically study the relations of brain functions and behavior.

The second part of this study was published in 1959,[17] in which Reitan compared the effects of brain pathology on the Halstead Impairment Index and the Wechsler-Bellevue scale, hoping to see which abilities were especially sensitive to cerebral impairment. All the IQ measures were significantly lower for the brain-damaged compared to a control group; in addition, for the subtests, all but the

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17 R. M. Reitan, "The Comparative Effects of Brain Damage on the Halstead Impairment Index and the Wechsler-Bellevue Scale," Journal of Clinical Psychology, Vol. 15, No. 3, 1959, p. 281-285.

Digit Span were significantly lower for the brain-damaged at the .01 probability level. Concerning the different aspects of the Wechsler, it was noted that the performance and verbal factors were not differentially sensitive to the effects of brain pathology for this heterogeneous group. When the W-B was compared with the Index, the latter was more sensitive to the impairment of abilities.

Halstead had originally concluded that the more severe impairment was associated with frontal encephalopathy. In a 1958 publication, Shure and Halstead[18] modified this stand, stating that only tests of abstraction were performed less significantly well by frontal lesion subjects as opposed to those with non-frontal lesions. When Chapman and Wolff[19] re-evaluated Shure and Halstead's data, they noted that an artifact had been introduced in the guise of larger amounts of cerebral tissue having been removed from those with frontal pathology. They did reassure the sensitivity of Halstead's battery vis-à-vis cerebral dysfunction, but unveiled the fact that the degree of impairment appears

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18 G. W. Shure and W. C. Halstead, "Cerebral Localization of Intellectual Processes," Psychological Monographs, Vol. 17, No. 12, 1958, p. 1-40.

19 Loring F. Chapman and Harold G. Wolff, "The Cerebral Hemispheres and the Highest Integrative Functions of Man," Archives of Neurology, Vol. 1, 1959, p. 357-424.

to be more directly related to the amount of brain tissue removed than the presence of pathology in the anterior or posterior sections of the cortex.

An essential step in the validity of the battery was the necessity of refuting K. Goldstein's theory that brain pathology caused qualitative, not quantitative, changes.[20] If Goldstein was correct, quantitative tests of behavior as a measure of organic functioning would be useless, since they are based on comparisons to normal controls. Reitan, in a series of studies, underlined the fact of quantitative change.

In the first study,[21] Reitan was attempting to show the relationship between psychometric intelligence, as measured by the W-B scales, and Halstead's biological intelligence. The W-B and the ten tests which composed the Impairment Index were administered to both a normal and a brain-damaged group, with fifty subjects in each group. The results of the neuropsychological tests, the W-B subtests and full-scale scores were correlated for each group.

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20 K. Goldstein, Human Nature, Cambridge, Harvard University Press, 1940, 258 p.; quoted by R. M. Reitan, "Qualitative versus Quantitative Mental Changes Following Brain Damage," Journal of Psychology, Vol. 46, 1958, p. 339-346.

21 R. M. Reitan, "Investigation of Relationships Between 'Psychometric' and 'Biological' Intelligence," The Journal of Nervous and Mental Disease, Vol. 123, No. 6, 1956, p. 536-541.

When only the W-B variable intercorrelations were considered, it was observed that for both groups of subjects most of the coefficients were significant beyond the .05 level. Reitan interpreted this as suggesting that the W-B variables are substantially interrelated regardless of the presence or absence of brain pathology.

When the significance of the differences of individual pairs of correlations in the two groups were tested, only two out of ninety-one pairs of coefficients were significantly different at $p < .05$. The conclusion offered was that the relationship of the W-B variables was approximately the same for both brain-damaged and normal groups.

The Halstead tests were not as highly intercorrelated for each group, suggesting each test was more independent. Again, when the groups were compared, only one out of fifty-five pairs of correlations was significantly different, indicating that brain pathology did not cause a substantial change in the interrelationships. Finally, when the Halstead battery was intercorrelated with the W-B scales for both groups, the evidence suggested that the relationships between performances was not differentially affected by the presence or absence of cerebral pathology.

Reitan concluded that, since the correlations between the measures of biological intelligence (the neuropsychological tests) and psychometric intelligence (the

W-B) were of a magnitude of .55 to .64, it indicated a substantial relationship between the two concepts of intelligence. Moreover, since the comparison of the correlations for both groups did not yield significant differences, it appeared that qualitative differences did not exist between the normal and brain-damaged groups, and that qualitative differences are not valid means to differentiate brain pathology.[22]

In another study using the same variables,[23] Reitan found that only seven out of three hundred intercorrelations were significantly different at the .05 level of probability, while the correlation between the correlation matrices for both groups was .85. The results indicate that highly similar abilities are being measured and that, even if those with brain pathologies do show impairment, their abilities are essentially of the same kind as the non brain-damaged, suggesting that the differences are primarily quantitative.

Finally, using the Halstead Category test, which has two subtests based on the same principle,[24] it was hypothesized that, if there was an improvement from one subtest to

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22 Ibid., p. 539.

23 Reitan, "Qualitative versus Quantitative Mental Changes following Brain Damage," p. 339-346.

24 --------, "Impairment of Abstraction Ability in Brain Damage: Quantitative versus Qualitative Changes," The Journal of Psychology, Vol. 48, 1959, p. 97-102.

the other, it would indicate a transition from the concrete to the abstract, arguing against Goldstein's hypothesis that the characteristic sign of brain pathology is a return to the concrete. Both the brain-damaged and normal groups improved. Although the normals improved both absolutely and proportionally more, the differences were not significant, indicating that there was a quantitative rather than a qualitative difference between the groups.

Other general studies followed, many of which included the Wechsler scales as a predictor of brain pathology. Investigating the relation between language and thinking, Reitan[25] researched the significance of dysphasia on both the neuropsychological battery and the Wechsler tests. Again, the control group was better than two groups of brain-damaged subjects, with the exception that the one group without dysphasia was not greatly inferior to the controls on the verbal scale of the W-B. Comparing the two brain-damaged groups, there were no significant differences between dysphasics and those without dysphasia on all tests except two tests of language symbols. Reitan concluded that the language function is less important in complex thinking than presumed, as the dysphasics were not more severely impaired generally.

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25 R. M. Reitan, "The Significance of Dysphasia for Intelligence and Adaptive Abilities," The Journal of Psychology, Vol. 50, 1960, p. 355-376.

Reed, Reitan, and Kløve,[26] comparing brain-damaged older children, age ten to fourteen, with their matched normal counterparts, achieved results indicating that, on twenty-four out of twenty-seven variables which included the Wechsler scales and the neuropsychological battery, the brain-damaged were lower than controls at the .005 level of significance, the three remaining tests differing at the .02 level. They also discovered that the brain-damaged children were more frequently impaired on tests of language functions than on other tests, a conclusion which was contrary to Reitan's previous findings[27] in which dysfunction in adults was more sensitive to the Category test than to the Wechsler verbal scale. A possible reason given was that adults had more of the verbal stored in long-term memory.

Vega and Parsons attempted to cross-validate the H-R battery. They briefly reviewed tests designed to discriminate brain pathology, and stated that the H-R battery best fitted the necessary requirements of a behavioral index of cerebral pathology. "However," they continued, "there are several questions regarding the methods by which

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26 Homer B. C. Reed, Jr., Ralph M. Reitan, and Hallgrim Kløve, "Influence of Cerebral Lesions on Psychological Test Performances of Older Children," Journal of Consulting Psychology, Vol. 29, No. 3, 1965, p. 247-251.

27 Reitan, "Impairment of Abstraction Ability in Brain Damage: Quantitative versus Qualitative Changes," p. 101.

the data are customarily analyzed and presented which must be settled before the norms would be of maximal use to investigators using these tests in other laboratories."[28] Often the mean raw scores are not presented; variables such as age and education are matched rather than being taken into account; little is given on how scores can shift as a function of the differences in the studied population. The purpose of their particular research was to possibly add to the validity as well as take into account some of the problems they had mentioned.

Comparing a heterogeneous group with unequivocal evidence of brain pathology to a group of non brain-damaged controls, most of whom were hospitalized, _t_ ratios for differences between mean raw scores on both the full WAIS and eight neuropsychological tests were significant at the .001 probability level for all tests except Time Sense-Memory. When the cut-off point for the Impairment Index was .6, 54% of the controls were misclassified. Placing it at .7, the total correct prediction for both groups was 73%, with a 34% false positive rate.

Vega and Parsons revised the Impairment Index in the hope of raising the proportion of hits. The control

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28 Arthur Vega, Jr., and Oscar A. Parsons, "Cross Validation of the Halstead-Reitan Tests for Brain Damage," Journal of Consulting Psychology, Vol. 31, No. 6, 1967, p. 619-625.

group's scores were rank ordered and converted into normalized T distributions with a mean of fifty and a standard deviation of ten. This was used as a conversion table for changing the brain-damaged group's scores into T scores. This procedure varies from most other studies, which rank order scores of all the groups and then change them into T normalized scores.

Having done this, the mean T scores across tests for each subject became the base of the revised index. A mean T of forty-six correctly classified 76% of the brain-damaged group and 78% of the control, with fewer false positives. When the Time-Sense test was removed, the percentages were eighty and seventy-eight, respectively.

The results of this study indicate that the H-R battery does discriminate between heterogeneous groups of brain-damaged and non brain-damaged subjects. They also pointed to the need for age norms for brain pathology even for adult groups and, in general, the need to take into consideration other variables. Education in years was not significantly correlated with the tests in the group with cerebral dysfunction. Other suggestions were the necessity of subtle patterns of scores instead of a mere reference to the level of performance. The authors also used a control group of patients who were hospitalized on a neurological ward for disorders other than brain damage. When heterogeneous groups are employed this has become a standard means of maximizing error to see if the battery will still discriminate.

One necessary aspect for validity is to ascertain if the tests will stand up in different geographic locales. Halstead and Reitan had used a Midwest population; Chapman and Wolff drew on the eastern metropolitan of New York City; and Vega and Parsons still another location. Kløve and Lochen[29] went a step further and cross-validated the battery on a group of Norwegian control and Norwegian brain-damaged subjects and a group of Wisconsin control and Wisconsin brain-damaged subjects. A high level of discrimination was obtained between the controls and brain-damaged groups which did not appear to be affected by different language and cultural backgrounds.

Not all studies have substantiated the validity of the H-R battery. Watson _et al._,[30] comparing fifty patients with chronic brain syndrome to fifty schizophrenics on two levels of chronicity, recent versus old admission, concluded

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29 H. Kløve and E. A. Lochen, "A Cross Cultural Validation of Neuropsychological Tests," 1970 (study in progress); quoted by Klove, "Validation Studies in Adult Clinical Neuropsychology," p. 6.

30 Charles G. Watson _et al._, "Differentiation of Organics from Schizophrenics at Two Chronicity Levels by Use of the Reitan-Halstead Organic Test Battery," _Journal of Consulting and Clinical Psychology_, Vol. 32, No. 4, 1968, p. 679-684.

that, in general, the battery did not differentiate the groups. The Category test, for example, correctly classified 90% of the organics, but misclassified 84% of the schizophrenics as brain-damaged. Only one of the twenty-four classifications, chronicity versus diagnosis, was significant. Even when eight experts clinically diagnosed the protocols, the mean correct classification was 25.5 out of 48. The authors concluded that the Halstead battery had little value in a psychiatric hospital, since it was unable to separate schizophrenics from those with brain dysfunction. Instead, they suggested using personality measures as discriminative tools.

The results from Lacks et al.[31] basically substantiated the forementioned research. Comparing the Halstead battery to the Bender-Gestalt on nineteen organics, twenty-seven schizophrenics and eighteen general medical patients, they noticed that the neuropsychological battery frequently misclassified the schizophrenics. The Bender-Gestalt was more effective in classifying non-organics, obtaining 91% correct classification as opposed to the battery's 62%.

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31 Patricia B. Lacks et al., "Further Evidence Concerning the Diagnostic Accuracy of the Halstead Organic Test Battery," Journal of Clinical Psychology, Vol. 26, No. 4, 1970, p. 480-481.

Both S. Goldstein[32] and Kløve[33] raise methodological problems about Watson's study that may be generally applied to Lacks et al. For example, neither study was as explicit as other studies in defining how it verified the presence of brain pathology, nor did Watson's research definitely exclude brain pathology from the schizophrenic group. Kløve remarks:

> The absence of information regarding neurological findings such as EEG, brain scan, spinal fluid examination, neuroradiological studies, and a failure to obtain expert neurological evaluation of both the neurologic and schizophrenic groups would in addition to the factors mentioned lead to the conclusion that the question regarding the ability of these neuropsychological tests to separate institutionalized chronic brain syndrome patients from schizophrenic patients remains unanswered.[34]

Others have pursued this problem. DeWolfe et al.,[35] pointing to the theoretical postulate that chronic schizophrenia has an organic base as the reason why some believe the two groups cannot be discriminated, suggested that more effort must be made to control for motivation and degree

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32 S. Goldstein, op. cit., p. 404.

33 Kløve, "Validation Studies in Adult Clinical Neuropsychology," p. 12-13.

34 Ibid., p. 13.

35 Alan S. DeWolfe et al., "Intellectual Deficit in Chronic Schizophrenia and Brain Damage," Journal of Consulting and Clinical Psychology, Vol. 36, No. 2, 1971, p. 197-204.

of impairment. If only average impairment is considered, any particular group with brain pathology can look better or worse than a schizophrenic group.

They compared a group of diffuse or bilateral brain-damaged subjects with a schizophrenic sample. Both were subdivided into two groups according to age, those twenty-five to fifty-nine, and those over sixty. Relating each subtest score on the WAIS and on nine Halstead tests to the individual mean for the entire test, a deficit pattern score was achieved. The WAIS scores significantly discriminated the two groups, while the Halstead scores gave a statistically reliable interaction between diagnosis and age, approaching significance. The battery did have differing patterns of deficits.

Stack,[36] in his doctoral thesis, gave the H-R battery and the MMPI to groups of medical, acute schizophrenics, and brain-damaged subjects. The over-all pattern of scores placed the schizophrenics between the medical patients and the brain-damaged groups, but closer to the medical. There were significantly different patterns of scores between the brain-damaged and both the schizophrenics

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36 James Thomas Stack, "Performance of Acute Paranoid and Non-paranoid Schizophrenic Patients on the Halstead-Reitan Battery Using Two Levels of Symptomatology," Dissertation Abstracts International, Vol. 32(5-B), 3018-B, November 1971.

and the medical patients, but not between the latter two. This study indicates that the H-R battery appears to have some validity in differentiating acute schizophrenics. The general conclusion must be, however, that this is a problem area and that this factor must be directly studied or controlled.

The influence of other variables and different diagnostic conditions on the results of psychological testing was also studied. Vega and Parsons and DeWolfe *et al*. had suggested age as a variable. In one of the first studies considering this factor, Reitan[37] found that the Impairment Index, as well as eight out of the ten tests on which it was based, gave highly significant differences between a non brain-damaged group and one with cerebral pathology. When this adult population was divided according to age in five-year intervals, the brain-damaged group had scores which tended to show a greater impairment with advancing age. The correlation between age and the Impairment Index was .23. All ages had scores within the impaired range. The group without cerebral pathology had a higher correlation ($r=.54$), the 45-65 year-old group having impaired scores, with each age having a poorer mean score.

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37 R. M. Reitan, "The Distribution According to Age of a Psychological Measure Dependent upon Organic Brain Functions," *Journal of Gerontology*, Vol. 10, 1955, p. 338-340.

Reed and Reitan also indicated that the effects of brain damage on intellectual functions parallel the results of normal aging.[38] They concluded that not only did this reflect that the aging process is a continuous deterioration, but also that brain damage is a quantitative change.

Acuteness of brain pathology in relation to psychological deficits is another variable that has been studied. Fitzhugh _et al_.[39] compared three groups with brain pathology to a control group with no central nervous system disturbance. The three brain-damaged groups consisted of those with acute dysfunction, another group with relatively static status, and the third chronic-static group having a long-standing brain dysfunction. The W-B was administered, in addition to seven subtests of the Halstead battery, and the Impairment Index.

In general, the control group was consistently better than all three groups with brain pathology, the acute being the most impaired, with the two static groups being fairly comparable. It was concluded that the tests can

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38 Homer B. C. Reed and Ralph M. Reitan, "Changes in Psychological Test Performances Associated with the Normal Aging Process," _Journal of Gerontology_, Vol. 18, 1963, p. 271-274.

39 Kathleen B. Fitzhugh _et al_., "Psychological Deficits in Relation to Acuteness of Brain Dysfunction," _Journal of Consulting Psychology_, Vol. 25, No. 1, 1961, p. 61-66.

basically differentiate, and that acuteness of the organic brain lesion is an important variable.

Reed and Fitzhugh[40] were concerned with the patterns of deficits as related to the severity of cerebral pathology. When mild and moderately impaired groups of children and adults were compared to their respective controls, both groups of impaired children were noted to have patterns of deficits similar to the moderately impaired adults. The age of onset of lesion was given as a possible explanation.

Several variables thus do have an influence on the test results, at least in some instances. If possible, they should be included in the analysis to see their effects.

Research attempting to further localize sites of dysfunction will not be covered in this review since they are not pertinent to the present study.

An underlying factor in much of the literature reviewed to date is discussed by Reitan when he analyzes the problems of applying problem oriented research to patient oriented clinical diagnosis:

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40 Homer B. C. Reed, Jr., and Kathleen B. Fitzhugh, "Patterns of Deficits in Relation to Severity of Cerebral Dysfunction in Children and Adults," Journal of Consulting Psychology, Vol. 30, No. 2, 1966, p. 98-102.

> An approach which may help toward improvement in communication between these areas would require a procedure which inquires about the effects of brain lesions, not in terms of their effects only on single variables, but as disturbances of patterns or relationships of abilities. In this case, however, our conventional research approaches may generate results which reflect the limitations of the statistical methods applied rather than the information inherent in the data.[41]

Some of the studies concerning various variables, and patterns of deficits, reflected this concern. Wheeler and others pioneered advancement in this area by analyzing the data with a different statistical technique. In the first of this series, Wheeler, Burke and Reitan[42] reported that there are four smaller problems which may be emphasized in experimental research on brain dysfunction. The first concerns the classification of subjects on the basis of a neurological assessment as the criterion since, without a correct preliminary classification, any subsequent behavioral classification would be invalid. A second aspect is the finding of individual indicators which can differentiate the groups.

A third important problem is the use of combinations of indicators, since patterns are much more powerful than

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41 Reitan, "Diagnostic Inferences of Brain Lesions Based on Psychological Test Results," p. 376.

42 Lawrence Wheeler _et al_., "An Application of Discriminant Functions to the Problem of Predicting Brain Damage Using Behavioral Variables," _Perceptual and Motor Skills_, Vol. 16, 1963, p. 417-440.

individual indicators. The approach to this can be done systematically using techniques such as discriminant analysis. They stressed, however, that such techniques only supplement the clinical (unsystematic) approach of combinations, since systematic techniques are bought at a price. For example, discriminant functions only utilize linear combinations. Finally, because of measurement error in any sampling, there is a necessity for cross-validation.

Wheeler et al., in this study, researched basically the use of discriminant functions as a means of combining scores, in addition to being a type of cross-validation to previous studies using the H-R battery and the Wechsler scores. Twenty-four behavioral indices were employed: eleven Wechsler subtests and eleven Halstead subtests (Category, CFF, CFF Deviation, Tactual Performance Test (TPT) Time, TPT Memory, TPT Localization, Seashore Rhythm, Speech Perception, Finger Tapping Speed, Time Sense Memory, Time Sense Visual) and two Trail Making tests. Combined scores such as the Impairment Index and the IQ scores were not used.

Comparisons of responses from four groups of subjects were made: sixty-one controls, consisting of normals, and others hospitalized for various reasons other than cerebral dysfunction; 25 patients with left cerebral pathology; 31 right hemisphere patients; and 23 with diffuse or bilateral damage. Age and education were included as variables. Handedness was not controlled for on the basis of Penfield and Roberts'[43] detailed study which failed to find a significant interaction between cerebral dominance and handedness if patients with cerebral injury before the age of two years were omitted.

Wheeler et al. presented a detailed explanation of how they used discriminant analysis. The cut-off point employed was the one which minimized the total number of classification errors. When different pairs of groups were compared, the following were the percentages of correct predictions using the discriminant analysis: controls versus all cerebral damage, 90.7%; controls versus left hemisphere pathology, 93%; controls versus right damage, 92.4%; controls versus diffuse damage, 98.8%; and right versus left damage, 92.9%.

When compared to other combined scores, the discriminant function was superior in all comparisons. Comparing only the controls versus all those with cerebral injury, the Impairment Index yielded an 87.2 % over-all correct classification, the Wechsler Full Scale IQ - 77.7%, Verbal Weighted Score - 76.2%, Performance Weighted Score -

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43 W. Penfield and L. Roberts, Speech and Brain Mechanisms, Princeton, Princeton University Press, 1959; quoted by Wheeler et al., op. cit., p. 427.

85.1%, and Trails A plus Trails B - 82.1%. Considering these and other combined scores, six out of the ten combined scores were better discriminators than any one of the twenty-six single indicators. When all the percentages of over-all correct predictions were rank ordered, five out of the top nine indices were based on discriminant functions and a discriminant function index did not occur at a lower rank. "The very best discriminator found was the twenty-four variable discriminant function."[44]

An interesting feature is that, while the weights attached to the twenty-four variables maintained fairly equal ranks across the different comparisons, they were found to shift sufficiently so that three classes of variables could be distinguished. The first class was those that consistently had high ranks, such as Similarities, TPT Total Time, Trail Making Test B and the Category test. These were hypothesized to measure general effects of cerebral pathology and should never be dropped from a behavioral analysis. Some had consistently low weights. Digit Span, Picture Completion, Time Sense - Memory, and CFF must be re-examined to see if they should be maintained. Finally, certain measures such as Block Design, Speech Perception, Object Assembly, and TPT Memory varied greatly

44 Wheeler et al., op. cit., p. 437.

in weight from one comparison to the other, and may be important in finer diagnosis such as localization.

Two other considerations were made by the authors. The first is that the effectiveness of discrimination of an individual indicator has no necessary bearing on its effectiveness in combination with other indices. Secondly, the various measures were not equally accurate in predicting both non brain-damaged and pathological groups. If people are brain-damaged, almost all of the indices could correctly predict this for 75% of the cases. However, if they did not have verified cerebral dysfunction, only about one-third of the indices could predict this with 75% accuracy.

> Thus, it becomes important, in selecting tests for brain damage, to know where one needs to be most accurate; that is, if one wishes to be certain not to call non-damaged people "damaged," then only a few of the indices are likely to be useful [...] Finally, if one wishes to minimize errors of both kinds, it is apparent that relatively few of the indices will do the job adequately.[45]

Wheeler and Reitan,[46] aware that measurement error could inflate classification percentages, cross-validated the linear discriminant function procedure on an additional sample of 164 added to the original 140 patients. Again, various group comparisons were analyzed.

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45 Ibid., p. 439.

46 Lawrence Wheeler and Ralph M. Reitan, "Discriminant Functions Applied to the Problem of Predicting Cerebral Damage from Behavioral Tests: a Cross-Validation Study," Perceptual and Motor Skills, Vol. 16, 1963, p. 681-701.

The discriminant function was applied to the sample in three ways. It was first applied to the 304 sets of data together to give an indication of the effects of group size on the efficiency of the method. With this larger size, the over-all correct classification was reduced to 85%. Another method was to divide the total group randomly into two equal groups, attain the discriminant function weights for each group, and then apply them both to the group from which they came and to the other group. The average increment due to reducing group sizes by half was six percentage points. When the weights were crossed, the weights decreased an average of 17%.

Finally, the group was divided temporally, those who had been tested earlier versus those who were tested later. In general, although some changes appeared to have occurred during the collection period, the analysis pointed to generally stable criteria over the ten years of data collection.

The authors concluded that, considering all the group comparisons, loss of classification accuracy observed in the validation varied between 10% and 20% of the uncrossed accuracy. Nevertheless, the obtained percentages for all comparisons except the lateralized damage versus non-lateralized damage groups were high enough to make the discriminant analysis a practical tool of discrimination over and above the loss due to error.

> The study has, in a sense, provided evidence that: (a) distinction between the damaged versus non-damaged brain may be made largely on the basis of linear relationships existing in the relevant behaviors; (b) distinctions between lateralized and non-lateralized damage must involve, to a much greater extent, consideration of non-linear relationships; and (c) the adequacy of the linear (vs non-linear) prediction in distinguishing laterality of damage is intermediate, relative to (a) and (b).[47]

An important note in the research was that the relatively simple Impairment Index was as effective as the discriminant function in all comparisons of control and brain-damaged patients, except in discriminating right from left cerebral damage. This observation was at variance with the earlier observation that the discriminant function was the best discriminator.

As a result of their remarks that some patterns of deficit may not fit a linear relationship, Wheeler and Reitan subsequently compared a linear and non-linear method of analysis on an aphasia screen test. Both methods produced averages of correct percentages within virtually the same range, but with a different pattern of accuracy of classification. The discriminant analysis results were similar to those in the previous study.[48]

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47 Ibid., p. 700.

48 Lawrence Wheeler and Ralph M. Reitan, "The Presence and Laterality of Brain Damage Predicted from Responses to a Short Aphasia Screening Test," Perceptual and Motor Skills, Vol. 15, 1962, p. 783-799.

The validity studies reviewed so far basically substantiate that the H-R neuropsychological battery is a valid indicator of brain pathology. Other studies have compared the battery to various neurological variables, one purpose being to see if the psychological test results were related to neurological criterion information. Doehring and Reitan[49] were interested in the comparative effects of homonymous visual field defects when in connection with brain pathology. Four groups were used, three of them with verified brain dysfunction, and the fourth a control group which had neither brain damage nor field defects. One of the brain-damaged groups had right homonymous visual field defects, the other left, and the third group had cerebral pathology without field defects. Twelve neuropsychological measures were used, including Trails A and B.

The controls were significantly better than all three brain-damaged groups on most measures, reflecting the sensitivity of the measures to organic brain pathology. When the three organic groups were compared, it was noted that the decrement due to the field defects was minimal in proportion to the other consequences of the pathology. Another finding was that the lesions of the non-dominant

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49 Donald G. Doehring and Ralph M. Reitan, "Behavioral Consequences of Homonymous Visual Field Defects in Brain-Injured Adults," _Journal of Comparative and Physiological Psychology_, Vol. 54, No. 5, 1961, p. 489-492.

hemisphere seemed to result in more serious behavioral consequences. A later study showed that the deficits were somewhat differential depending on the laterality of the lesion.[50]

Matthews and Booker[51] studied the relationship of a large range of behavioral indices, including the Halstead battery, between two groups of patients who varied according to the size of the ventricles in pneumoencephalographic findings. A relationship was discovered between the size of the ventricle and the performance on neuropsychological tests, the groups with the smallest ventricles achieving better results in twenty-one out of twenty-four comparisons, six of these significant at the 5% probability level. This, however, was achieved only when subjects at the extremes of the distribution of ventricle size were compared.

Another purpose in comparing the battery to various neurological variables is to see if the battery can be of value when neurological diagnosis is difficult. An important

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50 Donald G. Doehring and Ralph M. Reitan, "Language Disorders in Brain-damaged Subjects," Archives of Neurology, Vol. 5, 1961, p. 294-299.

51 C. G. Matthews and H. E. Booker, "The Relationship of Ventricle Size and Asymmetry Measurements to Neuropsychological Test Results in Adult Subjects," in a paper presented at the meeting of the International Neuropsychology Society, Washington, D.C., September 1967; quoted by Kløve, "Validation Studies in Adult Clinical Neuropsychology," p. 9.

study in this area is the one done by Matthews _et al_.,[52] where they compared a group which had both symptoms and proven brain pathology to a control group in whom no neurological disease or injury could be found, but had the signs and symptoms initially suggesting organic brain pathology. The two groups were matched for age, sex and years of education. The _MMPI_, _WAIS_ and neuropsychological battery were administered.

When the means of the T normalized score distributions were analyzed, fourteen of the twenty-nine variables discriminated between the groups at the .01, four at the .05, and seven at the .001 level of significance. The _WAIS_ Verbal IQ and the hand dynamometer did not differentiate the groups. Therefore, even between groups where differences might be expected to be attenuated, the battery proved sensitive to true neurologic conditions despite the fact they were masked by a false symptomatology.

The authors did note problems of classification, above and beyond discrimination. Single scores were insufficient. The Impairment Index, which had the largest discriminatory power, misclassified 61% of the pseudoneurologic group at the same time it correctly classified

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52 Charles G. Matthews, Dale J. Shaw, and Hallgrim Kløve, "Psychological Test Performances in Neurologic and 'Pseudoneurologic' Subjects," _Cortex_, Vol. 2, 1966, p. 244-253.

91% of those with true pathology. These results suggest again that a different approach to the data is required.

Kløve[53] had investigated the relationship between neuropsychological test performance and another neurologic variable, neurologic status based on the physical neurologic exam. It is this same problem that the present research is studying. The population in Kløve's research consisted of 105 subjects divided into three groups. Two groups had verified brain dysfunction and were matched for diagnostic categories. One of the groups, however, had positive (abnormal) neurologic findings, while the other had negative results. The third group was a control group.

When the T normalized score means were compared for both the Wechsler and the H-R battery, the conclusion was that, for both cognitive and behavioral impairment, the presence or absence of abnormal neurologic findings played virtually no role. The control group was significantly different from the two groups with brain pathology, while the latter groups were essentially similar. Kløve summed by stating:

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53 H. Kløve, "The Relationship between Neuropsychologic Test Performance and Neurologic Status," in a paper presented at the meeting of the American Academy of Neurology, Minneapolis, 1963, quoted by Kløve, "Validation Studies in Adult Clinical Neuropsychology," p. 8-9.

> One is clearly tempted to draw the conclusion that a neuropsychological examination is considerably more sensitive to the organic integrity of the cerebral hemispheres than is even a competently performed neurologic examination.[54]

Some methodological problems in this research may be noted, although the scarcity of reported information may be the root of the criticism. The ability for individual measures to discriminate is not indicative of their diagnostic power. Some other statistical technique could be more profitably employed, such as discriminant analysis. Finally, little information is reported on the control group.

An investigation which may prove important to the above results is Reitan's[55] research into the effect of sensorimotor functions on other variables. Using the results of five tests (e.g., finger tapping, grip strength), he divided subjects with sensorimotor problems into one group which consisted of the bottom third most impaired of the original group, and another group of the third least impaired. These two groups were compared for significant differences in T scores on the MMPI, Verbal and Performance IQ scores on the Wechsler, and certain tests of the H-R battery.

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54 *Ibid.*, p. 9.

55 R. M. Reitan, "Sensorimotor Functions, Intelligence and Cognition, and Emotional Status in Subjects with Cerebral Lesions," *Perceptual and Motor Skills*, Vol. 31, No. 1, 1970, p. 275-284.

The more salient findings indicated that the presence or absence of prominent sensorimotor deficits may play an important role in evaluating results and planning future testing and intervention. Even though the groups were formed to maximize sensorimotor differences, the Performance IQ, Category test, Part B of Trails and the Seashore Rhythm resulted in just as great differences, with the "intact" group having the better scores. Moreover, other scores followed the same difference pattern. Reitan concluded:

> Finally, the results of this study appear to have practical significance regarding neurological and neuropsychological clinical evaluation. While the physical neurological examination may well reveal sensorimotor deficits in patients with brain disease or damage, detailed assessment of intellectual and cognitive status customarily falls within the area of neuropsychology. Impairment of intellectual and cognitive functions may have a profound effect on the practical, everyday adjustments of an individual. Therefore, if neurological examination revealed the presence of sensorimotor deficits of the type investigated in this study, it appears especially advisable to perform a more extensive evaluation of neuropsychological status.[56]

An important aspect in the comparison of behavioral measures to the physical neurological exam is a review of the validity of the latter. Bachmann,[57] in his doctoral

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56 *Ibid*., p. 284.

57 Rudolph Franz Bachmann, *Accuracy and Confidence of Neurological Diagnostic Judgment as a Function of Judge's Experience, Amount and Type of Information, and Diagnostic Category*, unpublished doctoral thesis presented for the degree in Clinical Psychology at Wayne State University, Detroit, Michigan, 1971, ix-148 p.

thesis which touches on this subject, reported that only one study has been uncovered in which neurological judgments of patients have been investigated.[58] This study was concerned with the process of clinical neurological judgment and the cognitive styles of neurologists, and is not pertinent to this present research.

Bachmann's thesis investigated the validity of clinical neurological judgment as a function of the amount and type of information presented to the judges, the level of experience of the judges, and the confidence these judges expressed in their judgment. Judges consisted of a group of neurology residents, a group of medical students rotating on neurology service, and a third group of undergraduate university students.

The patients to be diagnosed consisted of three types: vascular, brain tumor, and degenerative cases. Data for each case were divided into three sequential levels: (1) physical exam, neurological history and laboratory data; (2) neurological examination; (3) other techniques, such as the EEG, brain scans, etc.

Results relevant to this present study are the following: The experience of the judges did make a

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58 B. Kleinmutz, Processing of Clinical Information: Formal Representation of Human Knowledge, New York, Wiley, 1968; quoted by Bachmann, op. cit., p. 21.

difference, although only the resident group differed significantly from the undergraduates whose results were not above chance expectation. The level of information produced important results. While accuracy did increase in proportion to the amount of information available, only the first and third levels reached significance, seemingly indicating that the middle level, the neurological examination, did not add that much information to the physical exam, neurological history and laboratory data. The type of case also was relevant, since all classes of judges found it more difficult to evaluate the degenerative cases. Moreover, the amount of information was important, with significant increments of expressed confidence at each information level. In the case of degenerative cases, the neurological exam added little to the confidence in the diagnosis.

Residents and medical students requested to see the neurological examination results after the first level of information indicating, it seems, their confidence in these results. However, the arteriogram was the favored diagnostic tool. Finally, it was noted that the rate with which confidence increased with increased amounts of information, at least with the degenerative cases, was well below that which could be justified by the accuracy of the diagnoses.

In summary, neither Kleinmutz nor Bachmann's research dealt directly with the validity of the physical neurological exam. Nevertheless, in the latter research, the amount of confidence the neurology residents and medical students placed in it seemed incongruent with the actual amount of diagnostic information it yielded.

Thus far, the plan for amassing data on a fairly consistent core of tests reveals that the H-R core battery does discriminate heterogeneous groups of subjects with cerebral pathology. Most significant in this area is the battery's power when compared to neurologic data, the importance of which various authors have underlined. A secondary stress in the review has been the demand for different statistical approaches to analyze the data. Validity studies concerning individual tests will be omitted for the sake of brevity. It now remains to conclude the review of the literature, giving direction to this research.

2. Summary and Purpose.

Spreen and Benton,[59] reviewing various psychological tests for brain pathology, reported the following. When a single test is employed to detect brain dysfunction, the

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59 Otfried Spreen and Arthur L. Benton, "Comparative Studies of Some Psychological Tests for Cerebral Damage," Journal of Nervous and Mental Disease, Vol. 140, No. 5, 1965, p. 323-333.

average of correct predictions is 71%, the reported maximum being 90%. The average hit rate for pooled scores is 80%, with a reported maximum of 94%. If the scores are weighed by special formulas such as the discriminant function, the average of correct predictions rises to 83%, the maximum achieved being 91%. These hit rates are comparable to those achieved by other techniques, such as EEG and radiology. They conclude, "the search for screening devices has reached its culmination point, has served its purpose and should not be indefinitely continued."[60]

Selection of a screening device from those available should be made on the basis of the presence of adequate test construction and empirical validational procedures rather than by comparing the minimal differences in hit rate. The review of the literature has shown that the validity studies using the H-R battery and the Wechsler scales have done precisely this, keeping the core of tests constant, and gradually accumulating evidence of the power of these indices to discriminate cerebral pathology.

Although these behavioral measures have been shown to consistently discriminate with a high degree of accuracy those with brain dysfunction as compared to normals, a more unique value exists in their being able, if possible, to

60 Ibid., p. 333.

classify cerebral pathology precisely when neurological diagnosis is difficult. One specific problem in this area is the one already investigated by Kløve, in which the fore-mentioned standardized behavioral measures of central nervous system functioning were compared to the classification results of the physical neurological exam. Two groups with proven brain dysfunction, one group having a positive physical neurological exam and the other having negative findings on the same exam, were not found to be significantly different from each other on the basis of the behavioral measures, although both were significantly different from a control group. This suggested that the neuropsychological battery was indeed more sensitive to central nervous system functioning than a competently performed neurological exam.

This present research addresses itself to the same problem. Are there significant differences between (1) a group of subjects with proven brain pathology and abnormal (positive) results on a physical neurological exam; (2) a group with definite cerebral damage and negative findings on the physical neurological exam; and (3) a group consisting of control subjects? If so, where do these differences lie? In addition to posing these questions, which will be phrased in the null hypothesis form at the end of the next chapter, this study will compare the classification hit rate of the physical neurological exam and the behavioral indices.

Certain differences from Kløve's research will be noted. Additional measures are added to the H-R core, in keeping with the actual use of tests at the Royal Ottawa Hospital. Moreover, asking whether there is a significant difference among the three groups on the basis of the neuropsychological behavioral measures appears to demand a method of discrimination specifically designed to discriminate groups. The multivariate discriminant function analysis, a statistical technique which combines the results of the individual tests for maximum discrimination, will be used.

The following chapter will explain in more detail the sample and tests used and the various statistical methods employed.

CHAPTER II

EXPERIMENTAL DESIGN

This chapter presents the experimental design used in the study, plus a brief description of the variables used. Section one describes the sample population, both in light of the entire pool of subjects from which they were drawn and also according to the criteria by which they were divided into groups. In section two, the variables employed are outlined. Section three explains the experimental procedures, and section four deals with statistical methods used in analyzing the data. This is followed by a formal statement of the hypotheses to be tested.

1. The Sample.

The sample consisted of 102 male and female adult subjects who had been tested at Dr. R. L. Trites' Neuropsychology Laboratory at the Royal Ottawa Hospital. These patients were tested in this laboratory during the period September 1969 to March 1973. The term adult denotes subjects fifteen years of age and over, according to the criteria in use for the Halstead-Reitan battery.

The 102 subjects were divided into three groups of thirty-four each. Two of the groups had verified brain pathology, based on a definite diagnosis gleaned from neurological reports, composed of a history of brain dysfunction, plus pathognomic signs on one or more of the following indications: skull x-ray, angiogram, pneumoencephalogram, electroencephalogram, echoencephalogram, laboratory studies, and surgical procedures.

In addition, it was required that each subject have had a physical neurological exam consisting generally of the following: reflex status, sensory status, locomotion, co-ordination, cranial nerves, and ophthalmology. The results on this exam were the means by which those with verified brain pathology were divided into one of two groups: positive findings on a physical neurological exam in which there were some signs of abnormality; and negative neurological findings according to this physical neurological workup, indicating that the neurologist or neurological surgeon considered the results to be within the normal limits.

The control group, having no verified brain pathology, also had no abnormal signs on physical exams. These subjects had been referred to the neuropsychology lab for these reasons: vague diagnosis of cranial cerebral injury; neurological complaints; no neurological complaints or symptoms, but hypothesized possibility of brain pathology; learning disorders; and psychiatric problems. These subjects were labelled control on the basis of negative neurological tests and/or no neurological sequellae for at least one year following onset of complaints or referral, and no other corroborating history. All psychiatric patients with histories of insulin shock therapy, electric convulsive shock therapy, or diagnosis of chronic alcoholism or drug abuse, were excluded. Diagnosed schizophrenics were also excluded, reflecting the problems portrayed in the literature.

To be certain that all subjects were properly classified, each file was reviewed a minimum of four times by the author and R. Trites. Uncertain cases were referred to the neurologist in question for final diagnosis or, in some cases, hospital charts were consulted for further detail. Cases with the least doubt were eliminated from the group.

To minimize other confounding influences, all cases in which surgery intervened between the physical neurological exam and the neuropsychological testing were rejected. If surgery was a factor, it was necessary that both tests were given either before or after surgery. In addition, both the physical neurological and the neuropsychological testing had to be given, as a general aim, within one year of each other. Most subjects had the testing well within six months; if the interval was greater than one year, it was necessary that the patient be in the continued care of the doctor who had referred him, as in the case of those with chronic brain pathology. In these cases, any change in the patient's status was normally reported.

Subjects in the different groups were not matched for age, sex, education, intelligence, or duration of pathology (i.e., chronic versus acute). Instead, it was decided to include these as variables in the statistical analysis. Because of the difficulty already experienced in obtaining a sufficient sample for each group, and since this exceeded the purpose of this study, there was no control for diagnostic categories and extent and localization of the pathology.

The additional following criteria existed for all subjects. Results had to be as complete as possible for subjects on all variables included in the statistical analysis. Out of 4,998 scores to be analyzed (102 subjects times forty-nine variables), a total of twenty-nine scores were missing from the data files. Since the computer program to be utilized had a listwise deletion for missing data, it was decided to calculate the means of the score of the particular criterion group to which the subject belonged, and substitute this score into the individual data file.

It was also imperative that each subject had to completely fill all the criteria for one group, so that he could not by any means be placed into another classification.

2. The Measuring Instruments.

The following tests used in this research comprise a large segment of the adult psychological test battery in use at the Neuropsychology Laboratory at the Royal Ottawa Hospital. This battery, although its core is the Halstead-Reitan battery, is larger and more varied than the tests reported in much of the literature. The reason other tests are included is to have the research reflect the practical everyday status of neuropsychological testing, and to see if the added tests have a role to play in discrimination among groups.

Knox Cube Test (KNOXMEAN).--[1] This test consists of four wooden blocks of approximately one cubic inch dimension, mounted at regular intervals on a 10-1/2" x 1-1/2" wooden strip. The patient's task is to observe, memorize, and tap the cubes in the same order as the examiner does, after the examiner has completed the trial. In each trial, the examiner touches the blocks at the rate of one per second. The order of cubes touched in each trial is in prescribed sequences of increasing length and complexity, starting with two blocks in a single trial up to seven

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1 The abbreviations in brackets in the description of each test are the code names used in the computer program for the score(s) derived from that variable, and are necessary in understanding some of the presented data. See Appendix 1 for a summary description of these abbreviations.

blocks, the score consisting of the number of series correctly reproduced out of a possible eighteen series. The test is discontinued after three consecutive failures. A retest is given later in the testing session; both scores, reflecting the number of correctly reproduced series, are tabulated to give a mean score which can be converted through norms into a mental age score. In this study, the mean score will be used.

This hypothesized test of visual attention and memory requires no verbal responses. If necessary, instruction can be easily given by pantomime.

Finger Agnosia - Tactile Finger Recognition (AGNOSIAZ).- This procedure, given without the use of vision, requires the subject to identify individual fingers on either hand after tactile stimulation. In certain instances, it is permissible to give the patient practice with his eyes open and the hand unshielded to ascertain that he can report reliably. Although any verbal means of identification can be used to identify which finger had been touched, it is customary for the examiner and subject to agree on a numerical method of reporting, labelling the thumb one, the index finger two, and so on. Four trials for each finger on each hand, given in a random fashion, yielding a total of twenty trials on each hand, are used. The score for this study is recorded as the number of errors for each hand totalled together.

Fingertip Number Writing Perception.- In this test the subject must report without the use of vision which of four standard numbers (3, 4, 5, 6) has been written on the fingertips. The numbers are first illustrated on the subject's palm as to how they will be written; any variance between the subject's and the examiner's method should be modified in favor of the subject. Using a different finger for each trial, proceeding from finger one (thumb) to finger five, the four numbers, arranged in a standardized random manner, are written until four trials have been given for each finger of the dominant hand (WRITDZ). The same procedure is repeated for the nondominant hand (WRITNZ). The score is the number of errors per hand.

Lateral Dominance: Hand Dynamometer Test.- The dynamometer, the handle adjusted for sex and hand size, is presented to the subject, dominant hand first (LDOMD). The subject is requested to point it straight at the floor, arm and hand away from the body, and to squeeze it as hard as he can. This same procedure is repeated with the non-dominant hand (LDOMN), alternating trials until each hand has two trials. If the difference between the two scores on one hand is greater than three kilograms, the entire procedure is repeated later in the testing session, the score for each hand being the average in kilograms of all four trials.

Wide Range Achievement Test (WRAT).-[2] The WRAT was first standardized in 1936 as a convenient means for assessing the basic school subjects of reading, written spelling, and arithmetic computation. Each of these subtests is divided into two levels, I and II. Level I is intended for children between the ages of five years zero months and eleven years eleven months. From twelve years zero months to adulthood, Level II is used. Using the 1965 revised edition, the three subtests take between twenty and thirty minutes to administer.

More specifically, the three subtests contain the following aspects. Reading (WRAR) consists of recognizing and naming letters and pronouncing words; Spelling (WRAS) - copying marks resembling letters, writing one's name, and writing single words to dictation; Arithmetic (WRAA) - counting, reading number symbols, solving oral problems, and performing written computations.

Two scores are available. The first is the raw score for each subtest. This can then be converted through norms to grade school ratings, for use as a general indication of scholastic standing. In this study, the raw scores are used for the statistical analysis.

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2 J. F. Jastak and S. R. Jastak, The Wide Range Achievement Test, Manual of Instructions, Wilmington, Guidance Associates, 1965 Revised Edition, 56 p.

Finger Tapping Test (Finger Oscillation).- This measure of finger tapping speed using the index finger is given first with the dominant hand (FINTAPD), and then the nondominant hand (FINTAPN). Making sure the arm, wrist and other fingers are kept at rest, the subject is required to tap as many times as he can in a ten-second period. The subject may rest his hand at any time. However, the examiner insists that he rest after the third trial for each hand.

As soon as five consecutive scores within a range of five points are obtained, the test with that hand is discontinued, the final score being the mean of all five scores. If this cannot be achieved, the test is discontinued after a maximum of ten trials, the final score being the mean tapping rate on the basis of the five best scores. The procedure is repeated for the other hand.

Foot Tapping Test.- In a standing position, with his shoes on, the heel on the floor, the subject is requested to tap as quickly as he can. If necessary, he may brace himself by holding on to a wall or chair, etc. The number of times he taps in ten seconds is recorded. The procedure is repeated five times with each foot, trials alternating between the dominant (FOOTAPD) and nondominant foot (FOOTAPN). The subject may rest at any time between trials, but must rest after the third trial with each foot. The mean tapping rate for each foot is computed on the basis of the three highest scores.

Trail Making Test.- The Trail Making Test, one of the performance subtests of the Army Individual Test, consists of two parts, A and B, both parts having a sample practice during which the subject may be helped, and the actual timed test. Part A test (TRIATZ) consists of twenty-five circles distributed over an 8-1/2" x 11" white sheet of paper, and numbered from one to twenty-five. The subject is required to connect the circles with a pencil line as quickly as possible, beginning with the number one and proceeding in numerical sequence. Part B test (TRIBTZ) also includes twenty-five circles, numbered from one to thirteen and lettered from A to L. The task is to connect the circles, alternating between numbers and letters in ascending sequence, in this manner: 1-A-2-B-3-C-4-etc.

If the examinee makes an error in the actual test, the examiner calls it to his attention immediately, having him continue from the point where the mistake occurred. Timing is not discontinued. The score is the time in seconds required to complete each section. Errors are recorded, but count only in the increased time of performance.

Grooved Pegboard Test.- The 4" x 4" pegboard has on its surface five rows with five holes in each row, each hole having a little groove on one side. This pegboard is placed in the midline of the subject with the board at the edge of the table, and a peg tray containing twenty-five pegs with a groove along one side immediately above the board. Using his dominant (PEGSDZ) hand (e.g., right), the subject, going from left to right on the top row and taking one peg at a time, must place the peg into the hole. To do so, he must turn the peg so that the grooves will match. Filling one row at a time, and always filling each row in the same way as the top row, the subject fills all holes as quickly as he can.

The procedure is repeated with the nondominant hand (PEGSNZ), with the subject filling the rows in the opposite direction from trial one. For the purpose of this research, the score for each hand is the total time taken divided by the number of pegs put in.

Maze Coordination Test.- In this test, the subject is seated in the midline before a maze set into an 8-3/4" x 11-1/2" metal plate, which is placed on a slanted stand, with the edge of the stand at the edge of the examining table. The subject cannot rest his arm on the edge of the table. Using his dominant hand first, the subject, placing a stylus in the indented starting position at the bottom of the maze, works his way through the one-quarter inch wide groove until he reaches the end. Although an average speed of going through the maze is illustrated, the emphasis is placed on care in not touching the sides of the groove. The subject may not brace his arm against his side or against the table, nor steady it with the other hand.

With the power source turned on, both the number of times (MAZECDZ) the edges are touched and the duration in seconds the contact is maintained (MAZETDZ) are automatically recorded. The task is performed twice with the dominant hand, and then twice with the other hand (MAZECNZ, MAZETNZ). For each hand, the score is the total of the two trials for both the counter and the total time in contact with the sides.

Static Steadiness Test.- The steadiness test apparatus consists of a 5" wide x 3-1/2" high slanted metal plate, placed at the edge of the table. On the plate are eleven holes of decreasing diameters from one-half inch for the largest to less than one-eighth inch for the smallest. Taking the stylus in his dominant hand, and without bracing his arm or hand in any way, the subject is required to put and hold the stylus inside the largest hole without touching the sides. The examiner turns on the power source for a period of fifteen seconds, at the end of which he notes the automatically recorded number of times the stylus touched the sides, and the duration for which it was in contact with the sides. This is continued for all eleven holes, the final score being the cumulative total time (STEADTDZ) and counter (STEADCDZ) for all the holes. The procedure is repeated for the nondominant hand (STEADTNZ, STEADCNZ).

Resting Steadiness Test.- The steadiness apparatus is placed on the table with enough room for the subject to comfortably rest his arm, wrist and elbow on the table. With the power source off, the subject is requested to place the stylus in the sixth hole, which is approximately three-sixteenths of an inch in diameter, leave it there until told to remove it, and to keep his hand at rest, not touching the sides. The power source is turned on for a period of fifteen seconds, during which the total time in seconds the stylus touches the edges (RSTEADTZ), and the number of times it does (RSTCDZ), is automatically recorded. If the sides are not touched, the procedure is repeated with the nondominant hand (RSTTNZ, RSTCNZ). If either hand touches the sides, each hand is given a total of three trials, the score being the total of the three trials for counter and timer for each hand.

Halstead Category Test (ADCATTOZ).- In the Halstead Category test, the subject is presented with seven subtests of varying number of visual stimuli projected onto a milk-glass screen with a total of 208 trials being given for each subject. The various stimulus figures are one to three inches in height. Below this screen is a panel of four horizontally positioned response levers, numbered from one to four. The subject is told that a pattern, when projected onto the screen, will remind him of a number and that he should depress one, and only one of these four levers for each of the pictures that appears on the screen. A correct response produces a pleasant-sounding chime, and an incorrect response activates an unpleasant-sounding buzzer. This test procedure allows the subject to test one principle after another until a hypothesis is reached which is positively reinforced consistently by the bell.

After the first subtest, the subject is told that the test is divided into seven subtests, each of which has a main idea or principle or reason running throughout the entire subtest. His task is to find this idea. After each subtest, he is told that one subtest is completed and that, in the next, the idea may be the same, or it may be different. Although the principle for any group is never revealed to the subject, a certain amount of help may be given by repeating the initial instructions, telling the subject to think of the reason why he gets the right answer, to watch how the patterns change, etc.

The subject is required to abstract the correct principle for categorizing the visual stimuli that may vary in color, number, shape, size, relative extent, and relative position. Subtest I, an eight-trial introductory series, requires only the matching of the Arabic numerals above each of the answer levers with individual Roman numerals that are shown on the screen. Subtest II, consisting of twenty items, requires the matching of the number of figures presented in a horizontal series with the proper lever. The third group of forty items is based on an uniqueness principle. Four figures are presented, one of which differs from the other three in color, size, shape, outline or solid figure, or a combination of these attributes. The correct response is depression of the lever whose horizontal position corresponds to the figure that differs most. Subtest IV presents forty items, which figures can be divided into quadrants, the correct response being that lever which matches the clockwise position of the quadrant that differs most. Subtests V and VI, each having forty trials, are based on the same principle. The presented figure can be divided into four segments; the required response is depression of the lever whose number corresponds to the number of segments in the figure. Finally, the twenty trials in the seventh group are a review of certain items used in the six other subtests.

The score registered is the total number of incorrect responses.

Rhythm Test (SEASHOR).- This subtest of the Seashore Test of Musical Talent appears to demand alertness, sustained auditory attention to the task, and the ability to perceive differing rhythmic sequences. In it, the subject must differentiate between thirty pairs of rhythmic beats which are sometimes the same, sometimes different. The score in this study is the total number of correct responses.

Speech Sounds Perception Test (SPECZ).- Six sets of ten spoken nonsense words, variants of the "ee" diagraph, are presented in multiple choice form. The words are played from a tape recorder with the sound intensity adjusted for each subject's preference. The subject's task is to select and underline the spoken syllable from four alternatives printed on the test form. This test thus requires attention through all the items, in addition to the perception and discrimination of auditory stimuli, and then relating these perceptions through vision to the correct word on the test form. The score is the number of errors.

Roughness Discrimination (Sandpaper) Test.- Four 2" x 2" x 3/4" wooden blocks, with sandpaper of varying roughness textures glued on top, are placed in front of the subject. The examiner demonstrates how, using one hand only, the subject is to use his touch to arrange the blocks from the right to the left in order of increasing roughness of the sandpaper. The examinee should not be allowed to touch the blocks until his trials begin.

The subject, now blindfolded, is given six trials, three with each hand, alternating between the dominant (SANDDZ) and the nondominant (SANDNZ) hands. The blocks are placed before the subject at the beginning of each trial in a prearranged manner. The scores used in this study are the total number of errors for each hand, computed according to a formula in which the order of blocks achieved by the subject is subtracted from the required order. The first trial for each hand is not counted.

Tactual Performance Test (Time, Memory, and Localization Components).- The TPT, a psychomotor problem-solving task, is a modification of the Sequin-Goddard form board. It consists of a 12" x 18" board with ten indentations of various shapes, and ten blocks to fit these shapes. The board is placed on a stand in front of the subject and the blocks arranged in a horizontal line on the table, in front of the stand. The subject is blindfolded before the test begins, and is not allowed to see the formboard or blocks at any time.

Taking the subject's dominant hand, the examiner guides him in feeling the board, the stand and the blocks. The subject then is required to fit the blocks into their proper space using only his preferred hand. The procedure is repeated using the other hand, and then repeated a third time using both hands. The task is repeated three times with the same hand if the subject cannot use one hand. If on any of the three trials less than seven blocks have been placed in their proper spaces on the board at the end of ten minutes, the trial is discontinued. If seven or more have been placed, fifteen minutes is the time limit, unless the subject is on the verge of completing the task.

After the third trial, the board and blocks are removed from the table. Then, removing the subject's blindfold, the examiner requests the subject to draw a diagram of the board representing the blocks in their proper spaces.

For this study, three scores will be utilized. Total time (ADTPTOTZ) represents the time taken for all three trials. The memory component (ADTPTMEM) is based upon the number of blocks correctly produced in the drawing and the localization component (ADTPTBLK) depends on the number of blocks approximately correctly localized; i.e., within the correct quadrant and not seriously out of relationship to other shapes.

Halstead-Wisconsin Impairment Index (IMPZ).- The Impairment Index, as used in the Royal Ottawa Hospital Neuropsychology Laboratory, is a summary value based upon the following ten tests, not all of which are used in this statistical analysis: (1) Category test; (2) TPT Time; (3) TPT Memory; (4) TPT Location; (5) Finger Tapping, dominant hand; (6) Speech Perception test; (7) Rhythm test;

(8) Sensory Deficit; (9) Aphasia-spatial; (10) Trials total weighted score. Each of the scores has a cut-off point separating normal functioning levels from impaired levels.

The Impairment Index for an individual subject is calculated by tallying the number of test scores which fall beyond the cut-off point. The Index ranges from 0.0 to 1.0, each test on which the score exceeds the cut-off point contributing one-tenth of a point toward the index. Descriptively, the Index is as follows: 0.0 to 0.2 indicates normal central nervous system functioning; 0.3 - 0.4 is borderline normal; 0.5 - 0.6 reflects mild cerebral dysfunction; 0.7 - 0.8 indicates moderate dysfunction; 0.9 - 1.0 suggests severe impairment.

A possible problem resulting from the inclusion of the Impairment Index in the statistical analysis, specifically the factor analysis, must be clarified. Generally, summary tests composed of other tests already included in the analysis will give spurious results. In this case, certain conditions were felt to be sufficiently important to overcome this problem. First, two tests in the Index were not included in the factor analysis. Secondly, there was not a necessary direct correlation between any of the tests and the Index although there was naturally some correspondence. This is based on the fact of the individual test's cut-off scores. For example, a score of one to fifty for one subject may be indicative of "normal" results, while a range of fifty-one to ninety will suggest abnormality. Thus, the wide range of results which can be the base of the Index was considered a sufficient reason to include this summary value.

Pseudo-Neurological Scale (PN).- This auxiliary scale of the MMPI was developed by Shaw and Matthews.[3] Comparing the MMPI performance of those with verified brain pathology to a pseudo-neurologic group, seventeen items were discovered to differentiate between them. A cut-off score of seven, at or above which indicated a pseudo-neurologic case, correctly classified 81% of the pseudo-neurological group, and misclassified only 25% of the subjects with brain pathology.

Other variables were included in the analysis. Age (AGE), years of formal education (EDUC), and both Wechsler Adult Intelligence Scale Verbal (WAISVIQ) and Performance (WAISPIQ) were utilized. An individual's occupational status (OCCUPZ), i.e., being employed or unemployed, was another addition. In this study, unemployed was defined as not able to work for some reason. Housewives, then, were considered employed, while those on sick leave of two weeks or more were not.

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3 Dale J. Shaw and Charles G. Matthews, "Differential MMPI Performance of Brain-damaged versus Pseudo-neurologic groups," Journal of Clinical Psychology, Vol. 21, 1965, p. 405-408.

Electroencephalographic results (EEGZ) were included under the following headings: (1) given or not; (2) normal or not; and (3) severity of abnormal results. Since the temporal duration of the pathology has been indicated to be important, this was also included (STATUSZ). For the purpose of this study, acute pathology meant that the onset of cerebral pathology was within one year of testing, while chronic pathology indicated any duration beyond that time. Finally, the criterion groups (CRITER) themselves were added for reasons to be noted later.

3. Experimental Procedure.

The neuropsychological assessment on which the results are based is a five-and-one-half to seven-hour one-day session, beginning at 8:15 in the morning and lasting until approximately four in the afternoon with an hour or less for lunch. All testing was conducted by highly trained technicians. These same technicians doublechecked each other's results, following this same doublecheck procedure for transferring the results to coding sheets.

The order of testing is reflected in the description of the results in the preceding section. Although the order is not a hard and fast rule, certain principles are followed. The motor tests are interspersed with other tests to offset problems of fatigue. For a similar reason, the WAIS is given early in the testing session. The three subtests of the WRAT are often interspersed throughout the day. The shortened version of the MMPI is generally given as the last test of the day. In all tests where applicable, the dominant hand was used first.

4. The Statistical Analysis.

Rather than attempt to use all forty-eight variables as a means of discriminating among the groups, a factor analysis was conducted on these variables in order to reduce the possible measures. The criteria for separating the three groups were also added as a variable, since any tests that did not load on the same factor as the criteria would not be expected to differentiate the groups. In addition, the factor analysis could possibly contribute to the theoretical context of behavioral measures of organic brain functioning.

Due to the structure of some of the tests, a high score did not necessarily mean a better score. To eliminate this problem for those variables, each score was subtracted from a constant.

The factor analysis procedure used was the Statistical Packages for the Social Sciences (SPSS) program for principal-axes factors with iterations. This program first determines the number of factors to be extracted from the original correlation matrix. The main diagonal elements are automatically replaced with initial communality estimates, which in this case is the maximum off-diagonal element of the correlation matrix. From this new matrix the same number of factors are extracted. The variances accounted for by these factors become the new communality estimates which are then substituted in the diagonal. The entire process is iterated until the differences in two successive communality estimates are negligible.

Since a main purpose of the study is to distinguish members of groups from one another on the basis of their score profiles after the groups of persons had been defined _a priori_, multivariate linear discriminant function analysis was employed, specifically the _Statistically Oriented Users Programming and Consulting_ (SOUPAC) program for this analysis.

Different problems can be analyzed by this approach. One problem is to determine whether there is a significant difference in the average profiles of the three groups, an approach which is relevant to a comparison with Kløve's study. A second use of the discriminant function analysis is germane to this study since it has clinical applications regarding the correct assignment of individuals into their proper group, and the probability of misclassification. It also provides a description of the combination of characteristics which best separate the groups. The analysis maximizes the discrimination among groups by assigning appropriate weighting coefficients to scores, and transforming the scores into a single score (Z) which has the best potential for distinguishing members of groups.

This can be illustrated spatially (see Figure 1) using two a priori groups, G_1 and G_2, with measures X_1 and X_2 for two variables. For discriminatory analysis to be useful, the members of each group must not be randomly scattered, but must occupy a fairly limited space. If G_1 and G_2 represent the center points of the dispersion of scores for the two groups, it is seen that most members of each group are within a fairly limited space. The amount of overlap is an indication of the amount the two groups are not discriminated by the two variables.

The variables for any subject are transformed into a single measure on the discriminant function which can be used to indicate the population into which the subject should be classified according to the pattern of scores. The function is

$$Z = a_1X_1 + a_2X_2$$

where Z = the score on the discriminant function, X_1, X_2 = raw scores on the variables, and a_1, a_2 = the weights for the variables. These weights in a function are determined so that the difference between classes is large relative to

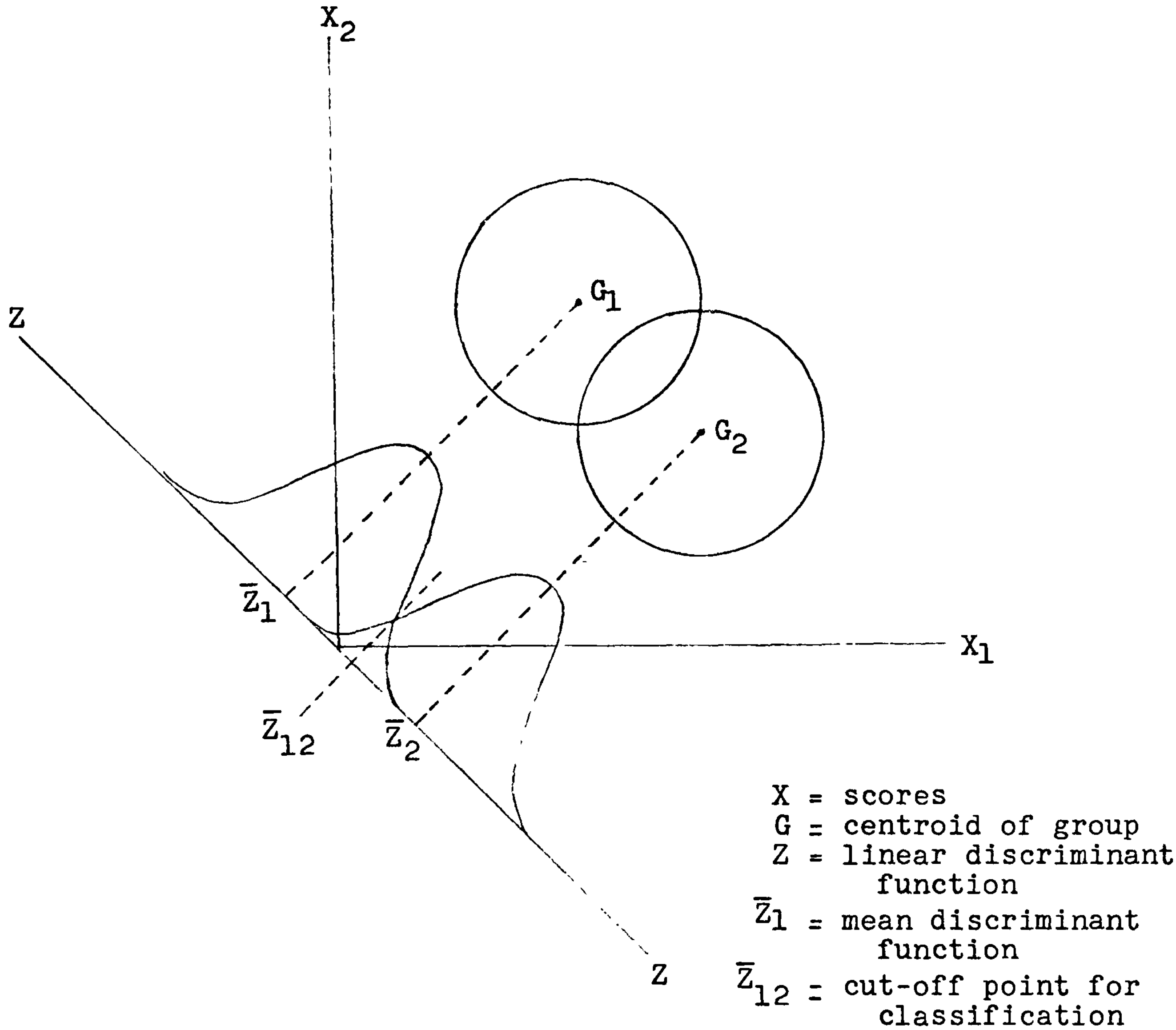

Figure 1.- A Hypothetical Dispersion of Scores of Two Groups on Two Variables and Their Transformation onto a Linear Discriminant Function.

the difference within classes, thus maximizing the separation between the groups.

This new score for each person, Z, has combined the information from the variables regarding the discrimination of the groups by the application of the weights to the raw scores. A new line Z can now be drawn on which all Z scores can be projected. There is now less overlap between the two groups and the means are farther apart.

The group means of the discriminant function is achieved by the following formulae:

$$\bar{Z}_1 = a_1\bar{X}_{G11} + a_2\bar{X}_{G12}; \ \bar{Z}_2 = a_1\bar{X}_{G21} + a_2\bar{X}_{G22},$$

where $\bar{Z}_1$ = the mean of Group one on the discriminant function, a_1 = weight for variable one, $\bar{X}_{G11}$ = the mean of Group one on variable one, and $\bar{X}_{G12}$ = the mean of Group one on variable two, etc.

To ascertain into which group a subject will fall based on his score profile, a critical cut-off point is required. If the individuals are assumed to have been sampled from the populations according to the same probability, and if the seriousness of misclassification are about equal, the logical critical discriminatory value is the mid-point between the two means on the discriminant function. Thus,

$$\bar{Z}_{12} = \frac{\bar{Z}_1 + \bar{Z}_2}{2},$$

where $\bar{Z}_{12}$ is the critical cut-off point between groups one and two. Then, if $\bar{Z} > \bar{Z}_{12}$ and $\bar{Z}_1 > \bar{Z}_2$, that is, if the individual's discriminant score is larger than the cut-off score, and the first mean is larger than the second mean discriminant score, the individual is allocated into the first population, and so on. This is labelled the maximum-likelihood procedure since each subject is assigned to the criterion group in which the occurrence of his particular discriminant score is most likely. Percentages of proper classification and misclassification can then be readily tabulated.

In multiple discriminant analysis where more than two groups are analyzed, one or more weighted combination of scores for distinguishing among members of different groups may be necessary to account for all the differences. The first discriminant function may distinguish well between certain groups, and not others, thus requiring a second or more function(s) to distinguish between groups that were not well separated by the first.

Tests of significance exist which indicate whether one or more discriminant functions are necessary to discriminate among the groups. In this research, Cooley and Lohnes'[4] rule-of-thumb will be employed, which suggests

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4 William W. Cooley and Paul R. Lohnes, Multivariate Procedures for the Behavioral Sciences, New York, Wiley, 1962, p. 118.

that a subset of functions that accounts for a major proportion of the discriminatory power of the test battery, say eighty to ninety percent, can be readily employed.

A problem exists in the fact that probabilities of misclassification are not equal for all possible discriminant function scores. For example, individuals whose Z scores lie near the chosen cut-off point are more likely to be placed in the wrong group. It is important, therefore, to estimate the probability of classification into any group for each subject, based on the normal-probability-density function. The multivariate discriminant analysis program BMD05M from the BMD Biomedical Computer Programs was used for this purpose.

An example will illustrate its utility. The probability of an individual belonging to each of three diagnostic groups is as follows: $G_1 = .14$, $G_2 = .45$, $G_3 = .41$. Thus, for this subject, the probability of his belonging to group one is 14%, to group two, 45%, and to group three, 41%. Assigning him to the most probable group would place the subject in group two, with a 41 + 14 = 55% probability of misclassification. There is also evidence of a strong possibility of classifying the person into group three. The conclusion to be made is that for some individual cases, the decision can confidently be made, while for others it will be made with uncertainty. The maximum-likelihood procedure indicates where to place the subject on the basis of his scores; the normal-probability-density function gives the additional information of how confidently the classification can be made.

Different decision rules can be made based on clinical purposes: the individual may be allocated to a group strictly on the basis of the maximum-likelihood procedure; the subject may be classified into a group if the probability of his belonging in the other groups is less than a certain percentage; or a definite classification is delayed until additional information has been examined. At the very least, calculation of the proportion of misclassification gives a meaningful index of the amount of separation between or among the groups.

An important aspect of discriminant analysis is some understanding of the differences among groups by interpreting the relative contribution of the original variables to each discriminant function. The weights originally arrived at are inappropriate since they are affected by the particular units in each variable. Scaled vectors[5] are a means of standardizing the discriminant weights so that the relative contribution of each variable to each discriminant function can be compared.

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5 M. Tatsuoka, Multivariate Analysis, New York, Wiley, 1971, p. 163.

Having established the theoretical and experimental background, the last section of this chapter will give the specific hypotheses to be studied in this research.

5. The Specific Hypotheses.

This research purports to specifically study the following proposals in reviewing what use are behavioral measures in discriminating among groups composed of a priori neurological diagnoses.

The main hypothesis, stated in the null form, is this:

> There are no significant differences at $p < .01$ on patterns of behavioral measures among three groups of subjects, one having no verified brain pathology, the other with verified brain pathology and a negative physical neurological exam, and a third having definite brain pathology and a positive physical neurological exam.

Sub-hypotheses, flowing from and connected to the main hypothesis, are these:

> There is no significant difference at $p < .01$ on patterns of behavioral measures between the control subjects and both groups with verified brain pathology.

> There is no significant difference at $p < .01$ on patterns of behavioral measures between two groups of subjects with definite brain pathology, when one group has negative, the other positive, results on a physical neurological exam.

Other interests to be examined may be expressed in the following manner. Theoretically, it will be important to see if there are other and different factors on the factor analysis, as compared to Halstead's and Russell's results. Clinically, the discovery of the value of different behavioral indices in diagnostic classification is important. Are some measures better than others in separating the groups? Finally, the percentages of proper classification and misclassification using these behavioral patterns will be analyzed.

Having completed the review of the literature, and having explained the experimental design, the next chapter will present the results of the experiment, followed by a discussion of these results.

CHAPTER III

PRESENTATION AND DISCUSSION OF RESULTS

This chapter will present the results of the statistical analysis and the discussion evolving from these results. The first section will be a further description of the sample according to variables such as occupation and neurological complaints. This will be followed by a description of the factor analysis, reviewing the number of factors, plus the hypothesized construct underlying each factor. A detailed breakdown of the results of the discriminant function analysis will be presented. Finally, the last section will discuss the results achieved.

1. Breakdown of the Subject Population and Individual Variables.

A more detailed description of the subject sample according to the criterion groups is presented to facilitate possible interpretations of their effect on the findings (see Table I). The fact of being employed or not seems to be comparable between the control group (CG) and the negative neurological group (NNG), with an approximate average of 82% being employed. The positive neurological group (PNG) is equally divided on this variable. On a gross behavioral level, then, the NNG appears to be more like the CG.

Table I.-

Frequency Breakdown on Certain Variables of the Population Sample Divided According to the Criterion Groups.

Variable	Categories	Control Group	Negative Neurological Group	Positive Neurological Group
Occupation				
	Employed	27	29	17
	Unemployed	7	5	17
Status				
	Control	34	0	0
	Chronic	0	16	4
	Acute	0	18	30
EEG				
	Not given	26	17	22
	Normal	7	2	0
	Mild	1	8	8
	Moderate-severe	0	7	4
Complaints				
	Yes	10	15	25
	No	24	19	9

Concerning the status of the groups, CG is by definition excluded. Of the other two groups, it is noted that the PNG is heavily loaded with patients diagnosed as having acute brain pathology, while the NNG is evenly divided between both diagnoses.

It is observed that many subjects were not given an EEG. More of those with a negative neurological exam were given EEGs than those with abnormal findings. Of those given to these two groups, more of the NNG had moderate-severe findings than the PNG. When neurological complaints were considered, an increasing incidence of complaints is observed as the neurological diagnosis moved from control to abnormal findings on the neurological exam.

Appendix 2 presents the breakdown of the groups according to their first diagnosis. Since this study considered all groups as heterogeneous, the data are presented to provide information for subsequent research.

The means and standard deviations of the variables according to criterion groups and sex, based on the scores of the variables before the transposition of certain scores by subtracting them from a constant, are provided in Appendix 3.

2. Factor Analysis Results.

The results of the factor analysis yielded thirteen factors, the eigenvalues and percentage of variance accounted for by each being presented in Table II. Since factors are representative of the tests included in the original battery, and are not necessarily in order according to their possible discriminatory power, all factors will be described according to their hypothesized constructs. Pure variables, an important aspect in the interpretation of factors, are defined as those that load on only one factor, and that do not have over a .30 loading on any other factor.

Appendix 4 presents the correlation matrix of all the variables. The results of the factor analysis are presented in Table III.

Factor 1 explains 39% of the variance and has three pure variables loading on it, WAISVIQ, WRAR, and WRAS, suggesting a verbal basis to this factor. The substantial loading of TRIBTZ, which contains alphabetic letters as a component, tends to reinforce this hypothesis. Loadings of other variables such as KNOXMEAN, WAISPIQ, WRAA, ADCATTOZ, SPECZ and AGNOSIAZ, may reflect the verbal component of this factor, or may rather point to a more general explanation of the utilization of basic aptitude, with a component of attention.

Table II.-

The Eigenvalues and Percentage of Variance Accounted for by the Extracted Factors.

Factor	Eigenvalue	Percentage of Variance	Cumulative Percentage
1	13.61094	39.4	39.4
2	4.23313	12.2	51.6
3	3.55688	10.3	61.9
4	2.39744	6.9	68.9
5	2.05099	5.9	74.8
6	1.73942	5.0	79.8
7	1.41190	4.1	83.9
8	1.27548	3.7	87.6
9	1.02776	3.0	90.6
10	0.97672	2.8	93.4
11	0.84201	2.4	95.8
12	0.76492	2.2	98.1
13	0.66998	1.9	100.0

Table III.-

Matrix of Factor Loadings after Varimax Rotation.

	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4	FACTOR 5	FACTOR 6	FACTOR 7	FACTOR 8	FACTOR 9	FACTOR 10	FACTOR 11	FACTOR 12	FACTOR 13
AGE	0.10266	-0.19335	-0.12258	0.10832	-0.58356	-0.12147	0.23526	-0.05956	-0.05229	-0.25915	0.08648	0.10236	0.02542
EDUC	0.30516	-0.10337	0.03120	0.10202	-0.18008	-0.50902	-0.21302	0.00688	0.17859	0.10843	-0.26747	-0.14274	0.23290
WAISVIQ	0.85847	0.02746	0.06579	0.02673	-0.11121	-0.01318	0.13125	-0.02206	0.04116	0.17605	-0.02578	0.02543	0.22133
WAISPIQ	0.66755	0.14175	0.16843	0.05185	0.04517	0.00374	0.19263	0.20492	0.15508	0.20847	0.35667	0.07296	0.04321
WRAR	0.76648	0.07563	-0.07171	0.14865	-0.07458	0.03013	-0.06483	0.10261	-0.00298	-0.10760	-0.04979	0.14524	[illegible]
WRAS	0.83770	0.16501	-0.17012	0.08852	-0.06835	0.02837	0.00623	-0.02237	0.05848	-0.13561	0.02493	0.05397	0.11878
WRAA	0.66421	0.15278	0.19942	-0.04045	0.19152	0.04709	0.09156	-0.03292	0.07855	0.15219	0.11249	-0.17796	0.09404
ACCATTOZ	0.48011	0.34850	0.21255	-0.03496	0.26012	0.08590	0.11834	-0.07959	0.10219	0.42636	0.23114	-0.18772	0.03790
ACTFTLTZ	0.12572	0.10301	0.00225	0.16938	0.57237	0.08240	0.08532	-0.05768	-0.06260	-0.05252	0.15405	0.01163	-0.04816
ACTFTMEM	0.09454	0.20117	0.12664	0.09458	0.49205	0.00364	0.11076	0.26573	0.25095	0.27623	0.23669	-0.03921	0.30356
ACTPTBLK	0.14266	0.14661	0.09741	0.01467	0.51031	0.05513	0.28535	0.24820	0.15311	0.31804	0.14056	0.27932	0.21923
FINTAPL	0.14570	0.51253	0.55336	0.11320	0.04284	0.02316	0.01757	0.19514	0.00361	0.23095	-0.00355	-0.31072	-0.05229
FINTAPN	0.13259	0.14626	0.52866	0.16378	0.04084	0.02594	-0.01020	0.17284	-0.05448	0.32255	0.24921	-0.31214	-0.17944
SPEEZ	0.40468	0.24448	0.07631	0.12388	0.34602	-0.04150	0.04535	0.03233	0.22603	0.17565	0.01304	0.20496	-0.09040
SEASHOR	0.61351	0.04664	0.09176	0.11461	0.29514	0.06441	-0.00988	-0.06268	0.20522	0.15390	0.20756	0.08687	-0.30126
TRIATZ	0.54614	0.54319	0.07122	-0.00338	0.20127	0.27797	0.13908	0.11919	0.20426	0.24409	0.32441	0.01011	-0.13927
TRIETZ	0.51801	0.49465	0.05516	-0.03956	0.29151	0.14441	0.14148	0.02081	0.21353	0.17050	0.17622	-0.00762	-0.07801
IMPZ	0.51667	0.19603	0.18868	0.13845	0.47191	0.05172	0.19311	0.17920	0.17224	0.42172	0.22120	0.00685	0.09627
[illegible]	0.07912	0.19290	0.87152	-0.10864	0.13433	-0.02199	0.06775	0.11243	0.00111	0.05510	-0.07201	0.06850	0.04444
[illegible]	0.03376	-0.00944	0.87302	-0.03439	0.14587	0.10919	-0.04225	0.11576	0.16554	0.06980	0.09490	0.00380	0.12311
FOUTAPD	0.05856	0.17191	0.45083	0.05584	-0.01055	0.04965	0.13977	0.64875	0.03066	0.10078	0.06857	-0.02584	-0.04622
FOUTAPN	0.03017	0.10933	0.45583	0.04141	0.00353	0.14286	-0.07814	0.65644	0.01877	0.18966	0.22572	-0.02342	0.04792
MAZETLZ	0.13562	0.75037	0.01651	-0.00084	0.11793	-0.03818	-0.02574	0.02566	0.12873	-0.01218	0.46872	0.06845	0.06900
MAZETNZ	0.14721	0.34477	0.09448	0.02398	0.14294	0.16473	0.10845	0.10683	0.10874	0.08530	0.42852	-0.01220	-0.01530
MAZECLZ	0.15770	0.74696	0.11268	0.06470	0.11011	0.06722	0.02979	0.01697	0.19917	0.00582	0.56226	0.04171	0.07840
MAZECNZ	0.22658	0.31518	0.13167	0.16416	0.08322	0.18932	0.04751	0.12082	0.10285	0.09023	0.81602	-0.01796	0.08172
SEX	0.01430	-0.02256	0.85648	-0.08314	-0.07256	-0.09988	0.00500	0.03686	-0.00871	-0.07253	0.07350	0.02970	-0.09461
ACNCSTAZ	0.43111	0.10415	-0.01203	0.07731	-0.02632	0.12799	0.58536	-0.04028	-0.18326	0.11283	0.03276	0.12037	-0.02277
WRITLZ	0.21641	0.02862	0.06983	0.10734	0.10857	0.01605	0.60548	0.07163	0.40799	0.08739	0.16682	0.05362	0.07465
WRITNZ	0.19926	0.13630	-0.13202	0.01020	0.15264	-0.05780	0.22483	-0.10822	0.75192	0.08904	0.32066	0.08251	-0.11551
[illegible]	-0.07320	0.29040	0.03138	0.16716	0.10314	0.09062	-0.03227	0.11858	0.43305	-0.01446	-0.06436	-0.05391	0.09209
[illegible]	[illegible]	0.03415	0.13604	-0.04766	-0.10367	-0.00951	-0.02223	-0.02227	0.25864	-0.00905	-0.00123	-0.03422	-0.03507
[illegible]	[illegible]	0.30754	-0.03475	0.46362	0.07990	-0.02146	0.48331	0.04222	0.08265	0.08020	-0.01246	0.10682	0.15531
STEATNZ	0.11392	0.22387	0.01540	0.70940	0.10076	0.20054	0.26488	0.17933	0.10020	0.07784	0.37555	-0.00896	0.05769
STEALCZ	0.07677	0.03183	-0.06877	0.82915	0.10463	-0.00309	0.06400	-0.11730	0.03315	-0.02748	0.00651	0.08643	-0.10640
STEALNZ	0.04018	0.01821	-0.05253	0.86139	-0.00985	0.14302	-0.03356	-0.00318	0.02595	0.02436	0.03434	-0.00723	-0.03377
MSTEALTZ	0.11621	0.87655	0.09186	0.07798	0.07277	0.04331	0.00980	0.05513	0.15804	0.09009	0.08423	0.06080	0.00675
[illegible]	[illegible]	0.27384	-0.00777	0.16922	0.15729	0.62756	-0.00789	0.11195	0.52230	0.11662	0.25078	-0.09918	-0.04695
MSTCLZ	0.14731	0.00331	0.14949	0.30543	0.04053	0.22304	0.00014	-0.08864	0.28907	0.17229	0.09642	-0.09999	-0.06602
MSTCNZ	0.14008	0.06478	0.01227	0.45174	0.06617	0.73933	0.00637	0.13800	0.07286	0.18818	0.15637	0.02386	0.02379
PECLEZ	0.00425	0.87399	0.08575	0.00344	0.14096	0.02482	0.14662	0.19401	-0.01685	0.13767	0.05366	-0.02281	0.12535
PECLNZ	[illegible]	0.06034	0.02099	0.11961	0.07950	0.41994	0.00654	0.23204	-0.05801	0.20384	0.46707	-0.09192	0.00434
[illegible]	0.75157	0.00471	0.09802	0.04616	0.14322	-0.07990	0.19444	-0.00901	-0.02630	0.20973	0.23235	-0.02789	-0.12651
CHLTERZ	0.23307	0.21766	0.16500	-0.04732	0.15526	0.07241	0.06605	0.18894	0.03176	0.70874	0.13714	0.05585	0.09515
STATLSZ	0.24455	0.04515	-0.06073	0.05311	0.07441	0.10065	0.08269	0.10248	0.00960	0.66047	0.02529	0.23550	-0.07541
[illegible]	0.25776	0.13812	-0.02822	-0.07817	0.03947	-0.05815	0.06032	-0.09202	-0.04577	0.01411	0.06237	-0.01124	0.53659
FECZ	0.11232	0.04197	0.00511	0.08707	-0.00604	0.00499	0.11602	0.00703	-0.06077	0.20804	-0.01061	0.75300	-0.02487
COMPL	-0.13715	0.22168	0.28415	0.08054	0.06048	0.02335	-0.00798	-0.11874	0.02163	0.37409	0.02765	0.05394	0.02666
RN	-0.10522	0.04330	-0.03206	-0.26683	0.20576	0.10979	-0.01938	0.41086	-0.00061	-0.00651	0.11832	0.04773	-0.18646

The second factor, having two pure variables RSTEADTZ and PEGSDZ, adds 12.2% of the variance. In conjunction with other variables such as MAZETDZ, MAZECDZ, FINTAPD, and both Trails tests, it strongly indicates a motor factor, possibly steadiness in manipulation of objects specifically referring to the dominant hand. Factor 3 also appears to be a motor factor, independent of the dominance variable, with emphasis on motor strength. Three pure variables exist here: LDOMD, LDOMN and SEX. Substantial loadings of the finger tapping and foot tapping tests may add weight to this interpretation.

A motor construct also appears to be at the basis of factor 4, the motor aspect being possibly steadiness in relation to motor tremor. Two pure variables again load on this factor, the steadiness counter scores for both hands. The loadings of the time steadiness score plus the resting steadiness counter score may reflect this same construct.

All three aspects of the TPT load heavily on factor 5, with ADTPTOTZ being a pure variable. Age is also a pure variable on this factor, and IMPZ also has a substantial loading. A possible interpretation is that this is a psycho-motor problem solving factor, a term descriptive of the TPT itself. The loading of age and the Impairment Index may indicate that increased age and/or greater impairment tends to influence these scores. The negative correlations of AGE and IMPZ with the TPT scores also seem to suggest this.

Factors 6, 7, 8, and 9 have very few pure variables, making them difficult to interpret and probably of little value if condensation of variables is the desired result. Factor 6 also seems to be a motor factor, with possible emphasis on the nondominant side. Substantial loadings here are RSTCNZ, RSTTNZ, and PEGSNZ. Education also loads most heavily here, although it is spread among other factors. Factor 7 has three variables with reasonable loadings: WRITDZ, AGNOSIAZ, STEADTDZ. Although difficult to interpret, this may be a sensory factor possibly with emphasis on the dominant side. Factor 8 has foot tapping as its construct, with the pseudoneurological scale being a pure variable, although its loading is only .41. Finally, factor 9 also appears to have a sensory construct at its base with loadings on variables WRITNZ, WRITDZ, SANDDZ and RESTNZ.

The next factor, 10, is important to this study since it may be termed the group distinction factor. CRITER loads heavily as a pure variable, as does STATUSZ. Of relevance here is the question whether other variables also load reasonably well on this factor, especially those which may have fairly high correlations with various other factors, since the orthogonality of these would make discrimination among groups greater. The variables which have loadings of .30 or higher on factor 10, and their heaviest loading on one or more other factors, are as follows: IMPZ - 1 and 5; ADCATTOZ - 1; COMPL; FINTAPN - 3 and 12; ADTPTBLK - 5.

A general performance construct seems to be the base of factor 11, with MAZECNZ being a pure variable and MAZETNZ also loading heavily. These two also suggest a nondominant laterality aspect to this factor. Looking at other variable loadings, however, would indicate a more general performance base since variables such as WAISPIQ, TRIATZ, MAZETDZ, MAZECDZ, PEGSNZ and WRITNZ load on it.

The last two factors are as follows. Eleven has EEG as a pure variable, with above .30 loadings on both finger tapping tests. The last is an occupation factor, with SEASHOR and ADTPTMEM also correlating with the factor.

3. Discriminant Analysis Findings.

Two discriminant analyses comparing the three groups were conducted on the basis of a differing rationale for the inclusion of certain tests. The first rationale evolved from the consideration of the loadings of different variables on the same factor as the criteria loaded on. As described above, six other variables had correlations of .30 or better with factor 10. Two of these were omitted from the discriminant analysis of the three groups because of the method of scoring them. The first was status. Since all control groups were automatically labelled as control as opposed to acute or chronic, the correlation with criteria had to be unnaturally high. The second variable was complaints. A yes-no dichotomy left little room for numerical differentiation in a discriminant analysis. The first analysis, then, was run using the following four variables: ADCATTOZ, IMPZ, FINTAPN, and ADTPTBLK. The raw data for these variables for all subjects are presented in Appendix 5.

For the discriminant analysis using the four variables, two functions were revealed, the first having an eigenvalue of .8696 and explaining 99.49% of the variance, the second with an eigenvalue of .0045, and explaining only .51% of the variance. According to the rule-of-thumb explained in the statistical analysis, the first discriminant function is sufficient to differentiate among the three groups.

The appropriate weights for each variable are presented in Table IV. When these were transformed into scaled vectors in order to make a direct comparison of the relative value of each variable in discriminating, these results, in order of importance, were obtained: IMPZ =19.314;F =7.191; ADTPTBLK = 5.294; ADCATTOZ = 5.083.

When the weights were applied to the raw scores in order to determine the discriminant function scores, the

Table IV.-

Weights and Scaled Vectors on the Four Variable Discriminant Function.

Variable	Weight[a]	Scaled Vector[a]
IMPZ	.96720	19.314
FINTAPN	.08846	7.191
ADTPTBLK	.23716	5.294
ADCATTOZ	.02112	5.083

a See p.69 and 74 of the Experimental Design for explanation of these terms.

means and standard deviations for each group were these (Table V): control - M = 119.519, S.D. = 2.472; negative neurological - M = 116.129, S.D. = 3.055; positive neurological - M = 113.193, S.D. = 2.781. Applying the weights to the mean raw scores, a function which gives the mean discriminant value for each group used in the classification of individuals, these results were obtained: $\overline{Z}_1$ control group = 119.55; $\overline{Z}_2$ negative neurological group = 116.33; $\overline{Z}_3$ positive neurological group = 113.19.

The critical cut-off scores derived from the formula $(\overline{Z}_1 + \overline{Z}_2) / 2 = \overline{Z}_{12}$, were the following: $\overline{Z}_{12}$ = 117.94, $\overline{Z}_{23}$ = 114.76. The F test of significant differences among the groups yielded a ratio of 8.89 with 8 and 192 degrees of freedom, which is significant at the .01 level of confidence. Thus, the main null hypothesis is failed to be accepted, suggesting that using these four variables in a discriminant function analysis yields significant differences in behavior pattern scores among the three groups.

To ascertain where the significant differences lay, the discriminant function program was run between all pairs. The F tests, all with 4 and 63 degrees of freedom, for each pair of contrasts were as follows: groups one and two = 5.397; groups one and three = 23.720; groups two and three = 4.58. All of these were significant at the .01

Table V.-

Means, Standard Deviations, and Cut-off Scores of the Four Variable Discriminant Function.

Group	Mean[a]	S.D.	$\bar{Z}$[b]	Cut-off Score[c]
Control(1)	119.519	2.472	119.55	
				$\bar{Z}_{12}$ = 117.94
Negative(2) Neurological	116.129	3.055	116.33	
				$\bar{Z}_{23}$ = 114.76
Positive(3) Neurological	113.193	2.781	113.19	

[a]These means and standard deviations are derived from the individual discriminant function scores in each group.

[b]This indicates the mean discriminant value for each group derived by applying the appropriate weights to the group mean raw scores of the variables.

[c]This cut-off score is based on the maximum-likelihood procedure, and is used to classify individuals.

level of probability, thereby failing to accept the null sub-hypotheses concerning the individual differences between groups.

The results of the more clinical problem of classification of individuals on the basis of their discriminant function scores are presented in Table VI. The numbers in brackets are the results of the BMD program which based the classification on the normal-probability-density function, as compared to the use of the critical cut-off point.

It is seen that, of those diagnosed a priori as being normal controls, the score patterns classified twenty-four out of the thirty-four as belonging to this group. However, nine had scores more typical of the group with verified brain pathology and a negative neurological exam, and one was similar to the group with a positive neurological exam. Thus, 70.6% of normals were properly classified as normals, with a misclassification rate of 29.4%.

The second criterion group had more difficulty being classified into their proper class according to the discriminant function scores. Only thirteen out of thirty-four, a percentage rate of 38.2%, were properly differentiated. Nine, or 26.5%, were classified as normal controls while, according to their scores, twelve belonged to the group with positive neurological signs.

Table VI.-

Number and Percentage of Classification Using the Four Variable Discriminant Function.

Group	Function						
	Control		Negative Neurological		Positive Neurological		Group 2+3
	N	%[a]	N	%	N	%	%
Control	24(23)[b]	70.6	9(10)	26.5	1(1)	2.9	
Negative Neurological	9(8)	26.5	13(15)	38.2	12(11)	35.3	73.5
Positive Neurological	1(1)	2.9	10(10)	29.4	23(23)	67.6	97.1

[a]This percentage reflects the correct classification into the subject's own a priori group on the basis of the discriminant function.

[b]The number in brackets is the frequency of classification in a particular group according to an individual's discriminant function using the BMD computer program.

When individuals from the positive neurological group were classified, the results were similar in accuracy to the control group. Twenty-three were correctly classified, ten were misclassified as belonging to the NNG, and one to the CG.

A more global view shows the following. There is a 58.8% over-all correct classification of individuals within their own criterion group. A more meaningful description is the correct percentage of classification of those with verified brain dysfunction into either of the two brain-damaged groups; that is, have they been diagnosed as having brain pathology and being significantly different from the control group on the tests, regardless of their physical neurological diagnosis? From this point of view, it is observed that 73.5% of the NNG and 97.1% of the PNG were correctly classified as brain-damaged, yielding an average correct percentage of 85.3. When the correct percentages of classification into control versus brain-damaged is considered, the average is now 77.95%.

As suggested, the probability of classification into any group on the basis of the discriminant function score is an important indicator of the true separation among the groups. Appendix 6 presents the results based on the normal-probability-density function. A very global indication of the separation is the average probability percentage of misclassification. Thus, for the control group there is an average 30% possibility that a subject could be placed in the NNG and 10% possibility of being placed in the PNG. For group NNG, the average percentages of misclassification are these: CG = 31, PNG = 33. For the PNG, the averages are CG = 11%, NNG = 31%.

The value of these probability indices lie more in the decision rule to be made concerning the individual and the confidence to be placed in this decision. If, for example, it is decided that individuals will not be definitely classified unless the probability of his belonging to a particular group is definite at the .10 level of probability, that is, he is 90% sure of being correctly classified, only two individuals (PNG) out of 102 would have been correctly classified. A more liberal decision rule, say 70% certainty, would result in the following definite classifications: CG = 20/34; NNG = 0/34; PNG = 13/34. An even chance yields these results: CG = 22/34; NNG = 3/34; PNG = 22/34.

A second discriminant analysis was run using eleven variables. The rationale here was that some variables do correlate quite highly with the criteria and possibly have discriminating value. With this in mind, variables with a correlation with the criteria of .40 or over were included. This comprised the four variables used in the first analysis, plus the following which are presented in light of their correlation with the criteria and the factor(s) on which they load the highest: ADTPTMEM = .40,5; FINTAPD = .40,3; WAISPIQ = .47,1; TRIATZ = .46,2; TRIBTZ = .41,1 and 2; SPECZ = .42,1; and PEGSDZ = .39,2. The latter was added since it was a pure variable of factor 2, and might add some discriminating power. The raw data for these variables are also included in Appendix 5.

Of the two functions resulting from the analysis, the first with an eigenvalue of 1.01809 explained 94.12% of the variance and was thus considered sufficient to discriminate among all three groups.

The appropriate weights and scaled vectors for each variable, in order of the relative value of each variable in the discriminant function, are presented in Table VII.

The means and standard deviations of the individual discriminant function score for each group were the following (Table VIII): CG - M = 154.393, S.D. = 2.364; NNG - M = 151.276, S.D. = 3.053; PNG - M = 147.317, S.D. = 3.354. It is noted that, with the increased number of variables, the dispersion of scores for the PNG had increased. Applying the weights to the mean raw scores to obtain the mean discriminant value for each group yielded the following results: $\overline{Z}_1$ control = 154.30;

Table VII.-

Weights and Scaled Vectors on the Eleven Variable Discriminant Function.

Variable	Weight[a]	Scaled Vector[a]
IMPZ	.77807	15.537
TRIBTZ	-.01458	-10.236
PEGSDZ	.42316	10.183
FINTAPN	.10066	8.182
ADCATTOZ	.03182	7.659
ADTPTBLK	.31734	7.084
SPECZ	.10866	6.484
ADTPTMEM	-.30248	-4.759
WAISPIQ	.01224	1.564
TRIATZ	.00514	1.347
FINTAPD	-.00259	-.202

[a]See p. 69 and 74 of the Experimental Design for explanation of these terms.

Table VIII.-

Means, Standard Deviations, and Cut-off Scores of the Eleven Variable Discriminant Function.

Group	Mean[a]	S.D.	$\bar{Z}$[b]	Cut-off Score[c]
Control(1)	154.393	2.364	154.30	
				$\bar{Z}_{12}$ = 152.87
Negative(2) Neurological	151.276	3.053	151.44	
				$\bar{Z}_{23}$ = 149.57
Positive(3) Neurological	147.317	3.354	147.70	

[a]These means and standard deviations are derived from the individual discriminant function scores in each group.

[b]This indicates the mean discriminant value for each group derived by applying the appropriate weights to the group mean raw scores of the variables.

[c]This cut-off score is based on the maximum-likelihood procedure, and is used to classify individuals.

$\overline{Z}_2$ negative neurological = 151.44; $\overline{Z}_3$ positive neurological = 147.70. The critical cut-off discriminant scores were 152.87 for $\overline{Z}_{12}$ and 149.57 for $\overline{Z}_{23}$.

An F ratio of 3.959 with 22 and 178 degrees of freedom was significant at the .01 probability level, thereby again failing to accept, on the basis of the eleven variable pattern, the null hypothesis that there is no significant difference among the groups. F tests for each pair of ratios, all with 11 and 56 degrees of freedom, indicated that there were significant differences at the .01 level between groups one and two, and one and three. The difference between groups two and three approached the .01 level of significance ($p < .05$).

The results of classifying the individuals on the basis of their eleven variable profile are presented in Table IX. The general pattern of proper classifications is similar to the four variable results, with the CG and PNG having comparable patterns, correctly classifying a relatively high percentage into their own proper group, having difficulty with individuals whose patterns resembled the NNG, but misclassifying only one subject into the most remote group.

Once again, the most difficulty lay in classifying the NNG, since more individuals in this group had score patterns typical of other groups than their own. Indeed,

Table IX.-

Number and Percentage of Classification Using the Eleven Variable Discriminant Function.

Group	Function						
	Control		Negative Neurological		Positive Neurological		Group 2+3
	N	%[a]	N	%	N	%	%
Control	23(23)[b]	67.6	10(10)	29.4	1(1)	2.9	
Negative Neurological	11(10)	32.4	15(18)	44.1	8(6)	23.5	67.6
Positive Neurological	1(1)	2.9	7(8)	20.6	26(25)	76.5	97.1

[a]This percentage reflects the correct classification into the subject's own a priori group on the basis of the discriminant function.

[b]The number in brackets is the frequency of classification in a particular group according to an individual's discriminant function using the BMD computer program.

eleven of this group were classified as being normal as compared to eight being placed in the PNG. However, with the greater number of variables, more were correctly classified into their characteristic group than with the four variable pattern.

When percentages of correct classification were compared, it is noted that 67.6% of the normals were correctly classified, a slight decrease over the percentage obtained using four variables. Proper classification of the NNG rose from 38.2 to 44.1%, while the PNG classification rate also advanced from 67.6 to 76.5%. The percentage of classification as having verified brain pathology regardless of the physical neurological exam was 67.6% for the NNG, and 97.1% for the PNG, a combined percentage of 82.3, which is roughly comparable to the four variable results. The average correct percentage of classification within an individual's particular group rose to 62.7%, while the average of the normal versus brain-damaged classification fell to 74.9%.

When the probability of classification according to the normal-probability-density function was reviewed, a 90% certainty of classification led to the following proper placements (see Appendix 7): CG = 0/34; NNG = 0/34; PNG = 8/34. With 70% certainty, the following is observed: CG = 16/34; NNG = 2/34; PNG = 17/34. A 50%

probability yielded the following results: CG = 23/34; NNG = 13/34; PNG = 23/34. These observations indicated that the eleven variable pattern gives greater true separation among the groups.

Two more analyses comparing the two groups with brain pathology were conducted which included the two formerly excluded variables of status and complaints. This was done to see if they were important in differentiating these two groups. These were added to the original four and eleven variables, resulting in a six and thirteen variable analysis, respectively. The group means on the six variable discriminant function were -9.136 and -8.230 for the NNG and PNG, respectively. The F test reported a ratio of 6.52, with 6 and 61 degrees of freedom, significant at the .01 level of probability. The appropriate weights and scaled vectors, in their order of importance in discriminating, are reported in Table X.

When thirteen variables were used, the group discriminant function score means were 15.755 and 14.637, the differences being significant at the .01 probability level. The weights and scaled vectors are also reported in Table X.

Having presented the results of the analyses, it now remains to discuss the findings in light of the reported literature and to suggest possibilities for further research and study.

Table X.-

Weights and Scaled Vectors on the Discriminant Function for Both the Thirteen and Six Variable Analysis.

Thirteen Variables			Six Variables		
Variable	Weight	Scaled Vector	Variable	Weight	Scaled Vector
STATUSZ	-.87724	-3.039	IMPZ	-.17807	-2.999
IMPZ	.16462	2.773	STATUSZ	.85599	2.965
PEGSDZ	.09351	2.240	COMPL	-.48163	-1.834
COMPL	.43219	1.646	ADTPTBLK	-.05989	-1.093
TRIATZ	-.00614	-1.588	ADCATTOZ	.00172	.379
SPECZ	.02842	1.385	FINTAPN	-.00321	-.223
ADTPTBLK	.07458	1.361			
FINTAPN	.01542	1.070			
FINTAPD	-.01399	-.940			
ADTPTMEM	-.03129	-.420			
ADCATTOZ	.00125	.277			
TRIBTZ	-.00021	-.144			
WAISPIQ	-.00070	-.079			

4. Discussion of Results.

This section will undertake to review the results analytically, culminating in a summary and salient conclusions. The first part is concerned with the description of the sample population and how this may have affected the results. This is followed by a brief description of the possible practical and theoretical applications of the factor analysis. The major portion reviews many aspects of the discriminant analysis outcome, followed by some considerations for future study.

Two of the descriptive variables, occupational status and EEG findings, are of general interest only, since the factor analysis did not suggest that they would aid in discriminating the criterion groups. A comparison of the fact of being employed or not indicated that for CG and NNG, there were similar patterns. This description is one brief hint that it may be hard to differentiate these two groups. The PNG understandably had more unemployed, since they were burdened with definite physical difficulties.

The frequency of administered EEGs was somewhat surprising for this subject population. The fact that the NNG had a higher number of EEGs might be indicative of more difficulty in classification and therefore the need of more information. The idea of classification problems is strengthened by the two normal EEGs in this group. In addition, the presence of seven moderate-severe diagnoses is another indication of the range of symptomatology of this group.

The next two variables are of more interest since they both had substantial loadings on the same factor as the criteria, indicating they might be important in differentiating the groups. Concerning the status of acute or chronic pathology, evidence of a strong influence on group discrimination might indicate that the composition of the groups in this regard may be an uncontrolled variable which influenced the results. The reason for this is that symptomatology often disappears or minimizes after a certain recovery period and that what is thus being measured in this study may be an artifact of time rather than true differences in physical neurological status.

It is obvious that the research would have been stronger if this factor had been more stringently controlled. However, certain considerations attenuate the above criticism. In this research, acute was operationally defined as having been tested any time within one year of onset of pathology. In addition, patients rarely were referred to the neuropsychological laboratory in the very acute stage, but were more often tested later. What this means is that there generally was time for recovery from certain symptoms even in acute cases, a fact which might modify the inequality of the cells on this variable. Nevertheless, a necessary future step would be to replicate this study, controlling for status either by creating equal subcells, or by studying one aspect at a time. Age of onset is also important in this regard.

Whether a subject presented himself with neurological complaints resulted in a ratio pattern which seems to follow the severity continuum of the groups. Approximately two-fifths of CG had no complaints, while the reverse was true for the PNG, with the NNG fairly evenly divided. Neurological complaints, then, is a fairly broad descriptive hint of the true diagnosis.

The actual weights and scaled vectors for the last two variables suggest that they could play some role in differentiating the two groups with cerebral pathology, with status being a stronger indicator.

A brief review of the factor analytic results yields some practical conclusions. If condensation of variables is a desired result, it appears that the first five factors are the main constructs underlying the test battery. This is based on two considerations. These factors explain 74.8% of the variance, while the next eight, for example, account for the remaining 25.2%. Secondly, these five have definite pure variables, important to the concept of simple structures in factor analysis. Possible research in this area suggests replicating the factor analysis with this larger number of tests on other larger populations and possibly with other group criteria to see if the factors remain stable. If so, the lengthy testing session may be able to be shortened by choosing representative tests of these factors.

Some theoretical considerations of the factor analysis present themselves. It is noted that there is a strong motor component in the factors, reflecting the type of tests in the over-all battery. One observation is that these components seem to have distinct aspects to them, such as a motor construct of the dominant body side, a strength factor, and a steadiness factor. This idea may possibly lead to research on the power of these aspects in differential diagnosis. For example, are there differential results for specific diagnoses such as Parkinson's and Huntington's Chorea? If so, can a prediction formula be developed on the basis of these constructs to aid in the diagnosis of these ailments?

Discussion of the results of the discriminant analysis is most relevant to this study. Both the four and eleven variable discriminant function yielded one function which was sufficient to discriminate the groups, suggesting the following possible interpretation. Since the nature of the discriminants aids in understanding the differences among the central tendency of groups, similar discriminant weights for all distinctions may indicate that the differences are similar. That is, it appears to suggest that the three groups are on a quantitative continuum, and are not qualitatively different. Finally, the nature of the one discriminant function may reflect the heterogeneity of the groups, since Wheeler et al.[1] suggested that groups classified according to localized pathology had different weights.

Those tests with high weights may be hypothesized then to measure general effects of cerebral pathology, since they differentiated groups composed of various diagnoses. These indications are in concordance with Wheeler et al.'s findings. The Category test and Trails B were high in both studies. This present research also suggests other tests which may be important for this general purpose, such as FINTAPN, ADTPTBLK, and PEGSDZ. Since finer diagnosis such as lateralization of pathology was not a goal of this study, the value of other tests in comparison to the forementioned study cannot be done.

There were significant differences using both four and eleven variables among all three groups, and thus the

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1 Lawrence Wheeler et al., "An Application of Discriminant Functions to the Problem of Predicting Brain Damage Using Behavioral Variables," Perceptual and Motor Skills, Vol. 16, 1963, p. 417-440.

null hypothesis is not accepted. The differences between groups were significant at the same level of probability for both patterns of variables, with the exception that the difference between the two groups with pathology, using the eleven variables, only approached this significance level.

The control group is, therefore, different from both brain-damaged groups, indicating the battery's basic validity in diagnosing brain pathology. When trying to diagnose individuals by use of the discriminant analysis which maximizes discrimination differences, the two brain pathology groups are significantly different according to their score patterns. The first statement supports Kløve's[2] claim, but the latter does not. Significant differences among groups in discriminant analysis may not be meaningful, however, unless the significant differences in individual tests are known. Thus, it is relevant to replicate Kløve's study using t tests of group differences. It is suggested that this be done three ways. The first would be to rank

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2 Hallgrim Kløve, "The Relationship between Neuropsychologic Test Performance and Neurologic Status," in a paper presented at the meeting of the American Academy of Neurology, Minneapolis, 1963, quoted by H. Kløve, "Validation Studies in Adult Clinical Neuropsychology," based on a paper entitled "Current Status of Adult Clinical Neuropsychology," read at a symposium entitled "Human Neuropsychology: The Significance of Brain Damage for Human Behavior," American Psychological Association annual meeting, 1970, p. 8-9.

order all groups, change these into T normalized standard scores, and then test for differences. This method, which Kløve apparently employed, maximizes group differences. The second procedure would be to change the scores of the control group into T normalized scores, and on this basis, convert the scores of the other two groups before testing for differences.[3] Finally, it seems apropos to convert all scores into T scores on the basis of fairly widely established norms.

Reitan's study[4] on the importance of sensorimotor functions in differential diagnosis is important to the interpretation. It is recalled that those with intact sensorimotor functions, even though brain-damaged, were significantly better on a number of tests than those whose sensorimotor functions were impaired. In fact, the former's results were comparably good, considering the fact they had cerebral pathology. What is the underlying factor to these differential results is the important question. Area and amount of pathology would appear to be a relevant issue,

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3 Arthur Vega, Jr., and Oscar A. Parsons, "Cross Validation of the Halstead-Reitan Tests for Brain Damage," Journal of Consulting Psychology, Vol. 31, No. 6, 1967, p. 622.

4 Ralph M. Reitan, "Sensorimotor Functions, Intelligence and Cognition, and Emotional Status in Subjects with Cerebral Lesions," Perceptual and Motor Skills, Vol. 31, No. 1, 1970, p. 284.

as would the question of acute versus chronic state of pathology. These considerations reiterate the need for a study with greater control of these factors.

More relevant is Kløve's conclusion that neuropsychological tests appear to be more sensitive to pathology than even a competently performed neurological exam, based on the fact there were no significant differences in his study between the two groups with brain pathology. This statement must be tempered according to the results of this study. The behavioral tests, which were chosen on the basis of having an excellent chance of discriminating the groups, had difficulty with the NNG. When the classification of individuals into a non brain-damaged or brain-damaged group is considered, it is observed that 25 to 30% less of the NNG were classified as brain-damaged than those who had a positive neurological exam. If probability of misclassification of the NNG as normal individuals is reviewed, the following is noted: with four variables, 26.5% are thus classified, while eleven variables puts 32.4% into this group.

It is evident, then, that the behavioral tests did have difficulty classifying this group, a fact which must be taken into account in the decision rule. Nevertheless, the score profile did diagnose 73.5% and 67.6% of the NNG group as having brain pathology, whereas the physical neurological exam did not. Moreover, this group was significantly different from the normals.

It has been stated that the nature of the individual weights helps to understand the differences among the groups. Considering the four variables, the Impairment Index is the strongest differentiator, with the remaining three being comparable in weight. The cut-off point on the ten tests, regardless of the actual quantitative results, is a valuable indicator of pathology.

A point to analyze is whether the Index by itself is as good a predictor as the discriminant function in which the Index is one variable. The following percentages of classification were obtained when the Index was placed at varying points in the 0 - 1.0 scale of pathology. Considering .5 and above as indicative of pathology, 79.4% of CG were correctly classified as normals, 64.7% of NNG and 91.1% of PNG as brain-damaged. Average correct classification of those with brain pathology was 77.9%. With the Index at .4, these were the results: CG = 67.6%, NNG = 76.5%, PNG = 97.1%, and average correct classification of brain damaged = 86.8%. Placing the Index at .6 yielded these correct percentages of classifications as normals or brain-damaged: CG = 85.3%, NNG = 38.2%, PNG = 70.6%, average of both brain-damaged groups = 54.4%. Finally, at .7, CG = 100%, NNG = 26.5%, PNG = 61.8%, and average of both brain-damaged groups = 44.2%.

The following observations can be made concerning the relationship of the Impairment Index and the four and eleven variable discriminant function used in this study. It is apparent that there is a direct relation of the Index and which group is correctly classified. At .6 and up, the normals are readily classified, while the percentage of correct classification of those with brain pathology drops markedly. The average of over-all correct classification is very similar for both .4 and .5. However, the question remains whether it is more important to correctly classify normals or those with cerebral organic impairment. The answer to this varies with the genre of the question. Is it a legal question? Is surgery involved?

When compared to the discriminant function, it appears that this research confirms Wheeler and Reitan's[5] conclusion that the Impairment Index is as effective as the discriminant function in discriminating control versus brain-damaged subjects. When the four variable discriminant function is compared to the .4 cut-off score on the Index, the Index was not as accurate with the normals (67.6 to

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5 Lawrence Wheeler and Ralph M. Reitan, "Discriminant Functions Applied to the Problem of Predicting Cerebral Damage from Behavioral Tests: a Cross-Validation Study," Perceptual and Motor Skills, Vol. 16, 1963, p. 695.

70.6%), but diagnosed more of the NNG as brain-damaged (76.5 to 73.5%). The eleven variable function leads to more misclassifications. It thus seems that, on a practical level, the use of the discriminant function in this study does not add sufficient proficiency to warrant the difficulty and time of applying it.

The motor test of finger dexterity for the non-dominant hand is also a good discriminator, as is the test of spatial location. Both of these tests are hypothesized to be tests of right hemisphere dysfunction, assuming that most subjects are right-handed. The last variable is the Category test, a measure of non-verbal reasoning ability and abstraction, which studies have reported to be a good general test of pathology with no brain localizing ability.[6] It appears that tests of general and right hemisphere cerebral functioning are most useful in classifying heterogeneous groups.

When the eleven variable pattern is discussed, the Impairment Index again emerges as the strongest indicator, with the other three variables of the four measure pattern maintaining their discriminatory strength. WAISPIQ, FINTAPD, and TRIATZ appear to be of little consequence in

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6 Donald G. Doehring and Ralph W. Reitan, "Concept Attainment of Human Adults with Lateralized Cerebral Lesions," Perceptual and Motor Skills, Vol. 14, 1962, p. 31.

comparison with the other weights. PEGSDZ, of the remaining variables, has strong discriminatory power, evidently from the fact that it loads on a different factor. SPECZ is also relatively high.

The explanation of the negatively weighted variables is difficult, especially since we have no clear knowledge of the underlying construct. It is evident, nevertheless, that the opposition of TRIBTZ is important. An explanation which offers itself is based on Reitan and Tarshes'[7] claim that Trails B is more influenced by left hemisphere pathology than Trails A. Since Trails B has a negative loading in contrast with the general and right hemisphere tests of the four variable pattern, this suggests the power of right hemisphere and general functioning in the diagnosis of heterogeneous groups. A study which may shed light on this suggestion is the WAIS research which observed that a group with bilateral pathology had a pattern of WAIS subtests very similar to the right hemisphere damaged group.[8]

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7 Ralph M. Reitan and Elaine L. Tarshes, "Differential Effects of Lateralized Brain Lesions on the Trail Making Test," Journal of Nervous and Mental Disease, Vol. 129, No. 3, 1959, p. 260.

8 C. Dene Simpson and Arthur Vega, "Unilateral Brain Damage and Patterns of Age-corrected WAIS Subtest Scores," Journal of Clinical Psychology, Vol. 27, No. 2, 1971, p. 206.

Certain indications contraindicate this suggestion. Reitan later termed the Trails as a good test of general pathology since so many factors may be influencing the results.[9] The strength of PEGSDZ, supposedly a left hemisphere test, also goes against this line of thought.

A more prudent interpretation is that, in a heterogeneous group, the tests of general pathology are strong discriminators. Other indicators might be reflecting the heterogeneity of the sample through their specific localizing ability. With this view, the negative weights are still difficult to incorporate in an interpretation.

It appears that statistical analysis of neuropsychological data cannot supplant clinical judgment. The level of decision confidence seems to indicate a need for more information before a decision can be reached, and that more tests should be reviewed to see subtleties of response patterns. A logical study resulting from this suggestion would be to give the neuropsychological data to a group of neuropsychologists for classification. Results would be scored on the basis of correct classification, plus on the amount of confidence the psychologists placed in their diagnoses. These then could be compared with the statistical results of this study.

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9 R. M. Reitan, "Validity of the Trail Making Test as an Indicator of Organic Brain Damage," Perceptual and Motor Skills, Vol. 8, 1958, p. 275.

The above suggestion leads to more possibilities for future research, some of which have already been suggested. The first step is a cross-validation on a similar sample. The procedure here would be to obtain weights on this second sample according to the procedure of this study. Following this, the weights would be exchanged to compare the proportion of correct classifications. In addition, the nature of the discriminants could be compared.

In this same vein, other groups could be compared, such as schizophrenics versus brain-damaged since the literature has revealed a problem in this area. Finally, as Yates[10] has suggested, the predictive validity, based on the achieved weights, for an unselected intake group, would be the crucial test.

Variations of the different sample theme lead to many possible topics. The obvious has already been suggested. In addition, groups could be made more homogeneous, considering specific lesion areas, for example. As Wheeler _et al_.[11] indicated, the weights of tests may have differing importance for different groups.

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10 Aubrey J. Yates, "Psychological Deficit," _Annual Review of Psychology_, Vol. 17, 1966, p. 113.

11 Wheeler _et al_., _op. cit_., p. 428.

Another possibility is to use the same or similar criteria, but with specific diagnoses. An example would be degenerative cases,who Bachmann[12] suggested were difficult to discriminate. It would be interesting to see how the behavioral measures matched against neurological criteria in this problem.

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12 Rudolph Franz Bachmann, Accuracy and Confidence of Neurological Diagnostic Judgment as a Function of Judge's Experience, Amount and Type of Information, and Diagnostic Category, unpublished doctoral thesis presented for the degree in Clinical Psychology at Wayne State University, Detroit, Michigan, 1971, p. 46.

SUMMARY AND CONCLUSIONS

In attempting to use behavioral measures to discriminate three groups defined *a priori* by neurological criteria, it was observed that, using a discriminant function analysis of four and eleven variables, there were significant differences among the three groups, thereby failing to accept the null hypothesis. When pairs of groups were analyzed for significant differences with the same statistical method, it was noted that there were significant differences between all but one pair of groups at the .01 confidence level for both the four and eleven variable analysis. The one exception was the difference between the two brain-damaged groups when the eleven variables were used, where the difference only approached this level of significance.

The neuropsychological battery, as employed in this study, then, is a valid indicator of cerebral pathology since it significantly discriminated the brain-damaged from the normals. In addition, in keeping with Kløve's claim, the battery does appear to be more sensitive than a physical neurological exam since it was able to diagnose as significantly different from normals those who had no indication of pathology on a physical neurological exam.

Nevertheless, there were problems in using the behavioral measures in discriminating the negative neurological group, with a 26.5 and 32.4 percentage classification of false negatives, evaluating some of the brain-damaged group with a negative neurological exam as normals according to their score pattern. In classifying those with abnormal physical neurological signs, the discriminant function was very accurate.

It is suggested that neuropsychological testing be an integral part of neurological diagnosis. It adds accuracy where diagnosis with the physical neurological exam has difficulty. Where the behavioral measures appear redundant, as with those who had abnormal signs, the battery can provide a more comprehensive picture of disabilities, as Reitan had noted.

The efficacy of the Impairment Index as compared to the discriminant function results indicates that the Index is a valuable, relatively simple indicator of pathology. A clinical corollary is the importance of the decision rule. Since the discriminant function did not result in strong confidence levels of decision making, it appears that the statistical cannot supplant the clinical use of behavioral measures. Extra information from the other tests is needed to diagnose and describe impairment more accurately.

Certain main ideas for future research were presented. The first is to see the value of the discriminant function differences by evaluating the differences of the individual tests. A cross-validation or replication of the same study is necessary to check the accuracy of the classification. Clinically, it was noted that temporal duration of pathology may play an important part in differential diagnosis and that this must be controlled. Finally, it was suggested that similar research be carried on using different criterion groups.

Ward Halstead emphasized research on the behavioral indices of central nervous system functioning when he began the search for that elusive "man on horseback," i.e., for the behavioral description of that neuropsychological substratum which was the functional force in man. This research, by using behavioral measures to discriminate neurological criteria and by showing that there are behavioral measures which tap the differences between effective and pathological central nervous system functioning, has hopefully contributed to this quest.

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One of the few studies on the validity of the neurologic judgment. Although it does not concern itself solely with the physical neurologic exam, inferences can be made on its efficacy from the author's results.

Fitzhugh, Kathleen B. et al., "Psychological Deficits in Relation to Acuteness of Brain Dysfunction," Journal of Consulting Psychology, Vol. 25, No. 1, 1961, p. 61-66.

This research illustrates the importance of temporal duration of pathology in influencing impairment indices.

Halstead, Ward C., Brain and Intelligence, A Quantitative Study of the Frontal Lobes, Chicago, University of Chicago Press, 1947, xiii-206 p.

The "first" book in the use of behavioral measures in clinical neuropsychology. Directly concerned with the theoretical factors of biological intelligence, it also gives direction to the pragmatic use of the tests in differential diagnosis.

Heilbrun, Alfred B., "Issues in the Assessment of Organic Brain Damage," Psychological Reports, Vol. 10, 1962, p. 511-515.

This theoretical paper clearly defines the boundaries of clinical and theoretical neuropsychology. It is also important in its valuable advice on research in this area.

Kløve, Hallgrim, "The Relationship between Neuropsychologic Test Performance and Neurologic Status," in a paper presented at the Meeting of the American Academy of Neurology, Minneapolis, 1963, quoted by H. Kløve, "Validation Studies in Adult Clinical Neuropsychology," based on a paper entitled "Current Status of Adult Clinical Neuropsychology," read at a symposium entitled "Human Neuropsychology: The Significance of Brain Damage for Human Behavior," American Psychological Association annual meeting, 1970, p. 8-9.

This study, comparing behavioral measures to the physical neurologic exam, was the impetus for the present research.

Matthews, Charles G., et al., "Psychological Test Performances in Neurologic and 'Pseudoneurologic' Subjects," Cortex, Vol. 2, 1966, p. 244-253.

An important study in the problem of validating the behavioral measures as indices of pathology when diagnosis is made difficult by confounding variables.

Reitan, Ralph M., "Investigation of the Validity of Halstead's Measures of Biological Intelligence," AMA Archives of Neurology and Psychiatry, Vol. 73, 1955, p. 28-35.

An important step in the validation of the Halstead battery, since it was among the first to obtain the same results on a different population.

--------, "The Comparative Effects of Brain Damage on the Halstead Impairment Index and the Wechsler-Bellevue Scales," Journal of Clinical Psychology, Vol. 15, No. 3, 1959, p. 281-285.

This, the second half of Reitan's 1955 research, indicated that the Wechsler scales also could differentiate cerebral pathology from normal central nervous system functioning. The Impairment Index, however, was more sensitive in this regard.

--------, "Sensorimotor Functions, Intelligence and Cognition, and Emotional Status in Subjects with Cerebral Lesions," Perceptual and Motor Skills, Vol. 31, No. 1, 1970, p. 275-284.

This research is important to the interpretation of the present study, pointing out the necessity of behavioral indices to complement neurological diagnosis.

Spreen, Otfried, and Arthur L. Benton, "Comparative Studies of Some Psychological Tests for Cerebral Damage," Journal of Nervous and Mental Disease, Vol. 140, No. 5, 1965, p. 323-333.

An excellent review of various tests of central nervous system functioning, comparing the hit rates of the various tests. It also gives methodological suggestions for future research.

Vega, Arthur, Jr., and Oscar A. Parsons, "Cross Validation of the Halstead-Reitan Tests for Brain Damage," Journal of Consulting Psychology, Vol. 31, No. 6, 1967, p. 619-625.

This study validates the Halstead-Reitan battery, stating that it alone withstands close scrutiny.

Wheeler, Lawrence, et al., "An Application of Discriminant Functions to the Problem of Predicting Brain Damage Using Behavioral Variables," Perceptual and Motor Skills, Vol. 16, 1963, p. 417-440.
This study is important since it is one of the few which undertakes to analyze data by statistical methods which may utilize information inherent in the data.

Wheeler, Lawrence, and Ralph M. Reitan, "Discriminant Functions Applied to the Problem of Predicting Cerebral Damage from Behavioral Tests: a Cross-Validation Study," Perceptual and Motor Skills, Vol. 16, 1963, p. 681-701.
A study which cross-validates Wheeler's first use of the discriminant analysis on the behavioral tests.

Yates, Aubrey J., "Psychological Deficit," Annual Review of Psychology, Vol. 17, 1966, p. 111-144.
This review develops general criteria for testing brain pathology with behavioral tests.

APPENDIX 1

A SUMMARY EXPLANATION OF THE ABBREVIATIONS USED FOR THE VARIABLES

APPENDIX 1

A SUMMARY EXPLANATION OF THE ABBREVIATIONS USED FOR THE VARIABLES

AGE -Age in years.

EDUC -Number of years of formal education.

WAISVIQ -Result on verbal tests of the Wechsler Adult Intelligence Scale.

WAISPIQ -Result on performance scales of WAIS.

WRAR -Raw score on the reading subtest of the Wide Range Achievement Test.

WRAS -Raw score on the spelling subtest of the WRAT.

WRAA -Raw score on the arithmetic subtest of the WRAT.

ADCATTOZ-Total number of incorrect responses on the Category test.

ADTPTOTZ-Total time of three trials for the Tactual Performance test.

ADTPTMEM-Memory component score on the TPT.

ADTPTBLK-Localization component score on the TPT.

FINTAPD -Mean of five scores on the finger tapper for the dominant hand.

FINTAPN -Mean of five scores on the finger tapper for the nondominant hand.

SPECZ -Number of errors on the Speech Sounds Perception test.

SEASHOR -Number of correct responses on the Seashore Rhythm test.

TRIATZ -Time in seconds required to complete part A of the Trail Making test.

TRIBTZ -Time in seconds required to complete part B of the Trail Making test.

IMPZ -Summary value of ten tests used as an indicator of brain pathology.

LDOMD -Average score in kilograms of two trials for the dominant hand on the hand dynamometer.

LDOMN -Average score in kilograms of two trials for the nondominant hand on the hand dynamometer.

FOOTAPD -Mean of three trials on the foot tapper with the dominant foot.

FOOTAPN -Mean of three trials on the foot tapper with the nondominant foot.

MAZETDZ -Duration in seconds that the stylus, held in the dominant hand, is in contact with the sides of the maze.

MAZETNZ -Duration in seconds that the stylus, held in the nondominant hand, is in contact with the sides of the maze.

MAZECDZ -Number of times the edges of the maze are touched when the stylus is held in the dominant hand.

MAZECNZ -Number of times the edges of the maze are touched when the stylus is held in the nondominant hand.

AGNOSIAZ-Number of errors for both dominant and nondominant hands on a test of Tactile Finger Recognition.

WRITDZ -Number of errors on the dominant hand in a test of Fingertip Number Writing Perception.

WRITNZ -Number of errors on the nondominant hand on a test of Fingertip Number Writing Perception.

SANDDZ -Total error score on two trials for the dominant hand on a test of Roughness Discrimination.

SANDNZ -Total error score on two trials for the nondominant hand on a test of Roughness Discrimination.

STEADTDZ-Duration in seconds that the stylus held by the dominant hand touches the edges of the holes into which it has been placed, when the hand is not braced in any way.

STEADTNZ -Duration in seconds that the stylus held by the nondominant hand touches the edges of the holes into which it has been placed, when the hand is not braced in any way.

STEADCDZ -Number of times the edges of the holes are touched when the stylus is held in the dominant hand which is not braced in any way.

STEADCNZ -Number of times the edges of the holes are touched when the stylus is held in the nondominant hand which is not braced in any way.

RSTEADTZ -When the dominant hand is resting, this score reflects the duration in seconds that the stylus touches the edge of the sixth smallest hole of the steadiness apparatus.

RSTTNZ -When the nondominant hand is at rest holding the stylus, this score reflects the duration in seconds that the stylus touches the edges of the sixth smallest hole.

RSTCDZ -Number of times the edges of the sixth smallest hole of the steadiness apparatus are touched by the stylus, when it is held by the dominant hand.

RSTCNZ -Number of times the edges of the sixth smallest hole of the steadiness apparatus are touched by the stylus, when it is held by the nondominant hand.

PEGSDZ -Duration in seconds of the average time the dominant hand takes to put each peg into its proper grooved hole.

PEGSNZ -Duration in seconds of the average time the non-dominant hand takes to put each peg into its proper grooved hole.

KNOXMEAN -Average score of correctly reproduced series on two trials of a test of visual attention and memory.

CRITERZ -Division of the subjects into three groups according to the given criteria.

STATUSZ -Breakdown of the sample into control, acute brain-damaged or chronic brain-damaged diagnosis.

OCCUPZ -Indication whether the subject is employed or unemployed.

EEGZ -Division of the subjects into one of four sub-groups: no EEG given; EEG given but normal results; EEG given, with results indicating mild brain pathology; EEG given, with results indicating moderate to severe brain pathology.

COMPL -Indication whether the subject reported neurological complaints or not.

PN -An additional MMPI scale, scores at or over seven reflecting pseudo-neurological complaints as opposed to true pathology.

APPENDIX 2

BREAKDOWN OF THE CRITERION GROUPS ACCORDING TO THEIR PRIMARY DIAGNOSIS

BREAKDOWN OF THE CRITERION GROUPS ACCORDING TO THEIR PRIMARY DIAGNOSIS

Diagnosis	Control Group	Negative Neurological Group	Positive Neurological Group
Grand mal and major motor - idiopathic	0	2	0
Psychomotor and temporal lobe - idiopathic	0	2	0
Mixed or multiple seizures - idiopathic	0	1	0
Other seizures - symptomatic	0	0	1
Head injuries	2	9	14
Hematomas	0	1	1
Psychopathology	12	0	0
Miscellaneous disease - no brain damage	4	0	0
Control normals	6	0	0
Tension headaches	1	0	0
Migraine and/or vascular headaches	1	0	0
Cerebral vascular disease	0	1	0
Completed vascular accidents	0	2	9
AV malformations and aneurysms	0	3	3
Tumors	0	1	4
Abscess and cyst	0	5	0
Multiple Sclerosis	0	0	1

Diagnosis	Control Group	Negative Neurological Group	Positive Neurological Group
Infections	0	1	1
Hydrocephalus	0	5	0
Primary reading disabilities	2	0	0
Undiagnosed disease of brain	0	1	0
Non-medical use of drugs	5	0	0
Hyperactivity	1	0	0
Total	34	34	34

APPENDIX 3

MEANS AND STANDARD DEVIATIONS ACCORDING TO CRITERION GROUPS AND SEX FOR ALL QUANTIFIABLE VARIABLES USED IN THE FACTOR ANALYSIS

APPENDIX 3

MEANS AND STANDARD DEVIATIONS ACCORDING TO CRITERION GROUPS AND SEX FOR ALL QUANTIFIABLE VARIABLES USED IN THE FACTOR ANALYSIS

Variable		Control			Negative Neurological			Positive Neurological		
		N	M	SD	N	M	SD	N	M	SD
AGE	T	34	26.65	12.99	34	32.00	14.00	34	37.27	15.67
	F	10	29.90	17.05	7	35.14	16.71	10	31.00	12.74
	M	24	25.29	11.05	27	31.19	13.46	24	39.88	16.26
EDUC	T	34	12.21	3.65	34	11.62	7.44	34	12.12	3.45
	F	10	12.90	3.87	7	11.14	2.80	10	11.30	2.63
	M	24	11.92	3.60	27	11.74	8.27	24	12.46	3.60
WAISVIQ	T	34	113.65	10.38	34	102.85	16.18	34	100.65	14.90
	F	10	114.40	10.11	7	103.29	14.48	10	95.60	13.78
	M	24	113.33	10.68	27	102.74	16.84	24	102.75	15.13
WAISPIQ	T	34	108.32	10.53	34	97.88	12.50	34	91.62	14.95
	F	10	107.10	11.75	7	96.57	14.59	10	85.50	12.83
	M	24	108.83	10.20	27	98.22	12.19	24	94.17	15.27
WRAR	T	34	12.32	3.11	34	10.79	3.87	34	10.64	3.54
	F	10	13.33	2.99	7	12.26	3.22	10	9.46	3.80
	M	24	11.90	3.12	27	10.41	3.99	24	11.14	3.38
WRAS	T	34	10.59	2.66	34	9.79	3.77	34	9.06	3.27
	F	10	11.88	1.77	7	11.67	3.10	10	8.73	3.12
	M	24	10.06	2.81	27	9.31	3.83	24	9.20	3.39
WRAA	T	34	8.89	2.99	34	7.59	2.85	34	6.11	1.78
	F	10	8.65	3.54	7	6.37	1.25	10	5.66	1.33
	M	24	8.99	2.80	27	7.90	3.08	24	6.30	1.94
ADCATTOZ	T	34	41.44	16.77	34	60.79	25.78	33	76.85	28.80
	F	10	46.10	23.33	7	64.57	17.72	10	87.70	33.53
	M	24	39.50	13.31	27	59.82	27.68	23	72.13	25.88

Variable		Control			Negative Neurological			Positive Neurological		
		N	M	SD	N	M	SD	N	M	SD
ADTPTD*	T	34	0.81	1.02	34	0.78	0.41	34	1.48	1.87
	F	10	0.64	0.52	7	0.74	0.50	10	2.39	3.00
	M	24	0.88	1.17	27	0.79	0.40	24	1.11	1.10
ADTPTN*	T	34	0.50	0.29	34	0.75	0.81	34	0.98	0.97
	F	10	0.39	0.25	7	0.51	0.23	10	1.49	1.40
	M	24	0.55	0.29	27	0.81	0.89	24	0.76	0.65
ADTPTMEM	T	34	7.65	1.43	34	6.85	1.54	34	5.88	1.75
	F	10	7.50	0.97	7	7.14	1.46	10	5.80	2.04
	M	24	7.71	1.60	27	6.78	1.58	24	5.92	1.67
ADTPTBLK	T	33	5.67	2.27	34	4.03	2.47	32	2.47	2.06
	F	9	5.89	1.90	7	4.00	2.16	10	2.30	2.16
	M	24	5.58	2.43	27	4.04	2.58	22	2.55	2.06
FINTAPD	T	34	45.71	6.86	34	43.00	6.13	34	37.84	9.74
	F	10	40.30	6.02	7	38.58	8.02	10	31.25	10.67
	M	24	47.96	5.95	27	44.15	5.11	24	40.58	8.05
FINTAPN	T	34	43.62	7.37	34	40.35	7.27	34	35.52	9.72
	F	10	38.00	5.12	7	33.14	4.81	10	28.04	10.64
	M	24	45.96	6.95	27	42.22	6.65	24	38.64	7.54
SPECZ	T	33	4.36	2.92	33	5.85	4.38	31	10.99	7.63
	F	9	4.33	2.06	7	4.57	3.31	8	12.00	10.34
	M	24	4.38	3.23	26	6.19	4.62	23	9.57	6.61
SEASHOR	T	32	26.97	3.22	34	25.06	3.67	32	23.75	4.57
	F	9	26.44	4.88	7	24.57	3.05	9	22.89	4.70
	M	23	27.17	2.41	27	25.19	3.85	23	24.09	4.58
TRIATZ	T	34	26.03	7.08	34	43.50	26.10	34	59.59	36.12
	F	10	29.70	9.02	7	37.14	13.83	10	61.00	23.69
	M	24	24.50	5.64	27	45.15	29.45	24	59.00	40.64

*These two sections reflect the original intention of the study, which desired to analyze the time per block according to dominant or nondominant hand, rather than total time for all three trials.

Variable		Control			Negative Neurological			Positive Neurological		
		N	M	SD	N	M	SD	N	M	SD
TRIBTZ	T	34	73.15	36.05	34	108.21	64.44	34	149.74	97.36
	F	10	70.60	36.20	7	108.14	35.23	10	158.60	91.02
	M	24	74.21	36.72	27	108.22	70.60	24	146.04	101.54
IMPZ	T	33	0.27	0.19	34	0.49	0.22	34	0.70	0.19
	F	10	0.28	0.20	7	0.50	0.18	10	0.75	0.17
	M	23	0.27	0.19	27	0.49	0.23	24	0.68	0.20
LDOMD	T	34	37.74	12.54	34	36.44	11.52	34	30.74	12.41
	F	10	20.85	5.82	7	22.45	5.83	10	17.00	5.59
	M	24	44.77	6.07	27	40.07	9.71	24	36.47	9.07
LDOMN	T	34	34.04	11.70	34	32.32	10.42	34	28.83	12.06
	F	10	19.43	6.28	7	19.66	4.99	10	15.83	5.33
	M	24	40.13	7.03	27	35.61	8.81	24	34.24	9.67
FOOTAPD	T	34	43.50	8.69	34	40.93	7.79	34	36.64	10.19
	F	10	37.10	5.86	7	32.71	4.03	10	33.28	8.04
	M	24	46.17	8.36	27	43.06	7.10	24	38.03	10.80
FOOTAPN	T	34	42.09	8.27	34	39.21	7.27	34	33.71	10.28
	F	10	35.80	7.12	7	33.71	5.02	10	28.01	7.94
	M	24	44.71	7.35	27	40.63	7.14	24	36.09	10.35
MAZETDZ	T	34	1.06	1.83	34	1.24	1.49	34	4.82	9.30
	F	10	0.86	0.88	7	2.05	1.49	10	4.75	5.11
	M	24	1.15	2.11	27	1.03	1.44	24	4.85	10.67
MAZETNZ	T	34	1.34	1.45	34	2.95	3.71	34	6.82	5.47
	F	10	1.55	1.62	7	4.44	3.48	10	7.08	5.55
	M	24	1.25	1.40	27	2.56	3.73	24	6.55	5.63
MAZECDZ	T	34	6.91	8.97	34	9.41	9.19	34	23.74	32.88
	F	10	7.50	6.84	7	14.43	8.75	10	27.70	25.67
	M	24	6.67	9.85	27	8.11	8.10	24	22.08	35.74
MAZECNZ	T	34	12.15	13.36	34	20.15	18.65	34	36.94	36.01
	F	10	13.30	10.31	7	29.57	20.61	10	41.80	31.58
	M	24	11.67	14.62	27	17.70	17.70	24	34.92	38.27
SEX	T	34	0.71	0.46	34	0.79	0.41	34	0.71	0.46
	F	10	0.00	0.00	7	0.00	0.00	10	0.00	0.00
	M	24	1.00	0.00	27	1.00	0.00	24	1.00	0.00

Variable		Control N	Control M	Control SD	Negative Neurological N	Negative Neurological M	Negative Neurological SD	Positive Neurological N	Positive Neurological M	Positive Neurological SD
AGNOSIAZ	T	34	0.97	1.98	34	2.09	3.15	34	2.57	2.98
	F	10	0.70	1.89	7	1.14	2.19	10	3.05	2.94
	M	24	1.08	2.04	27	2.33	3.34	24	2.08	3.01
WRITDZ	T	34	1.25	2.02	34	2.18	2.22	34	3.00	3.28
	F	10	1.10	1.79	7	3.14	2.34	10	3.00	3.68
	M	24	1.31	2.14	27	1.93	2.17	24	3.00	3.19
WRITNZ	T	34	0.82	1.19	34	1.15	1.78	34	1.97	3.19
	F	10	0.70	0.82	7	0.43	0.54	10	1.30	1.83
	M	24	0.88	1.33	27	1.33	1.94	24	2.25	3.60
SANDDZ	T	34	0.41	1.08	34	0.35	0.77	34	0.61	1.04
	F	10	0.80	1.40	7	0.00	0.00	10	0.40	0.84
	M	24	0.25	0.90	27	0.44	0.85	24	0.69	1.12
SANDNZ	T	34	0.24	0.82	34	0.29	0.87	34	0.30	0.72
	F	10	0.60	1.35	7	0.00	0.00	10	0.60	0.97
	M	24	0.08	0.41	27	0.37	0.97	24	0.18	0.56
STEADTDZ	T	34	12.50	8.85	34	14.65	9.31	34	24.41	20.84
	F	10	10.90	5.14	7	12.13	6.76	10	16.71	8.61
	M	24	13.16	10.02	27	15.30	9.87	24	23.37	24.01
STEADTNZ	T	34	16.90	11.63	34	19.62	11.60	34	26.93	19.82
	F	10	14.87	5.61	7	18.48	9.58	10	25.73	19.05
	M	24	17.75	13.39	27	19.92	12.21	24	27.43	20.51
STEADCDZ	T	34	91.56	57.34	34	97.71	62.64	34	89.82	54.84
	F	10	70.70	31.36	7	69.00	30.44	10	83.90	37.65
	M	24	100.25	63.75	27	105.15	66.99	24	92.29	61.15
STEADCNZ	T	34	108.41	63.78	34	106.88	54.31	34	114.29	91.62
	F	10	91.90	36.35	7	93.14	46.52	10	103.20	64.76
	M	24	115.29	71.77	27	110.44	56.40	24	118.92	101.62
RSTEADTZ	T	34	0.05	0.14	34	0.39	0.76	34	2.60	5.55
	F	10	0.00	0.00	7	0.65	0.15	10	3.17	5.03
	M	24	0.67	0.16	27	0.32	0.64	24	2.36	5.84
RSTTNZ	T	34	0.21	0.45	34	0.99	2.14	34	3.15	6.38
	F	10	0.19	0.51	7	0.77	1.43	10	1.29	1.13
	M	24	0.21	0.43	27	1.05	2.31	24	3.92	7.47

Variable		Control			Negative Neurological			Positive Neurological		
		N	M	SD	N	M	SD	N	M	SD
RSTCDZ	T	34	0.62	1.86	34	2.56	4.38	34	6.06	11.33
	F	10	0.00	0.00	7	1.86	2.80	10	7.80	14.21
	M	24	0.88	2.17	27	2.74	4.73	24	5.33	10.16
RSTCNZ	T	34	1.18	2.14	34	6.12	13.78	34	9.29	17.96
	F	10	0.90	1.91	7	4.14	8.95	10	4.60	3.20
	M	24	1.29	2.26	27	6.63	14.87	24	11.25	21.10
PEGSDZ	T	34	2.58	0.40	34	2.89	0.66	34	5.09	4.12
	F	10	2.48	0.44	7	2.87	0.65	10	5.27	3.71
	M	24	2.63	0.38	27	2.90	0.67	24	5.02	4.35
PEGSNZ	T	34	2.87	0.65	34	3.41	1.86	34	4.94	3.91
	F	10	2.98	0.99	7	3.13	0.52	10	4.32	1.72
	M	24	2.83	0.46	27	3.49	2.07	24	5.20	4.54
KNOXMEAN	T	34	13.74	1.76	34	12.06	2.41	34	11.53	2.45
	F	10	13.55	1.89	7	11.79	2.23	10	10.90	2.54
	M	24	13.81	1.73	27	12.13	2.49	24	11.79	2.41
PN	T	31	7.07	3.21	31	6.42	3.15	25	5.60	2.97
	F	9	7.22	2.44	7	5.00	3.11	8	6.13	3.09
	M	22	7.00	3.53	24	6.83	3.10	17	5.35	2.98

APPENDIX 4

CORRELATION MATRIX OF THE ORIGINAL FORTY-NINE VARIABLES

APPENDIX 4

CORRELATION MATRIX OF THE ORIGINAL FORTY-NINE VARIABLES

	AGE	EDUC	WAISVIQ	WAISPIQ	WRAR	WRAS	WRAA	ADCATTOZ	ADTPTOTZ	ADTPTMEM
AGE	1.00000	0.05233	0.15332	0.10375	0.18628	0.14510	-0.19851	-0.27085	-0.25180	-0.35584
EDUC	0.05233	1.00000	0.32571	0.08874	0.31595	0.26717	0.17155	0.07835	-0.24072	-0.01538
WAISVIQ	0.15332	0.32571	1.00000	0.68893	0.75491	0.69512	0.64706	0.47142	0.06794	0.18187
WAISPIQ	0.10375	0.08874	0.68893	1.00000	0.54064	0.48908	0.59110	0.58270	0.20145	0.44606
WRAR	0.18628	0.31595	0.75491	0.54064	1.00000	0.85819	0.50331	0.29639	0.10127	0.10287
WRAS	0.14510	0.26717	0.69512	0.48908	0.85819	1.00000	0.52897	0.29334	0.08765	0.04151
WRAA	-0.19851	0.17155	0.64706	0.59110	0.50331	0.52897	1.00000	0.55354	0.24951	0.32455
ADCATTOZ	-0.27085	0.07835	0.47142	0.58270	0.29639	0.29334	0.55354	1.00000	0.19996	0.43739
ADTPTOTZ	-0.25180	-0.24072	0.06794	0.20145	0.10127	0.08765	0.24951	0.19996	1.00000	0.31018
ADTPTMEM	-0.35584	-0.01538	0.18187	0.44606	0.10287	0.04151	0.32455	0.43739	0.31018	1.00000
ADTPTBLK	-0.32299	-0.10075	0.19063	0.42164	0.11959	0.12061	0.26979	0.42432	0.33787	0.65586
FINTAPD	-0.25604	0.01082	0.19764	0.34949	0.09096	0.06743	0.38791	0.33409	0.13300	0.33552
FINTAPN	-0.16577	0.05213	0.13522	0.32700	0.02891	-0.00802	0.32830	0.35569	0.14910	0.28111
SPECZ	-0.24151	0.07139	0.35006	0.43898	0.36330	0.39092	0.34748	0.30308	0.28218	0.35716
SEASHOR	-0.22078	0.07248	0.47031	0.52386	0.45029	0.46825	0.50789	0.55458	0.29504	0.25127
TRIATZ	-0.23479	-0.25508	0.31990	0.57384	0.26127	0.33609	0.44601	0.48693	0.21391	0.48413
TRIETZ	-0.23070	-0.09225	0.48435	0.62999	0.38603	0.44686	0.53958	0.54256	0.29431	0.48343
IMPZ	-0.31016	0.04129	0.52200	0.71830	0.41782	0.36859	0.60692	0.70124	0.42464	0.66119
LLCMD	-0.24022	0.00136	0.13669	0.27890	0.00717	-0.07224	0.28279	0.27563	0.04263	0.25970
LLCMN	-0.23138	0.01531	0.09912	0.28950	-0.03724	-0.13440	0.27560	0.28443	0.10905	0.31441
FCCTAPD	-0.11551	-0.02440	0.06227	0.36138	0.06767	-0.00863	0.16786	0.17056	-0.03598	0.33561
FCCTAPN	-0.19839	-0.04317	0.12413	0.37375	0.08100	0.00073	0.20597	0.24112	0.00474	0.38470
MAZETCZ	-0.19439	-0.10553	0.12162	0.39053	0.15908	0.28326	0.30200	0.20638	0.20313	0.37360
MAZETNZ	-0.13142	-0.31591	0.16100	0.55457	0.16088	0.26566	0.37271	0.39366	0.26117	0.45575
MAZECDZ	-0.15982	-0.16579	0.16445	0.48228	0.18373	0.26943	0.34383	0.31096	0.25709	0.45017
MAZECNZ	-0.03052	-0.21904	0.21564	0.58478	0.20786	0.25364	0.36998	0.43655	0.23919	0.45848
SEX	-0.00647	0.00796	0.05151	0.12777	-0.05064	-0.14699	0.13928	0.15762	-0.05400	0.03044
AGNESIAZ	0.12477	-0.09124	0.44201	0.39492	0.37426	0.39165	0.35127	0.32798	0.11215	0.08635
WRITCZ	0.05500	0.01826	0.28780	0.39754	0.18238	0.24366	0.34667	0.30267	0.13813	0.37177
WRITNZ	-0.00154	0.01132	0.18056	0.42188	0.09714	0.20714	0.27201	0.33672	0.16512	0.34649
SANGCZ	-0.20242	0.03354	0.04904	0.06463	0.04844	0.03836	0.08128	0.02854	0.03960	0.34761
SANGNZ	0.06351	0.07373	0.12833	0.12719	0.06867	0.03619	0.06649	0.12525	0.04708	-0.04744
STEADTCZ	0.00889	-0.00529	0.24360	0.23384	0.15324	0.22871	0.16155	0.11844	0.21329	0.26555
STEADTNZ	0.00252	-0.17054	0.18413	0.42388	0.19223	0.19511	0.21150	0.25857	0.27982	0.40794
STEACCDZ	0.14225	0.03332	0.02675	0.10040	0.18279	0.14763	0.00078	0.02388	0.31064	0.08008
STEACCNZ	0.04386	0.03798	0.06338	0.09919	0.15877	0.10419	0.01511	0.02105	0.11073	0.07683
RSTEADTZ	-0.19336	-0.06525	0.16660	0.34618	0.16935	0.22011	0.26853	0.20987	0.17822	0.37075
RSTTNZ	-0.25515	-0.27495	0.06120	0.32497	0.08927	0.16987	0.24909	0.29120	0.20520	0.35525
RSTCDZ	-0.20143	-0.08153	0.14837	0.32990	0.14811	0.23566	0.29618	0.28222	0.16477	0.30923
RSTCNZ	-0.12147	-0.30561	0.14927	0.27747	0.20900	0.16075	0.18185	0.24632	0.17337	0.24578
PEGSDZ	-0.23379	-0.08269	0.10994	0.29794	0.11067	0.08469	0.24485	0.24644	0.18445	0.39434
PEGSNZ	-0.09412	-0.30313	0.09598	0.30426	0.06352	0.03850	0.16003	0.32773	0.23321	0.31660
KNOXMEAN	-0.00220	0.13456	0.66422	0.71799	0.50325	0.54035	0.59027	0.57412	0.19617	0.23214
CRITERZ	-0.28655	0.00961	0.35165	0.47784	0.16880	0.17309	0.39964	0.51693	0.11536	0.40145
STATUSZ	-0.14673	-0.01467	0.33154	0.36853	0.18205	0.11554	0.25770	0.33667	0.09226	0.23962
OCCUPZ	0.02874	0.17959	0.32699	0.20637	0.25602	0.29806	0.27401	0.17165	0.07081	0.19976
EDUZ	0.04909	-0.08574	0.16295	0.20590	0.19759	0.10606	-0.01044	-0.01002	0.04925	0.04813
COMPL	-0.25435	0.03707	0.01010	0.03532	-0.11782	-0.12846	0.06385	0.25250	0.01935	0.21551
PN	-0.24626	-0.19979	-0.18145	0.05894	-0.11327	-0.15324	-0.01968	-0.02830	0.13388	0.09781

	AUTPTBLK	FINTAPO	FINTAPN	SPECZ	SEASHOR	TRIATZ	TRIBTZ	IMPZ	LDOMD	LDOMN
AGE	-0.32299	-0.25604	-0.16977	-0.24151	-0.22078	-0.23479	-0.23070	-0.31016	-0.24022	-0.23139
EDUC	-0.10075	0.01082	0.05213	0.07139	0.07248	-0.25508	-0.09225	0.04129	0.00136	0.01531
WAISVIQ	0.19063	0.19764	0.13522	0.35006	0.47031	0.31990	0.48435	0.52200	0.13069	0.09912
WAISPIQ	0.42164	0.34949	0.32700	0.43898	0.52386	0.57384	0.62999	0.71830	0.27890	0.28950
WRAR	0.11959	0.09096	0.02891	0.36330	0.45029	0.26127	0.38603	0.41782	0.00717	-0.03724
WRAS	0.12061	0.06743	-0.00802	0.39092	0.46825	0.33609	0.44686	0.36859	-0.07224	-0.13440
WRAA	0.26979	0.38791	0.32830	0.34748	0.50789	0.44601	0.53958	0.60692	0.28279	0.27560
ALCATTOZ	0.42432	0.33409	0.35569	0.30308	0.55458	0.48693	0.54256	0.70124	0.27563	0.28443
ACTFTCTZ	0.33787	0.13300	0.14910	0.28218	0.29504	0.21391	0.29431	0.42464	0.04260	0.10805
ALTPTMEM	0.65586	0.33552	0.28111	0.35716	0.25127	0.48413	0.48343	0.66119	0.25970	0.31441
ALTPTBLK	1.00000	0.25349	0.25994	0.36481	0.24376	0.49846	0.45503	0.69922	0.26418	0.28788
FINTAPO	0.25349	1.00000	0.66561	0.22940	0.18630	0.47794	0.42142	0.45165	0.59363	0.52739
FINTAPN	0.25994	0.66561	1.00000	0.17958	0.28798	0.34310	0.29610	0.42138	0.42986	0.52553
SPECZ	0.36481	0.22940	0.17958	1.00000	0.54693	0.47585	0.53787	0.58704	0.20850	0.15310
SEASHOR	0.24376	0.18630	0.28798	0.54693	1.00000	0.48124	0.54608	0.61447	0.12028	0.11497
TRIATZ	0.49846	0.47794	0.34310	0.47585	0.48124	1.00000	0.77425	0.65620	0.21661	0.19849
TRIBTZ	0.45503	0.42142	0.29610	0.53787	0.54608	0.77425	1.00000	0.66156	0.20947	0.18440
IMPZ	0.69922	0.45165	0.42138	0.58704	0.61447	0.65620	0.66156	1.00000	0.32950	0.33007
LDOMD	0.26418	0.59363	0.42986	0.20850	0.12028	0.21661	0.20947	0.32950	1.00000	0.82623
LDOMN	0.28788	0.52739	0.52553	0.15310	0.11497	0.19849	0.18440	0.33007	0.82621	1.00000
FOUTAPO	0.31958	0.53183	0.43596	0.16280	0.15744	0.33955	0.21250	0.38514	0.53088	0.44018
FOUTAPN	0.32416	0.49885	0.50085	0.14855	0.12838	0.38233	0.22822	0.39984	0.45998	0.54768
MAZETDZ	0.27685	0.38176	0.21174	0.33558	0.27096	0.62192	0.55183	0.39718	0.16819	0.10053
MAZETNZ	0.36286	0.34393	0.39065	0.29111	0.40522	0.70554	0.52942	0.52934	0.15627	0.22679
MAZECDZ	0.36829	0.46020	0.31292	0.33209	0.32077	0.71747	0.61731	0.50213	0.22910	0.20299
MAZECNZ	0.37078	0.31709	0.42272	0.23896	0.39383	0.65952	0.49879	0.53957	0.15923	0.25929
SEX	0.01629	0.41995	0.46137	0.04947	0.12151	0.01522	0.02913	0.10176	0.72867	0.70674
AGNOSIAZ	0.22316	0.08574	0.10342	0.17906	0.32992	0.31373	0.33022	0.37097	0.07049	-0.05666
WRITDZ	0.43842	0.12443	0.13327	0.32198	0.28252	0.33657	0.31160	0.48214	0.12139	0.16799
WRITNZ	0.33176	0.02418	0.01954	0.38671	0.45824	0.44652	0.48101	0.43318	-0.06685	0.04221
SANDDZ	0.17070	0.18173	0.02827	0.09802	0.06675	0.19480	0.22436	0.18114	0.06124	0.11790
SANDNZ	-0.06454	0.15559	0.10952	0.03570	0.13074	0.07204	0.09523	0.11033	0.12419	0.15446
STEALTDZ	0.31331	0.24003	0.11824	0.32664	0.16783	0.31932	0.34799	0.35490	0.05000	-0.02605
STEALTNZ	0.31024	0.23577	0.29723	0.32111	0.26536	0.42111	0.34693	0.46663	0.01687	0.10658
STEALCDZ	0.06001	0.04621	0.08408	0.15893	0.21765	0.10583	0.05306	0.17864	-0.11002	-0.03082
STEALCNZ	0.07042	0.08134	0.09717	0.11233	0.15931	0.06527	0.02327	0.16132	-0.13349	-0.06174
RSTEALTZ	0.33058	0.52503	0.23642	0.34950	0.18651	0.64090	0.62072	0.39134	0.24619	0.17239
RSTTNZ	0.31688	0.26504	0.21355	0.30859	0.36208	0.62652	0.47992	0.42730	0.04285	0.20980
RSTCDZ	0.25971	0.55470	0.37198	0.31089	0.30102	0.59055	0.51117	0.40367	0.22374	0.21912
RSTCNZ	0.26580	0.17808	0.24438	0.18933	0.27554	0.41563	0.29462	0.37726	0.00672	0.14723
PEGSDZ	0.35941	0.54222	0.21037	0.28572	0.08729	0.55721	0.53165	0.44331	0.33845	0.11113
PEGSNZ	0.21516	0.16729	0.39241	0.07491	0.27413	0.36267	0.25888	0.38920	-0.02564	0.16465
KNOXMEAN	0.34133	0.23170	0.28269	0.40067	0.57908	0.43402	0.57911	0.61223	0.21115	0.15062
CRITERZ	0.50010	0.40370	0.40070	0.42454	0.30875	0.46785	0.41918	0.64536	0.26900	0.22181
STATUSZ	0.36876	0.17728	0.19615	0.24992	0.27410	0.35459	0.32073	0.48192	0.03780	0.05182
OCCUPZ	0.20055	0.03233	-0.07948	0.08273	0.05011	0.05238	0.16961	0.22528	0.03510	0.05014
FEDZ	0.15739	-0.12008	-0.12921	0.21917	0.19781	0.10006	0.11363	0.17375	0.06984	0.01972
COMPL	0.14350	0.27021	0.29292	0.22221	0.10820	0.24146	0.11796	0.25201	0.26411	0.21708
FN	0.14610	0.02887	0.08271	0.01781	0.05331	0.10451	0.04766	0.06284	0.04829	0.06657

	FOOTAPD	FOOTAPN	MAZETDZ	MAZETNZ	MAZECDZ	MAZECNZ	SEX	AGNOSIAZ	WRITDZ	WRITNZ
AGE	-0.11551	-0.19839	-0.19439	-0.13142	-0.15982	-0.08052	-0.00847	0.12477	0.05503	-0.00154
EDUC	-0.02440	-0.04317	-0.10553	-0.31591	-0.16579	-0.21904	0.00796	-0.09124	0.01828	0.01132
WAISVIQ	0.06227	0.12413	0.12162	0.16100	0.16445	0.21564	0.05151	0.44201	0.28780	0.18056
WAISPIQ	0.36138	0.37375	0.39053	0.55457	0.48228	0.58478	0.12777	0.39492	0.39754	0.42188
WRAR	0.06767	0.08100	0.15908	0.16088	0.18373	0.20786	-0.05064	0.37426	0.18238	0.09714
WRAS	-0.00960	0.00073	0.28326	0.26566	0.26943	0.25364	-0.14699	0.39165	0.24366	0.20714
WRAA	0.16786	0.20597	0.30200	0.37271	0.34383	0.36998	0.13928	0.35127	0.34667	0.27201
ACCATTDZ	0.17056	0.24112	0.20638	0.39366	0.31096	0.43655	0.15762	0.32798	0.30267	0.33672
ACTPTOTZ	-0.03598	0.00474	0.20313	0.26117	0.25709	0.23919	-0.05400	0.11215	0.13813	0.16512
ACTPTMEM	0.33561	0.38473	0.37360	0.45575	0.45017	0.46848	0.03344	0.08635	0.37177	0.34649
ACTPTLOC	0.31558	0.32416	0.27685	0.36286	0.36829	0.37078	0.01629	0.22816	0.43842	0.33176
FINTAPD	0.33183	0.47885	0.38176	0.34393	0.46020	0.31709	0.41999	0.08574	0.12443	0.02408
FINTAPN	0.43556	0.50085	0.21174	0.39065	0.31292	0.42272	0.46137	0.10342	0.13327	0.01954
SPECZ	0.16280	0.14855	0.33558	0.29111	0.33209	0.23896	0.04947	0.17906	0.32199	0.38671
SEASHOR	0.15744	0.12838	0.27096	0.40522	0.32077	0.39383	0.12151	0.32992	0.28252	0.45824
TRIATZ	0.33955	0.39233	0.62192	0.70554	0.71747	0.65952	0.01522	0.31373	0.33657	0.44652
TRIETZ	0.21250	0.22822	0.55183	0.52942	0.61731	0.49879	0.02913	0.33022	0.31160	0.48101
IMPZ	0.38514	0.39984	0.39718	0.52934	0.50213	0.53957	0.10176	0.37097	0.48214	0.43318
LOCMD	0.53088	0.45558	0.16819	0.15627	0.22910	0.15923	0.72867	0.07049	0.12139	-0.06655
LOCMN	0.44018	0.54768	0.10053	0.22879	0.20299	0.25929	0.70674	-0.05666	0.16793	0.04221
FOOTAPD	1.00000	0.72343	0.18012	0.28449	0.28756	0.30334	0.39729	0.10865	0.19471	0.00905
FOOTAPN	0.72343	1.00000	0.22783	0.37155	0.29046	0.41314	0.40058	0.01550	0.11684	-0.01660
MAZETDZ	0.18012	0.22783	1.00000	0.68896	0.90405	0.68225	0.02888	0.12297	0.22481	0.39118
MAZETNZ	0.28449	0.37155	0.68896	1.00000	0.84691	0.95409	0.09018	0.20666	0.38237	0.45834
MAZECDZ	0.28756	0.29046	0.90405	0.84691	1.00000	0.80548	0.10530	0.16580	0.28696	0.44101
MAZECNZ	0.30334	0.41314	0.68225	0.95409	0.80548	1.00000	0.13181	0.20499	0.32922	0.36957
SEX	0.39729	0.40058	0.02888	0.09018	0.10530	0.13181	1.00000	-0.02062	0.06821	-0.11847
AGNOSIAZ	0.10865	0.01550	0.12297	0.20666	0.16580	0.20499	-0.02062	1.00000	0.45293	0.09670
WRITDZ	0.19471	0.11684	0.22481	0.38237	0.28696	0.32922	0.06821	0.45293	1.00000	0.53512
WRITNZ	0.00905	-0.01660	0.39118	0.45834	0.44101	0.36957	-0.11847	0.09670	0.53512	1.00000
SANDDZ	0.07718	0.14257	0.17962	0.13807	0.22481	0.14291	0.00686	-0.04594	0.16305	0.27437
SANDNZ	0.08843	0.01984	0.00178	0.06244	0.12976	0.06403	0.12979	-0.00996	0.03291	0.23299
STEACTDZ	0.22554	0.05966	0.32933	0.22558	0.37789	0.28310	-0.10353	0.41379	0.47680	0.23650
STEACTNZ	0.25539	0.31595	0.38914	0.53149	0.50020	0.62919	-0.03696	0.29878	0.42289	0.29850
STEACCDZ	0.00743	-0.09023	0.02257	0.06088	0.09989	0.14592	-0.16633	0.11988	0.10412	0.14845
STEACCNZ	0.00746	0.05202	0.03844	0.08725	0.09724	0.22079	-0.09030	0.10119	0.09907	0.02961
RSTEADTZ	0.22453	0.26995	0.73581	0.34648	0.80776	0.45916	0.05630	0.13695	0.17354	0.32004
RSTTNZ	0.23136	0.28607	0.36479	0.48814	0.56317	0.57793	-0.09836	0.03186	0.38462	0.50744
RSTCDZ	0.20479	0.17522	0.54475	0.41581	0.63906	0.44214	0.02810	0.11989	0.24911	0.37896
RSTCNZ	0.23522	0.27563	0.15254	0.35884	0.27575	0.43658	-0.10677	0.21693	0.18969	0.11459
PEGSDZ	0.41155	0.25670	0.69538	0.45787	0.67705	0.37095	0.02722	0.22529	0.13999	0.16269
PEGSNZ	0.26020	0.44848	0.27235	0.55296	0.30564	0.51889	-0.04288	0.15829	0.09068	0.14699
KNOXMEAN	0.13144	0.16162	0.20620	0.36980	0.28909	0.41865	0.08492	0.45732	0.31080	0.29011
CRITERZ	0.29261	0.36904	0.27778	0.39574	0.32357	0.37382	0.03577	0.20222	0.25673	0.21120
STATUSZ	0.11340	0.18272	0.09175	0.18162	0.13071	0.19047	-0.11434	0.26880	0.18964	0.16366
OCCUPZ	-0.02007	-0.01350	0.19488	0.11610	0.20659	0.16491	-0.05622	0.14069	0.06618	0.05014
EEGZ	0.03407	0.05008	0.09387	0.04356	0.06259	0.04899	-0.00368	0.27461	0.13332	0.08225
COMPL	0.16080	0.15511	0.20192	0.18288	0.23739	0.15142	0.24774	0.07820	0.08538	-0.00010
PN	0.25019	0.22819	0.12791	0.17454	0.10363	0.14292	0.03529	-0.04633	0.04458	-0.01441

	SANDCZ	SANDNZ	STEADTDZ	STEADTNZ	STEADCDZ	STEADCNZ	RSTEADTZ	RSTTNZ	RSTCDZ	RSTCNZ
ACE	-0.20242	0.06031	0.00889	0.00292	0.14239	0.04386	-0.19336	-0.25515	-0.20143	-0.12147
EDUC	0.03354	0.07370	-0.00529	-0.17054	0.03332	0.03798	-0.06525	-0.27499	-0.08153	-0.10561
WAISVIQ	0.04904	0.12833	0.24360	0.18413	0.02675	0.06338	0.16660	0.06120	0.14887	0.14527
WAISPIQ	0.06463	0.12719	0.23384	0.42388	0.10040	0.09919	0.34618	0.32497	0.32990	0.27747
WRAR	0.03344	0.06667	0.15324	0.19223	0.18279	0.15877	0.16935	0.08927	0.14811	0.20900
WRAS	0.03836	0.03619	0.22871	0.19511	0.14763	0.10419	0.22011	0.16987	0.23566	0.16075
WRAA	0.08128	0.06649	0.16155	0.21150	0.00078	0.01511	0.26853	0.24909	0.29618	0.18185
ACCATTOZ	0.02854	0.12525	0.11844	0.25857	0.02388	0.02105	0.20987	0.29120	0.28222	0.24632
ACTPTOTZ	0.03960	0.04208	0.21829	0.27982	0.31064	0.11073	0.17822	0.20520	0.16477	0.17337
ACTPIMEM	0.34761	-0.04744	0.26555	0.40794	0.08008	0.07683	0.37075	0.35525	0.30923	0.24578
ACTPTBLK	0.17070	-0.06454	0.31331	0.31024	0.06001	0.02042	0.30058	0.31688	0.25971	0.26580
FINTAPD	0.18173	0.15959	0.24003	0.28577	0.04621	0.08134	0.52503	0.26504	0.55470	0.17808
FINTAPN	0.02827	0.10952	0.11824	0.29723	0.08408	0.09717	0.23642	0.21355	0.37198	0.24488
SPECZ	0.09802	0.03570	0.32664	0.32111	0.15893	0.11233	0.34950	0.30859	0.31089	0.18933
SEASHOR	0.06675	0.13074	0.16783	0.26536	0.21765	0.15931	0.18651	0.36208	0.30102	0.27554
TRIZTZ	0.19480	0.07204	0.31932	0.42111	0.10583	0.06527	0.64090	0.62652	0.59055	0.41563
TRIBTZ	0.22436	0.09523	0.34799	0.34693	0.05306	0.02327	0.62072	0.47992	0.51117	0.29462
IMPZ	0.18114	0.11033	0.35490	0.46663	0.17864	0.16132	0.39134	0.42730	0.40367	0.37726
LOCMD	0.06124	0.12419	0.05000	0.01687	-0.11002	-0.13349	0.24619	0.04285	0.22374	0.00672
LOCMN	0.11790	0.15446	-0.02608	0.10658	-0.08082	-0.06174	0.17239	0.20980	0.21912	0.14723
FCCTAPD	0.07718	0.03343	0.22594	0.25539	0.00643	0.00746	0.22453	0.23136	0.20479	0.23522
FCCTAPN	0.14257	0.01984	0.05966	0.31985	-0.09023	0.05202	0.26999	0.28607	0.17522	0.27563
MAZETDZ	0.17962	0.08178	0.32933	0.38914	0.02257	0.03344	0.73581	0.36479	0.54475	0.15254
MAZETNZ	0.13897	0.06244	0.22558	0.53149	0.06088	0.08725	0.34648	0.48814	0.41581	0.35984
MAZECDZ	0.22481	0.12976	0.37789	0.50020	0.09989	0.09724	0.80776	0.56317	0.63506	0.27575
MAZECNZ	0.14291	0.06403	0.28310	0.62919	0.14592	0.22079	0.45916	0.57793	0.44214	0.43658
SEX	0.00666	0.12379	-0.10353	-0.03696	-0.16633	-0.09030	0.05630	-0.09836	0.02810	-0.10677
AGNOSIAZ	-0.04554	-0.00996	0.41379	0.29878	0.11988	0.10119	0.13695	0.03166	0.11589	0.21693
WRITDZ	0.16305	0.03291	0.47680	0.42289	0.10412	0.09907	0.17354	0.38462	0.24911	0.18969
WRITNZ	0.27437	0.23299	0.23850	0.20850	0.14845	0.02961	0.32004	0.50744	0.37896	0.11489
SANDCZ	1.00000	0.30863	0.21328	0.25599	0.11734	0.19600	0.26692	0.34365	0.27361	0.19733
SANDNZ	0.30863	1.00000	0.03292	-0.00245	-0.01533	-0.09034	0.10413	0.10217	0.12505	-0.02318
STEADTDZ	0.21328	0.03292	1.00000	0.60897	0.43811	0.36519	0.40266	0.22440	0.38410	0.25556
STEADTNZ	0.25559	-0.00245	0.60897	1.00000	0.57606	0.69887	0.37077	0.49439	0.44547	0.60559
STEADCDZ	0.11734	-0.01533	0.43811	0.57606	1.00000	0.71697	0.08711	0.18579	0.30875	0.38102
STEADCNZ	0.19600	-0.09034	0.36519	0.69887	0.71697	1.00000	0.10777	0.26520	0.33510	0.53030
RSTEADTZ	0.26692	0.10413	0.40266	0.37077	0.08711	0.10777	1.00000	0.38058	0.67513	0.18166
RSTTNZ	0.34365	0.10217	0.22440	0.49439	0.18579	0.26520	0.38058	1.00000	0.57826	0.69685
RSTCDZ	0.27361	0.12505	0.38410	0.44547	0.30875	0.33510	0.67513	0.57826	1.00000	0.41921
RSTCNZ	0.19733	-0.02318	0.25556	0.60559	0.38102	0.53030	0.18166	0.69685	0.41921	1.00000
PEGSDZ	0.19953	0.12170	0.42166	0.33316	0.02502	0.03388	0.83510	0.32728	0.50059	0.16253
PEGSNZ	0.01371	0.06197	0.12123	0.45787	0.03923	0.14584	0.20928	0.47106	0.21989	0.53782
KNOXMEAN	-0.03749	0.00517	0.15443	0.27960	0.13575	0.10154	0.13904	0.10748	0.18109	0.14610
CRITERZ	0.06523	0.04052	0.24990	0.26021	-0.03826	0.00437	0.32293	0.31339	0.31359	0.25581
STATUSZ	0.02719	0.03041	0.14499	0.20137	0.10891	0.08661	0.15620	0.18821	0.21803	0.19595
COLORZ	-0.04981	0.06495	0.20665	0.04496	-0.06339	-0.11409	0.16310	-0.00456	0.06415	-0.00578
EEGZ	-0.04763	-0.00951	0.23183	0.10178	0.15641	0.06517	0.12341	-0.07132	0.02680	0.10085
COMPL	0.06234	0.01476	0.17497	0.11127	0.02977	0.04023	0.23172	0.17134	0.19319	0.15282
PN	0.04676	0.02106	-0.10836	-0.03688	-0.27166	-0.19450	0.04885	0.16369	-0.08703	0.05713

	PEGSDZ	PEGSNZ	KNOXMEAN	CRITERZ	STATUSZ	OCCUPZ	EEGZ	COMPL	PN
AGE	-0.23879	-0.09412	-0.00220	-0.28655	-0.14673	0.02874	0.04909	-0.25435	-0.24626
EDUC	-0.08269	-0.30313	0.13456	0.00961	-0.01467	0.17959	-0.08574	0.03707	-0.19979
WAISVIQ	0.10954	0.09598	0.66422	0.35165	0.33154	0.32699	0.16295	0.01010	-0.18145
WAISPIQ	0.29794	0.30426	0.71799	0.47784	0.36853	0.20637	0.20590	0.03532	0.05394
WRAR	0.11067	0.06352	0.50325	0.16890	0.18205	0.25602	0.19759	-0.11762	-0.11327
WRAS	0.08469	0.03850	0.54035	0.17309	0.11554	0.29806	0.10606	-0.12846	-0.15324
WRAA	0.24485	0.16003	0.59027	0.39964	0.25770	0.27401	-0.01044	0.06365	-0.01568
ACCATTDZ	0.24644	0.32773	0.57412	0.51693	0.33667	0.17165	-0.01002	0.25250	-0.02830
ACTPTOTZ	0.18445	0.23321	0.19617	0.11536	0.09226	0.07081	0.04925	0.01935	0.13388
ACTPTMEM	0.39434	0.31660	0.23214	0.40145	0.28962	0.19976	0.04813	0.21551	0.09781
ACTPTMLK	0.35841	0.21516	0.34133	0.50010	0.36876	0.20055	0.15739	0.14350	0.14610
FINTAPD	0.54222	0.16725	0.23170	0.40370	0.17728	0.03233	-0.12008	0.27021	0.02387
FINTAPN	0.21037	0.39241	0.28269	0.40070	0.19615	-0.07948	-0.12921	0.29292	0.08271
SPECZ	0.28572	0.07491	0.40067	0.42454	0.24992	0.08273	0.21917	0.22221	0.01781
SEASHOR	0.08729	0.27413	0.57908	0.30075	0.27410	0.05011	0.19781	0.10820	0.05331
TRIITZ	0.55721	0.36267	0.43402	0.46785	0.35459	0.05238	0.10006	0.24146	0.10451
TRIPTZ	0.53165	0.25888	0.57911	0.41918	0.32073	0.16961	0.11363	0.11796	0.04766
IMPZ	0.44331	0.38920	0.61223	0.64536	0.48192	0.22528	0.17375	0.25201	0.06284
LOCMD	0.33845	-0.02584	0.21115	0.26900	0.03780	0.03510	0.06984	0.26411	0.04829
LOCMN	0.11113	0.16485	0.15082	0.22181	0.05182	0.05014	0.01972	0.21708	0.06657
FOOTAPD	0.41155	0.26020	0.13144	0.29261	0.11340	-0.02007	0.03407	0.16080	0.25019
FOOTAPN	0.25670	0.44848	0.16162	0.36904	0.10272	-0.01350	0.05008	0.15511	0.22819
MAZETCZ	0.69538	0.27235	0.20620	0.27778	0.09175	0.19488	0.09387	0.20192	0.12791
MAZETNZ	0.45787	0.55236	0.36980	0.35574	0.18162	0.11610	0.04356	0.18288	0.17454
MAZECDZ	0.67705	0.30564	0.28909	0.32357	0.13071	0.20659	0.06259	0.23739	0.10363
MAZECNZ	0.37595	0.51889	0.41865	0.37382	0.19047	0.16491	0.04899	0.15142	0.14292
SEX	0.02722	-0.04288	0.08492	0.03577	-0.11434	-0.05622	-0.00368	0.24774	0.03529
AGNOSIAZ	0.22529	0.15829	0.45732	0.20222	0.26880	0.14069	0.27461	0.07820	-0.04633
WRITCZ	0.13999	0.09068	0.31080	0.25673	0.18764	0.06618	0.13332	0.08538	0.04458
WRITNZ	0.16269	0.14699	0.29011	0.21120	0.16366	0.05014	0.08225	-0.00010	-0.01441
SANCDZ	0.19153	0.01371	-0.03749	0.06523	0.02719	-0.04981	-0.04760	0.06234	0.04676
SANCNZ	0.12170	0.06157	0.00517	0.04052	0.03041	0.06495	-0.00951	0.01476	0.02106
STEALTCZ	0.42166	0.12123	0.15443	0.24990	0.14499	0.20665	0.23183	0.17497	-0.10835
STEAUTNZ	0.33316	0.45787	0.27960	0.26021	0.20137	0.04496	0.10178	0.11127	-0.03688
STEALCDZ	0.02502	0.01923	0.13575	-0.03826	0.10891	-0.06339	0.15641	0.02977	-0.27166
STEACCNZ	0.03338	0.14584	0.10154	0.00437	0.08661	-0.11409	0.06517	0.04023	-0.19450
RSTEALTZ	0.83510	0.20528	0.13904	0.32293	0.15620	0.16310	0.12341	0.23172	0.04385
RSTTNZ	0.32728	0.47106	0.10748	0.31339	0.18821	-0.00456	-0.07132	0.17134	0.16369
RSTCDZ	0.50059	0.21589	0.18108	0.31359	0.21803	0.06415	0.02680	0.19319	-0.08763
RSTCNZ	0.16253	0.53782	0.14610	0.25581	0.29595	-0.00578	0.10085	0.15282	0.05713
PEGSDZ	1.00000	0.21227	0.12661	0.39012	0.14789	0.20548	0.05917	0.26074	0.14461
PEGSNZ	0.21227	1.00000	0.15964	0.31804	0.16590	0.02927	0.04028	0.07953	0.12001
KNOXMEAN	0.12661	0.15964	1.00000	0.38158	0.39463	0.15385	0.10567	-0.04962	-0.05459
CRITERZ	0.39012	0.31804	0.38158	1.00000	0.63860	0.23159	0.19517	0.33638	0.20792
STATUSZ	0.14789	0.16590	0.39463	0.63860	1.00000	-0.01428	0.38832	0.14891	0.06815
OCCUPZ	0.20548	0.02927	0.15385	0.23159	-0.01428	1.00000	0.02320	-0.04950	-0.16311
EEGZ	0.05917	0.04028	0.10567	0.19517	0.38832	0.02320	1.00000	0.12488	0.00699
COMPL	0.26074	0.07953	-0.04962	0.33638	0.14891	-0.04950	0.12488	1.00000	-0.13710
PN	0.14461	0.12001	-0.05459	0.20792	0.06815	-0.16311	0.00699	-0.13710	1.00000

DETERMINANT = -0.0000000(-0.22607549D-20)

APPENDIX 5

RAW SCORES FOR ALL SUBJECTS ON VARIABLES USED IN THE DISCRIMINANT ANALYSIS

APPENDIX 5

Subj	ADCATTOZ*	IMPZ*	FINTAPN	ADTPTBLK	ADTPTMEM	FINTAPD	WAISPIQ	TRIATZ*	TRIBTZ*	SPECZ*	PEGSDZ*
	Control Group										
1	949	94	43	3	4	52	86	974	938	87	97.24
2	964	95	43	4	7	45	120	979	880	88	96.96
3	979	98	49	3	9	56	120	977	967	98	97.32
4	969	99	33	8	8	28	109	970	972	96	97.52
5	960	99	41	8	8	39	116	984	961	100	97.56
6	982	98	37	7	9	46	103	965	934	97	97.48
7	927	95	39	6	7	44	94	972	850	96	96.84
8	958	99	45	6	8	56	110	980	928	98	97.64
9	972	98	42	6	9	48	106	980	822	94	97.72
10	963	98	42	7	7	43	100	978	898	96	96.92
11	958	100	52	7	8	51	109	972	930	98	97.72
12	952	99	32	5.6	8	37	99	973	943	99	97.68
13	969	98	37	8	9	42	98	983	964	93	97.28
14	967	96	37	3	7	34	96	979	951	99	96.60
15	968	99	41	8	8	48	119	980	958	98	97.16
16	956	98	44	9	9	40	118	969	923	96	97.24
17	972	98	42	7	8	48	125	972	945	95	97.88
18	900	94	33	7	7	35	92	950	893	92	96.52
19	961	96	50	4	9	44	107	970	949	99	97.56
20	942	94	46	3	6	46	101	966	898	96	97.48
21	941	94	55	2	5	53	116	988	959	92	97.72
22	935	96	36	4	6	44	100	963	864	96	97.20
23	980	99	43	8	9	38	123	980	966	94	97.84
24	969	98	56	7	8	47	114	974	949	93	97.16
25	975	99	44	9	9	48	125	975	955	97	97.80
26	959	100	50	5	8	51	114	972	914	97	97.44
27	944	98	66	9	9	55	104	971	896	95	97.48
28	965	98	45	4	8	58	108	978	930	95	97.64
29	964	96	34	4	7	40	99	973	907	96	97.48
30	967	94	45	2	4	48	96	970	894	98	96.36
31	961	99	43	5	8	45	121	981	951	98	97.88
32	964	98	38	7	8	42	102	975	955	95	97.96
33	964	97	53	6	6	53	110	975	929	95	97.84
34	935	97	47	1	10	50	123	967	940	96	97.92

*Denotes variables whose scores were inverted by subtracting them from a constant.

APPENDIX 5

Negative Neurological Group

ubj	ADCATTOZ*	IMPZ*	FINTAPN	ADTPTBLK	ADTPTMEM	FINTAPD	WAISPIQ	TRIATZ*	TRIBTZ*	SPECZ*	PEGSDZ*
1	966	95	35	4	6	44	92	932	910	94	97.40
2	972	97	41	1	6	43	123	964	915	92	97.64
3	935	95	45	8	8	47	103	974	914	86	97.88
4	975	95	41	4	6	36	99	954	916	98	96.56
5	981	99	43	6	7	39	119	969	949	94	97.32
6	929	96	37	5	5	41	113	971	910	97	96.40
7	895	92	42	3	6	47	72	960	815	94	96.44
8	916	92	38	2	5	45	99	885	818	90	97.64
9	946	98	40	8	9	44	106	979	926	99	98.00
10	902	93	33	6	8	40	89	931	925	96	96.56
11	893	96	41	5	9	49	102	969	916	99	97.28
12	960	95	43	2	5	31	104	973	902	98	97.84
13	940	96	40	2	7	52	105	947	930	97	96.64
14	941	94	44	5	6	47	83	976	884	94	97.20
15	897	91	36	4	7	36	83	940	666	81	96.60
16	922	93	41	2	6	40	75	849	695	93	94.92
17	938	97	49	7	8	47	105	982	941	96	97.40
18	980	99	51	5	8	54	110	979	955	100	97.60
19	918	92	33	0	7	46	94	953	914	87	96.12
20	958	96	36	1	6	48	87	966	926	94	97.04
21	898	95	43	4	6	46	91	961	925	93	97.52
22	918	95	31	3	7	45	113	975	909	96	97.60
23	909	93	28	4	7	26	96	940	882	93	96.20
24	957	99	47	9	9	47	102	979	947	99	97.76
25	940	95	66	3	6	48	90	963	926	98	97.24
26	952	94	41	1	5	42	110	946	846	94	96.40
27	938	93	27	4	9	33	85	954	844	90	97.20
28	953	99	46	7	8	46	116	971	929	90	97.52
29	946	93	35	2	5	40	86	958	882	90	97.72
30	955	94	41	1	3	43	91	942	878	89	96.52
31	981	98	40	9	10	45	104	974	924	99	97.68
32	950	94	33	3	7	33	76	955	846	99	97.52
33	940	95	48	6	9	50	101	977	941	91	97.24
34	932	95	37	1	7	42	98	957	915	96	97.20

*Denotes variables whose scores were inverted by subtracting them from a constant.

APPENDIX 5

Positive Neurological Group

Subj	ADCATTOZ*	IMPZ*	FINTAPN	ADTPTBLK	ADTPTMEM	FINTAPD	WAISPIQ	TRIATZ*	TRIBTZ*	SPECZ*	PEGSDZ*
1	917	91	37	3	6	42	55	931	653	74	97.48
2	947	95	47	3	6	52	89	972	888	94	97.20
3	944	92	35	3	9	23	87	941	884	92	86.40
4	897	93	40	0	7	38	87	897	893	91	96.40
5	928	90	40	2.5	4	55	97	956	901	89	96.80
6	953	93	37	1	7	41	93	946	856	63	97.52
7	879	92	12	1	5	36	76	928	708	96	96.40
8	914	91	32	1	5	38	88	919	804	87	95.68
9	873	92	29	1	5	38	99	951	836	90	96.80
10	908	93	43	3	6	42	78	958	934	85	94.56
11	860	91	32	0	2	30	71	950	846	89	94.00
12	953	95	40	7	7	48	104	950	910	87	97.56
13	949	96	51	8	9	53	107	978	897	93	97.88
14	929	92	51	0	6	47	87	936	811	84	95.80
15	869	95	50	4	7	43	94	964	865	98	96.56
16	925	92	25	4	5	42	87	950	922	95	95.32
17	892	90	35	1	5	30	60	880	658	90	90.04
18	948	93	39	2	5	31	105	925	810	94	84.80
19	958	94	48	2	9	47	112	960	880	92	94.88
20	933	93	35	3	5	43	116	970	928	92	97.44
21	866	90	35	0	2	26	78	828	545	80	88.80
22	902	92	35	2	5	36	92	962	893	94	95.96
23	940	94	38	2	5	42	126	974	958	96	95.92
24	934	95	26	7	7	38	89	964	929	90	96.80
25	955	95	40	3	7	40	96	964	906	90	96.96
26	942	96	21	4	7	45	112	974	941	97	97.76
27	915	94	6	4	6	5	101	926	852	93	94.84
28	929	95	38	2	7	36	95	970	871	98	96.92
29	935	91	35	1	4	38	91	952	915	90	97.36
30	928	93	36	2.5	6	29	91	944	919	98	96.18
31	923	90	32	2	5	36	71	834	751	82	93.44
32	938	95	33	4	8	33	88	952	930	91	97.16
33	956	97	36	1	8	47	98	964	921	97	97.72
34	952	93	34	0	3	21	95	901	694	83	80.10

*Denotes variable whose scores were inverted by subtracting them from a constant.

APPENDIX 6

EVALUATION OF THE CLASSIFICATION FUNCTION FOR EACH CASE BASED ON THE NORMAL-PROBABILITY-DENSITY FUNCTION USING THE FOUR VARIABLE DISCRIMINANT ANALYSIS

EVALUATION OF THE CLASSIFICATION FUNCTION FOR EACH CASE BASED ON THE NORMAL-PROBABILITY-DENSITY FUNCTION USING THE FOUR VARIABLE DISCRIMINANT ANALYSIS

Case	Control Group				
	Function			Largest Prob.	Function Number[a]
	CG 1	NNG 2	PNG 3		
1	.17248	.47508	.35244	.47508	2
2	.33082	.46790	.20129	.46790	2
3	.71908	.25427	.02665	.71908	1
4	.79587	.18470	.01942	.79587	1
5	.80891	.17804	.01305	.80891	1
6	.74800	.22312	.02888	.74800	1
7	.24942	.49374	.25684	.49374	2
8	.78780	.19773	.01446	.78780	1
9	.72843	.24334	.02824	.72843	1
10	.72667	.24621	.02712	.72667	1
11	.87849	.11774	.00377	.87849	1
12	.70508	.25624	.03868	.70508	1
13	.73685	.23385	.02930	.73685	1
14	.37966	.43285	.18749	.43285	2
15	.82364	.16474	.01162	.82364	1
16	.75839	.22265	.01895	.75839	1
17	.74836	.22763	.02401	.74836	1
18	.10428	.43403	.46169	.46169	3
19	.49016	.42131	.08853	.49016	1
20	.17609	.49652	.32738	.49652	2
21	.20719	.54216	.25065	.54216	2
22	.30254	.47020	.22726	.47020	2
23	.85005	.14144	.00851	.85005	1
24	.79954	.19042	.01004	.79954	1
25	.85748	.13531	.00721	.85748	1
26	.85226	.14170	.00604	.85226	1
27	.81667	.17805	.00528	.81667	1
28	.68302	.28182	.03516	.68302	1
29	.37386	.42738	.19875	.42738	2
30	.20101	.47549	.32150	.47549	2
31	.76866	.21267	.01867	.76866	1
32	.70847	.25703	.03450	.70847	1
33	.67520	.29505	.02975	.67520	1
34	.41741	.46497	.11762	.46497	2

[a]This indicates the group into which the subject is most likely to be placed on the basis of the largest probability according to the normal-probability-density function.

Case	Negative Neurological Group				
	Function			Largest Prob.	Function Number[a]
	CG 1	NNG 2	PNG 3		
1	.27356	.44338	.28307	.44338	2
2	.49069	.39582	.11349	.49069	1
3	.36689	.48498	.14813	.48498	2
4	.34804	.44919	.20276	.44919	2
5	.82459	.16356	.01185	.82459	1
6	.31942	.47590	.20468	.47590	2
7	.02622	.30890	.66488	.66488	3
8	.02471	.26942	.70586	.70586	3
9	.69398	.27316	.03286	.69398	1
10	.05321	.35203	.59475	.59475	3
11	.24990	.52903	.22107	.52903	2
12	.26747	.47856	.25397	.47856	2
13	.29508	.48071	.22421	.48071	2
14	.20178	.49709	.30113	.49709	2
15	.01170	.20475	.78355	.78355	3
16	.05843	.37673	.56485	.56485	3
17	.60115	.35383	.04502	.60115	1
18	.83493	.15669	.00838	.83493	1
19	.01378	.19556	.79065	.79065	3
20	.28878	.45134	.25988	.45134	2
21	.16777	.52298	.30925	.52298	2
22	.12283	.42103	.45614	.45614	3
23	.03361	.27257	.69382	.69382	3
24	.83790	.15439	.00771	.83790	1
25	.39652	.51754	.08594	.51754	2
26	.13157	.43883	.42961	.43883	2
27	.04888	.28580	.66532	.66532	3
28	.79798	.18972	.01229	.79798	1
29	.06126	.33424	.60450	.60450	3
30	.13657	.43946	.42397	.43946	2
31	.79519	.18750	.01732	.79519	1
32	.11906	.39615	.48478	.48478	3
33	.35058	.49573	.15368	.49573	2
34	.14488	.44889	.40623	.44889	2

[a] This indicates the group into which the subject is most likely to be placed on the basis of the largest probability according to the normal-probability-density function.

Case	Positive Neurological Group				
	Function			Largest Prob.	Function Number[a]
	CG 1	NNG 2	PNG 3		
1	.01434	.21271	.77295	.77295	3
2	.28622	.50283	.21095	.50283	2
3	.03732	.28138	.68130	.68130	3
4	.02878	.30803	.66318	.66318	3
5	.04712	.29431	.65857	.65857	3
6	.00942	.17909	.81149	.81149	3
7	.06454	.34155	.59391	.59391	3
8	.00230	.07219	.92551	.92551	3
9	.00718	.14720	.84562	.84562	3
10	.00628	.15083	.84289	.84289	3
11	.06073	.40521	.53406	.53406	3
12	.00252	.10846	.88902	.88902	3
13	.35630	.46087	.18283	.46087	2
14	.56648	.37874	.05478	.56648	1
15	.04339	.37604	.58057	.58057	3
16	.15005	.57532	.27463	.57532	2
17	.01863	.19632	.78504	.78504	3
18	.00298	.11074	.88628	.88628	3
19	.07627	.37496	.54877	.54877	3
20	.20213	.49650	.30137	.49650	2
21	.05893	.34211	.59896	.59896	3
22	.00163	.09091	.90746	.90746	3
23	.01685	.23072	.75243	.75243	3
24	.11349	.42271	.46380	.46380	3
25	.19812	.42602	.37587	.42602	2
26	.25684	.47182	.27134	.47182	2
27	.20593	.39752	.39655	.39752	2
28	.02011	.15915	.82075	.82075	3
29	.16281	.46677	.37042	.46677	2
30	.01206	.18091	.80703	.80703	3
31	.05361	.33935	.60703	.60703	3
32	.00483	.12001	.87516	.87516	3
33	.18983	.44799	.36218	.44799	2
34	.39826	.43020	.17154	.43020	2

[a] This indicates the group into which the subject is most likely to be placed on the basis of the largest probability according to the normal-probability-density function.

APPENDIX 7

EVALUATION OF THE CLASSIFICATION FUNCTION FOR EACH CASE BASED ON THE NORMAL-PROBABILITY-DENSITY FUNCTION USING THE ELEVEN VARIABLE DISCRIMINANT ANALYSIS

EVALUATION OF THE CLASSIFICATION FUNCTION FOR EACH CASE BASED ON THE NORMAL-PROBABILITY-DENSITY FUNCTION USING THE ELEVEN VARIABLE DISCRIMINANT ANALYSIS

Case	Control Group				
	Function			Largest Prob.	Function Number[a]
	CG 1	NNG 2	PNG 3		
1	.20447	.40131	.39422	.40131	2
2	.53479	.29491	.17030	.53479	1
3	.67803	.29578	.02619	.67803	1
4	.76576	.21431	.01993	.76576	1
5	.83401	.15894	.00705	.83401	1
6	.68579	.29452	.01969	.68579	1
7	.35917	.51173	.12910	.51173	2
8	.83325	.15880	.00795	.83325	1
9	.83868	.15453	.00679	.83868	1
10	.79619	.19209	.01172	.79619	1
11	.88206	.11615	.00178	.88206	1
12	.65926	.30779	.03295	.65926	1
13	.68918	.26428	.04655	.68918	1
14	.31033	.54811	.14156	.54811	2
15	.87199	.12016	.00785	.87199	1
16	.78320	.20481	.01199	.78320	1
17	.82024	.16640	.01337	.82024	1
18	.08319	.38261	.53420	.53420	3
19	.32936	.62167	.04897	.62167	2
20	.21686	.64144	.14170	.64144	2
21	.31066	.48234	.20700	.48234	2
22	.43722	.45220	.11057	.45220	2
23	.86705	.12571	.00724	.86705	1
24	.80551	.18662	.00787	.80551	1
25	.88499	.11104	.00397	.88499	1
26	.88067	.11597	.00335	.88067	1
27	.88910	.07519	.03572	.88910	1
28	.72167	.25001	.02832	.72167	1
29	.41650	.47311	.11039	.47311	2
30	.31601	.57812	.10588	.57812	2
31	.81212	.17606	.01182	.81212	1
32	.68356	.28789	.02855	.68356	1
33	.75813	.23269	.00918	.75813	1
34	.31553	.51946	.16502	.51946	2

[a] This indicates the group into which the subject is most likely to be placed on the basis of the largest probability according to the normal-probability-density function.

Case	Negative Neurological Group				
	Function			Largest Prob.	Function Number[a]
	CG 1	NNG 2	PNG 3		
1	.22357	.63595	.14049	.63595	2
2	.62932	.29611	.07458	.62932	1
3	.41655	.40000	.18345	.41655	1
4	.31472	.61051	.07477	.61051	2
5	.86609	.12624	.00767	.86609	1
6	.50928	.34815	.14257	.50928	1
7	.03735	.49313	.46952	.49313	2
8	.03471	.59780	.36749	.59780	2
9	.68570	.29679	.01751	.68570	1
10	.02215	.39975	.57810	.57810	3
11	.19535	.55570	.24895	.55570	2
12	.34263	.59666	.06071	.59666	2
13	.23429	.53135	.23435	.53135	2
14	.24634	.60881	.14485	.60881	2
15	.03966	.28143	.67891	.67891	3
16	.04461	.82111	.13427	.82111	2
17	.60502	.35934	.03564	.60502	1
18	.81202	.18404	.00394	.81202	1
19	.00347	.06044	.93609	.93609	3
20	.24994	.49319	.25687	.43919	2
21	.14408	.52215	.33377	.52215	2
22	.16978	.36314	.46708	.46708	3
23	.02218	.25448	.72334	.72334	3
24	.79727	.19817	.00456	.79727	1
25	.24550	.73184	.02266	.73184	2
26	.24490	.53205	.22304	.53205	2
27	.03793	.34969	.61238	.61238	3
28	.85980	.12662	.01358	.85980	1
29	.08563	.48444	.42993	.48444	2
30	.20696	.49768	.29537	.49768	2
31	.73531	.25674	.00795	.73531	1
32	.10658	.76930	.12412	.76930	2
33	.27487	.50679	.21834	.50679	2
34	.11166	.52780	.36054	.52780	2

[a] This indicates the group into which the subject is most likely to be placed on the basis of the largest probability according to the normal-probability-density function.

Case	Positive Neurological Group: Function CG 1	NNG 2	PNG 3	Largest Prob.	Function Number[a]
1	.03930	.34573	.61497	.61497	3
2	.32792	.56136	.11073	.56136	2
3	.00078	.00946	.98975	.98975	3
4	.00726	.31559	.67715	.67715	3
5	.00198	.00171	.99631	.99631	3
6	.01517	.19724	.78758	.78758	3
7	.01390	.03787	.94823	.94823	3
8	.00960	.17870	.81170	.81170	3
9	.00796	.15362	.83841	.83841	3
10	.00749	.09516	.89735	.89735	3
11	.01166	.10060	.88773	.88773	3
12	.00128	.03400	.96472	.96472	3
13	.39435	.42577	.17989	.42577	2
14	.60969	.36212	.02819	.60969	1
15	.04080	.36882	.59038	.59038	3
16	.15015	.62876	.22109	.62876	2
17	.01297	.14885	.83817	.83817	3
18	.00198	.09171	.90631	.90631	3
19	.01113	.02142	.96745	.96745	3
20	.15671	.41552	.42777	.42777	3
21	.10127	.30665	.59209	.59209	3
22	.00183	.03678	.96139	.96139	3
23	.01633	.20577	.77790	.77790	3
24	.15243	.28770	.55987	.55987	3
25	.14778	.30516	.54706	.54706	3
26	.23491	.47943	.28565	.47943	2
27	.25556	.32133	.42311	.42311	3
28	.01196	.08158	.90646	.90646	3
29	.18157	.59679	.22165	.59679	2
30	.01517	.25927	.72555	.72555	3
31	.03880	.57380	.38740	.57380	2
32	.00197	.13939	.85865	.85865	3
33	.09177	.45639	.45184	.45639	2
34	.31427	.54011	.14562	.54011	2

[a] This indicates the group into which the subject is most likely to be placed on the basis of the largest probability according to the normal-probability-density function.

APPENDIX 8

ABSTRACT OF

Use of Behavioral Measures in Discriminating Neurological Status

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Use of Behavioral Measures in Discriminating Neurological Status[1]

Neuropsychological behavioral measures, specifically the Halstead-Reitan battery, have been consistently proven to validly infer the presence of cerebral pathology. A particular problem in the growing validation of these indices has been the comparison to neurological diagnosis in cases of verified central nervous system dysfunction. One specific aspect within this area is the use of behavioral measures in diagnosing pathology as compared to the physical neurological exam, a problem first studied by Hallgrim Kløve.

Three groups were compared: a control group, having no cerebral pathology; a verified brain-damaged group, but with negative results on a physical neurological exam; and a third group with definite cerebral pathology which had abnormal signs on a physical neurologic exam.

A factor analysis, conducted to minimize the number of variables which may discriminate the groups, resulted in two sets of chosen variables, one with four and the other with eleven variables. Multivariate discriminant function analysis

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1 Donald T. Stuss, Master's thesis presented to the School of Graduate Studies of the University of Ottawa, Ontario, October 1973, ix-158 p.

using these sets of variables indicated that there were significant differences among the groups; these significant differences on the discriminant function also occurred between all pairs of groups, with the exception that the eleven variable function only approached the .01 probability level between the two groups with pathology.

The basic validity of the chosen variables to discriminate pathology was reinforced. Classification of individual subjects yielded a high average correct classification, with the negative neurological group being the most difficult to classify. Consideration of the normal-probability-density function suggested that the confidence to be had in the decisions often had to be attenuated. It appeared, nevertheless, that the behavioral indices were more sensitive to pathology than the physical neurological exam.

Comparison of the results of classification by using the relatively simple Impairment Index to the discriminant function results suggested that the Impairment Index was a simpler, more practical, classification tool.

It was concluded that the neuropsychological behavioral indices be included in normal neurological diagnoses, since they not only add a certain practical validity in diagnosis as compared to more sophisticated and expensive medical techniques, but they also yield valuable additional information which may be important in aiding a patient in adjustment to his state, and to his future rehabilitation.