THE EFFECT OF AGE AND ABILITY LEVEL ON A BATTERY OF NEUROPSYCHOLOGICAL TESTS

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ABSTRACT

The purpose of the present study was to investigate the relative roles of age and ability level on the performance of a battery of neuropsychological tests called the Halstead Battery. The design of the study also allowed two theoretically important questions to be examined: the generality of the differentiation-integration hypothesis, and the possibility of differential effects of aging in different ability groups. One hundred and twenty-nine subjects were selected on the basis of age and I.Q. so that there was an adequate representation of high, medium, and low ability ranges, and young, middle-aged, and old adults. Statistical analysis of the Halstead Battery scores of these subjects revealed significant age and I.Q. effects on nearly all of the indicators in the Battery. In order to determine whether there was differential aging in different ability groups, the scores of the young and old subjects were submitted to analyses of variance. These analyses indicated that there was significant interaction between age and I.Q. on some of the tests. Correlational matrices and factor analyses for the young and old groups were compared in order to determine the tenability of the differentiation-integration hypothesis. It was concluded that: a) The Halstead Battery is sensitive to both age and ability level. These findings were discussed in relation to previous studies which did not adequately control for the latter variable, and the need for revised Halstead Battery norms. b) The tenability of the differentiation-integration hypothesis is greatly augmented by the present supportive findings.

c) There are different effects of aging in different ability groups and these effects correspond to an a priori ranking of the tests along the dimension of immediate adaptive ability vs. stored information.

TABLE OF CONTENTS

LIST OF EIGURES

LIST OF TABLES

CHAPTER I

INTRODUCTION

Perhaps the most obvious psychological aspect of human aging is the performance deficit evidenced on many sensory, motor, perceptual, and cognitive tasks. Until little more than a decade ago, studies on human aging were mainly concerned with documenting the performance decrement of older people on these various tasks. As the science of gerontology progressed, greater emphasis was placed on the discovery of possible influences of the performance decrement and the role that one or more correlates of the aging process played in the resulting decrement.

In keeping with the present trend of multi-variable studies which attempt to determine the relative contribution of two or more independent variables to age-related performance deficits, the present study attempts to determine the relative roles of chronological age and intelligence on performance of a group of neuropsychological tests.

There are numerous correlates associated with the process of aging. These can be grouped under health changes, social changes, personality changes, and biological changes. Each of these changes have been proposed by various investigators to explain age-associated decrements in psychological test performance.

Anatomical, physiological, and biochemical alterations associated with the aged nervous system have been well documented. Despite many methodological difficulties, several investigators have found that diminished brain weight and size are a consistent age-associated event (Appel & Appel, 1942; Grünthal, 1936; Hoff & Sietelberger, 1957). Cell counts indicate a loss of neurons accompanied by gliosis (Brody, 1955; Critchley, 1942; Harms, 1944) although this finding has not been replicated by Moyer (1959). Certain electrophysiological changes such as slowing of the alpha rhythm (Obrist, 1954) and elevation of the threshold to electroshock (Holmberg, 1954) have been definitely shown to accompany the aged nervous system. Age changes in neural integration and synaptic transmission in the central nervous system have been inferred from knowledge of peripheral nerve function. Birren (1959) found that the electrophysiological characteristics of old peripheral nerves are normal. They conduct at least as rapidly as young ones, and show no rise in threshold, fall in action potential, or rise in refractory period. This has led many investigators to the conclusion that the frequently observed increased latency in the performance of older people on simple tasks is the result of alterations in central synaptic and integrative mechanisms. Therefore, even though no unequivocal statement can be made about a loss in central nervous system cells, all evidence indicates altered function of central processes in the aged individual.

These biological alterations of the central nervous system perhaps bear a more fundamental relationship to the behavioural aspects of aging than any other area of psychology (such as motivation, or personality changes). However, due to prohibitive ethical and methodological problems the direct relationship of these changes to test performance is not amenable to empirical investigation. In any scientific discipline, the ideal model for determining the relationship which one variable exerts on another is to either hold constant or measure all other pertinent variables while the investigator actively manipulates the variable under study and measures the resultant change in the dependent variable(s). In research with human beings, direct manipulation or mutilation of the brain in order to create the desired independent variable is not ethically possible. Indeed, even the direct measurement of biological variables in living aged subjects is not possible. Thus the degree to which biological transformations modify behaviour remains largely unevaluated.

However, Halstead (1947) has devised an indirect method for assessing the functional condition of the brain. He developed a battery of neuropsychological tests (called the Halstead Battery) which satisfied the criterion of successfully differentiating between individuals having brain damage and those who did not. Halstead concluded that these tests are maximally sensitive to the organic condition of the brain.

Another methodological problem associated with the study of human aging concerns the time scale of age-related changes in performance. The ideal method for studying aging is the logitudinal method. Since age changes in individuals are being studied, these individuals should be followed in time (follow-up method). However, longitudinal studies although methodologically ideal have practical disadvantages which obviate this method as a frequently employed research design. Problems of investigator time and commitment, continued subject participation, antiquation of methods, and uncertain financial support lead many investigators to choose the compromise to the longitudinal study, the cross-sectional study. However, the cross-sectional design, involving the comparison of two or more groups of different ages, is often confounded by secular changes. This is a serious disadvantage since if subjects are not comparable in all respects except chronological age, any differences between groups cannot be unequivocally attributed to the effects of age - they may be due to gradual cumulative historical effects such as educational or cultural changes. Research terminology reflects the basic assumptions underlying each design. In general, the term "age change" is used to refer to the results from longitudinal studies, since the same persons actually have changed their scores from one testing to the next. The term "age difference" is used to refer to the results from cross-sectional studies and reflects the less equivocal conclusions feasible due to the possible presence of confounding secular variables.

The Halstead Battery has demonstrated validity for detecting cerebral pathology (Halstead, 1947; Reitan, 1955b, 1959). In a series of studies (Reed & Reitan, 1936a, 1963b; Reitan, 1955a), Reitan uses the argument that if these measures also detect age-associated ability changes in normal older subjects, then such age-associated ability changes may be due to undetected cerebral pathology in the older subjects.

In the first of the series of studies, Reitan (1955a) chose the Halstead Impairment Index, which is a composite score obtained by counting the number of tests on which a subject's performance falls into the range characteristic of brain damage, for study of biological changes involved in aging. The Halstead Battery was administered to a group with unequivocal evidence of brain damage and to a group with no neurologic evidence of brain damage. The relationship between age and test result was relatively low for the former group, but was significantly higher for the latter group. The significant correlation between age and Impairment Index in the normal group was the result of the fact that many subjects over the age of 45 years obtained a high Impairment Index characteristic of brain damage. These results indicate that besides the similar performance of many old subjects and of many brain-damaged subjects, age is an important variable in assessing the performance of older subjects on the Halstead Battery.

It is a well established fact that age affects the performance of different psychological tests differentially. However, generalizations are made difficult by the diversity of psychological tests, and differences in the composition of samples. It appears that tests requiring active problem-solving behaviour are more influenced by age than tests which require the recall of stored information (Heston & Cannell, 1941; Jones, 1959; Willoughby, 1927). Also, the related aspect of complexity of response required of the subject has been shown to be a relevant variable (Welford, 1959). Reitan (1963a) decided to study these dimensions with respect to the Halstead Battery. Twenty tests which included the tests from the Halstead neuropsychological Battery and 11 subtests of the Wechsler-Bellevue Intelligence Scale, Form 1, were rated by three judges. The judges were instructed to order the tests on the dimension of immediate adaptive intelligence vs. stored memory. The raters were also instructed to consider the dimension of complexity of response. The prediction that the performance of young subjects would exceed that of the old subjects to a relatively greater degree on those tests which required immediate adaptive intelligence was supported. The young and old groups were most clearly separated by those measures which previous research had demonstrated to be most sensitive in differentiating patients with diffuse or heterogeneous brain lesions from non-damaged control subjects. Reitan concludes that "The results of the present investigation add support to the possibility that age-associated changes in abilities may be conceived in terms of the adequacy of brain functioning (p. 273)."

Later, Reed and Reitan (1963b) conducted a further study with the Halstead Battery "concerned with the possibility of attributing part of the age-associated decrements in psychological test performance to change in brain functioning (p. 177)." Forty young non-brain-damaged subjects were matched in pairs with 40 brain damaged subjects on the variables of age, education, sex, and race. The Halstead Battery tests were then ranked according to the success with which each test discriminated between the brain-damaged and the non-brain-damaged subjects. The tests were then given to a group of normal middle-aged subjects (age 40-49) and to a group of older normal subjects (age 50-59). This time the tests were ranked according to the relative sensitivity of the tests to the differences associated with aging. There was a significant relationship (rho = 0.49) between the two rank order distributions, "suggesting that differences in test performances associated with aging may partially be explained on the basis of changes in the organic condition of the brain (p. 179)."

However intuitively appealing as Reitan's reasoning may be, two major criticisms can be levelled at his methods and his conclusions. Reitan arrives at his conclusions through indirect means, since inferences about the influence of independent variables in human studies are almost exclusively limited to those derived from statistical analysis. Reitan uses essentially circular reasoning to arrive at his conclusions. His reasoning is that if a test is sensitive to brain damage and then is found to be sensitive to normal aging, then the explanation given why the test is sensitive to brain damage is the same explanation why the test is sensitive to normal aging. The possible fallacy of his reasoning is illustrated by the following analogy: Suppose an instrument is devised which can differentiate between dead leaves and leaves which are alive. The explanation given for this behaviour is that the instrument is photosynthesis-sensitive. Then it is found that this instrument also differentiates between green paint and brown paint. It is evident that it would be fallacious to argue that the green paint has photosynthesizing properties. In this case, the instrument probably is sensitive to quite a different differentiating property, just as the Halstead Battery may be sensitive to normal aging for reasons other than the one supplied by Reitan. In this case, causal inferences should be attenuated by other possible considerations for the observed behaviour. In Reitan's 1955 study and 1963a study, the quantitative similarity of the performance of aged and brain damaged subjects are established. In his 1963b study, he attempts to show that there is a qualitative similarity also. He found that the rank order correlation coefficient between the tests ranked according to their sensitivity to brain damage and the tests ranked according to their sensitivity to aging was significant. However, with a rho of 0.49, only one-fourth of the variance in the rank order distribution of the tests of the older subjects can be explained in this way.

There is evidence from another study (Schludermann, 1966) on the question of qualitative similarity between the performance of brain damaged subjects and normal old subjects. Schludermann found that the tests which were most sensitive in separating brain-damaged and non-brain-damaged subjects were not the same tests which were most sensitive in separating old from young subjects. He concludes that "The changes following frontal brain damage do not simulate in detail psychological changes following normal aging." He interprets these findings as supporting the multiple process view of mental deterioration which holds that the decline in psychological functions associated with aging involves an essentially different process from the decline in psychological functions resulting from brain damage. However, since there is the possibility that Schludermann's control group (healthy managerial executives) was above average in ability, there is the question of whether his results are representative of human aging in general.

Another criticism of Reitan's work concerns the adequacy of his control groups. In his 1955 study, he used both paraplegics and subjects with personality disturbances for his "normal" control group. In both the 1963 studies, hospitalized subjects with unspecified medical and psychiatric complaints were used as control subjects. In the present research, only healthy subjects with no medical or psychiatric complaints requiring hospitalization are used in comprising the normal group. Thus the effects of age should not be confounded by any possible temporary biological or motivational condition.

Also, Reitan attempts to make comparisons between individuals who are comparable in ability level by selecting subjects who have the same number of years of formal education. However, the change in educational opportunities is an important secular variable. Whereas the average educational level for persons now 65 years and over is about the equivalent of the seventh grade, that of the 21 to 31 year old population is at the eleventh grade level. Thus, the amount of education of old people living today is not a reliable indicator of the person's ability. Not only has the amount of education changed, but also the quality of education has been improved, so that studies which use young and old groups comparable in years of formal education do not provide the most adequate control of this secular variable. Since I.Q. is a more reliable indicator of ability than educational level, comparisons in the present research were carried out between groups comparable in this respect.

By making comparisons between old and young groups of different ability levels, a question of considerable theoretical importance can be examined - that is, whether there are differential effects of aging in different ability groups. This question has been examined in several ways. Bromley (1966) poses the logical argument that "if the range of individual differences increase with age, if the mean score on tests is steadily reduced, and if each person maintains his position relative to other people in his age group, then it follows that the rate of intellectual decline must be faster for the initially less able (p. 243)." Since there is evidence for each of the above assumptions, he feels that the conclusion is a reasonable one.

Using another approach to the problem, Vernon (1947-48) compared cross-sectional age differences in the performance of the Progressive Matrices Test for different occupational levels. The Progressive Matrices Test (Raven, 1948) is a non-verbal test requiring logical reasoning by analogy and therefore is relatively independent of language and of specific acquired knowledge. He found that the age-associated decline in the Progressive Matrices Test was related to occupational level and that this decline was greatest at the lowest occupational levels. He found that high scores remained relatively constant up to 25-30 years. These results are in close agreement with similar occupation studies by Gilbert (1941) and Sorenson(1933, 1938).

Owens (1956) attempted to answer the related question of whether age is kinder to the initially more able by means of a longitudinal study. One hundred and twenty seven males who took the Army Alpha Test as a college entrance examination in 1919 were retested 31 years later. He found no relationship between initial ability and subsequent test scores. However, it can be argued that Owens' group was too homogeneous to reveal differential effects, since all were prospective college students. Also, the study investigates age changes only until the relatively young age of 50 years. It is possible that if the restricted range of both dependent and independent variables was increased, the results would be more in line with the cross-sectional studies.

Where a relationship between ability level and age changes are found, the disuse theory is used to explain the results. This theory holds that persons with high levels of mental ability enjoy and practice mental functions more than those who are less proficient. This theory, then, would apply to tests where it is possible for the subject to utilize overlearning such as in tests of vocabulary or general information. Although a cogent argument can be made for the novelty of the tests in the Halstead Battery, Reitan has ranked the tests according to whether they depend on a relatively greater amount of stored memory than immediate adaptive ability. Using Reitan's ranking of the tests, the prediction is made that high ability subjects will be relatively more proficient on those tests which require stored memory; on those tests requiring immediate adaptive ability, intelligence level will not interact with the effects of age.

There is one theory, the theory of differentiation which attempts to account for the change in intelligence with age. This theory was developed by Garrett (1946) and Burt (1954), and was later extended by Lienert and Crott (1964) to explain the changes in intelligence in adults. According to this theory, intellectual development in the early years involves a process of differentiation of intelligence from a fairly unified and general ability to a loosely organized group of abilities or factors. The theory of differentiation is supported by studies on children (Balinsky, 1941; Burt, 1954; Garrett, 1946) where it was shown that increasing age is accompanied by a decrease in average test intercorrelations, by an increase in the total number of factors, and by a decrease in the contribution of the first centroid factor which is interpreted as the general factor or g of intelligence. In testing whether the theory of differentiation explained adult test performance, Lienert and Crott (1964) found that, contrary to the early developmental trend to differentiation in the factor structure of intelligence from childhood to adolescence, the trend was toward integration from adolescence to old age. There was an increase in test intercorrelations and a decrease in the number of factors. Since the theory of differentiation adequately describes only the first part or ascending portion of the age curve of intelligence, Lienert and Crott proposed the differentiation-integration hypothesis to account for the entire curve.

The Halstead Battery, because of its sensitivity to the biological condition of the brain, is often called a test of biological intelligence (Halstead, 1951). If integration of the factor structure of intelligence occurs in adults with the Halstead Battery tests, then the tenability of the differentiation-integration hypothesis is greatly augmented, since confirming evidence would come from a different battery of psychological tests, and this would constitute evidence for the universality of this phenomena. The functional basis for an integration in factor structure would be that biological changes due to aging would increase the correlation between abilities, especially where the rate of aging is not the same for different individuals.

Therefore, by attempting to determine the relative roles of age and intelligence on performance of a group of neuropsychological tests, two questions of theoretical importance will be dealt with:

1. The divergence-convergence hypothesis: Does the factorial structure of adults on the Halstead Battery lend confirming support to this hypothesis? According to this hypothesis, aging would become an important source of variance in older subjects, producing an increase in average correlations and a simpler factor structure.
2. Is the course of aging the same in different ability groups? If the disuse theory holds where only a minimal amount of stored information can be utilized by the subject, the hypothesis is made that high ability subjects will do better than low ability subjects only on those tests requiring a relatively greater degree of stored memory than immediate adaptive ability.

By attempting to provide a more adequate sample of "normal" subjects and a more adequate control of the secular variable of educational opportunities, the present research also attempts to test the validity of some of Reitan's results:

1. To what extent is the Halstead Battery sensitive to differences in ability level?
2. Does the more adequate normal control group attenuate any of Reitan's results?

CHAPTER II

PROCEDURE

Experimental Design

Because of time limitations, the design of the present research utilizes the cross-sectional method, but attempts have been made to control for the possible biasing effects of secular changes by making comparisons only between groups which are comparable in ability. Since I.Q. is a more reliable indicator of ability than educational level (due to changes in the quality of and opportunities for education), comparisons in the present research were carried out between groups comparable in this respect.

Therefore, subjects were selected on the basis of two independent variables, age and I.Q., and were systematically tested on a battery of tests, the scores of which comprised the dependent variables.

Subject Selection

A concerted effort was made to ensure that there was adequate sampling of healthy normal young and old subjects who were comparable in I.Q. level. This necessitated the cooperation of several institutions.

Young and middle-aged volunteer subjects (female as well as male) were obtained from the working staff of the Winnipeg General Hospital, unemployment agencies, and the Pre-Vocational School. Older subjects were obtained from Senior Citizen's groups, the Age and Opportunity Day Centres, and from the Lion's Club Residence which is a low-rental apartment block for older citizens. All subjects were normal and healthy in the sense that they were not suffering from any physical or mental disorder requiring medical or psychiatric care. None of the old age subjects were suffereing from senility, the practical criterion being whether they could care for themselves. Table 1 indicates the detailed breakdown of the subjects in the different age and I.Q. groups. Table 2 indicates the final distribution used in the statistical analyses. A total of 129 subjects participated in the study. All subjects were residents of Winnipeg and were fluent in the English language.

As can be seen from Table 2, there is an adequate representation of subjects in the extremes of both I.Q. and adult age dimensions. Subjects in the I.Q. range of 80-99 will hereafter be called the low I.Q. group, subjects in the I.Q. range of 100-109 will be called the medium I.Q. group, and subjects in the I.Q. range of 110-132 will be called the high I.Q. group. Subjects in the age ranges of 15-29 years, 30-50 years, and 51-84 years will be respectively called the young, middle-aged, and old groups.

Test Battery

All subjects were tested on 8 indicators of the Halstead Battery supplemented by the Trail Making Test (Reitan, 1958). Since a detailed description of the tests has been given elsewhere (Halstead, 1947), only a brief description of the tests is given below.

The Category Test measures abstraction ability. It consists of a series of slides projected on a screen, along with an answer panel of

TABLE 1

DETAILED DISTRIBUTION OF SUBJECTS IN DIFFERENT

AGE AND I.Q. GROUPS

I.Q.		15-19	20-29	30-39	40-49	50-59	60-69	70-84
	80-89	4	1	2	1		1	
	90-99	12	11	3	1	3	1	9
I.Q.	100-109	5	8	14	3	4	4	14
	110-119	3	7	5	1	1	3	3
	120-132		3	1	2		1	2

AGE

TABLE 2

FINAL DISTRIBUTION USED IN ANALYSES

I.Q.		15-29	30-50	51-84
	80-89	14	9	10
I.Q.	100-109	13	12	22
	110-132	28	9	12

AGE

4 buttons. The subject is asked to press one of the buttons, numbered one to four, which is the same number as the number the pattern on the screen reminds him of. The principle is not stated, the subject being required to find the principle on the basis of trial-and-error, using knowledge as to which answers are correct (a chime sounds) and which are incorrect (a buzzer sounds). The principles involved are those such as "sameness", "differentness", and "numerosity". The score is based on the number of errors.

The Speech Sound Perception Test involves the presentation to the subject of 60 tape-recorded nonsense words with different consonants before and after the vowels "ee". The subject is required to identify the spoken nonsense word from among four written alternatives. The score on this test is based on the number of errors.

The Rhythm Test is derived from the Seashore Test of Musical Talent. The subject is required to determine whether thirty pairs of rhythmic beats are the same or different. The score is based on the number of errors.

The Tactual Performance Test is a modification of the Sequin-Goddard formboard. The blindfolded subject is required to place various shaped blocks into their matching spaces on an upright board as quickly as he can. The subject does this first using only his dominant hand, then using only his non-dominant hand, then using both his hands. Time scores based on the above three trials contribute to the total time required (TPT time). After removing the formboard and blocks, the blindfold is removed, and the subject is required to draw a picture of the form board, and is instructed to remember the shapes of the blocks as well as their position on the board. The number of shapes correctly remembered regardless of location comprises a TPT memory score. The number of correct figures correctly localized comprises the TPT localization score.

The Trail Making Test is composed of two parts. Part A consists of 25 consecutively numbered circles randomly scattered over an $8\frac{1}{2}$ x 11 in. page. The subject is required to connect these serially as quickly as possible. Part B also consists of 25 circles containing either numbers or letters. The subject is required to alternate between letters and numbers, taking each series in order. The score for both parts A and B is based on the time required to finish the task. Any errors are pointed out by the tester and since the subject must correct all mistakes, this increases his time score. Adding the time score on both parts contributes to a Trail Total score.

In the Finger Tapping Test, the subject is first asked to tap with his index finger of his dominant hand as quickly as he can for five trials of ten seconds each, then with his index finger of his non-dominant hand. The score for each hand is based on the average of the five trials.

Administration Procedure

Prior to testing, a short medical history was obtained from each subject in order to rule out the possibility of earlier neurological injury.

Before being tested on the Halstead Battery, all subjects were given the Wechsler Adult Intelligence Scale. The WAIS has age norms.

Even though there is a decline of absolute performance on WAIS subtests with age, the I.Q. of an individual is determined by comparing his performance only with the performance of his own age group. Consequently, psychological age changes do not result in lowered I.Q. scores; the mean of each age group is represented by an I.Q. of 100 and a standard deviation of 15 I.Q. points.

In administering the Halstead Battery, the different tests were given in a random order. Rather than presenting a fixed set of instructions, emphasis was placed on the subject understanding the instructions and the task he was about to perform. Complete test administration for one subject lasted approximately 3 hours.

At the end of the testing procedure, all subjects were paid $5.00 for participating in the study.

CHAPTER III

RESULTS

All of the raw data were transferred to IBM cards in order to make use of the computer facilities (IBM 360) in the data analyses. In the appropriate cases, the data for the factor analyses were transformed so that increasing scores in all of the tests of the battery were indicative of poorer performance.

Analyses of Variance

The first set of data analyses consisted of 10 3x3 analyses of variance to determine whether there were statistically significant age and I.Q. effects on each of the Halstead Battery indicators. The data were tabulated as in Table 2 where one dimension of the analysis comprised the age variable and the other the ability variable.

The following tests showed age and I.Q. effects significant at the .01 level of confidence: Category, Speech Perception, Rhythm, Trail A, Trail B, Trail Total, and TPT-Memory. The analysis of variance for TPT-Localization indicated that the variable of age produced effects significant at the .01 level, the variable of I.Q. produced effects significant at the .05 level. The Tapping tests (dominant hand and nondominant hand) showed age effects significant at the .01 level, but I.Q. did not produce significant effects.

Overlap Analysis

In order to determine to what degree the variable of age separated the score distributions of low intelligence and high intelligence groups, an overlap analysis was performed on the data. The optimal cut-off point was calculated by using the formula $C = \frac{\overline{X}_1\sigma_2 + \overline{X}_2\,\sigma_1}{\sigma_1 + \sigma_2}$

The deviation of the group means from the cut-off point was calculated by using the formula $\frac{\overline{X}_1 - C}{\sigma_1} = \frac{\overline{X}_2 - C}{\sigma_2}$ where $\overline{X}_1 + \overline{X}_2$ and $\sigma_1 + \sigma_2$ are the respective means and variances in the two groups. The degree of overlap was found by looking up the proportion of area under a normal probability curve beyond the given Z-score. Maximal overlap according to this measure is 50% and optimal separation is 0% overlap.

Tables 3 and 4 indicate the means, standard deviations, and overlap of respectively the low I.Q. and high I.Q. groups, as a function of age.

Although all of the tests show significant age effects, Table 3 indicates that some of the tests are more sensitive to age than others. The Category, Trail Total and TPT-Memory tests seem to be the most sensitive, since the degree of overlap between the young and old groups is least for these tests.

By comparing the overlap analyses for the low and high I.Q. groups (Tables 3 and 4), it is evident that the tests which are most sensitive to age in the low I.Q. group are not necessarily those which are most sensitive to age in the high ability group. For the high I.Q. group (Table 4), the test most sensitive to the variable of age is the Speech Perception test. Thus, depending on the I.Q. level, some tests show differential aging effects.

TABLE 3

MEANS, STANDARD DEVIATION, AND OVERLAP ANALYSIS

LOW I.Q. GROUP

TEST	YOUNG $\overline{X}$	YOUNG σ	OLD $\overline{X}$	OLD σ	% OVERLAP
Category	67.4	24.7	112.1	16.9	14%
Speech	7.36	4.8	17.1	7.7	22%
Rhythm	7.9	6.6	10.8	5.8	41%
Trail A	42.2	13.8	93.0	44.0	19%
Trail B	99.5	30.5	181.5	52.9	16%
Trail Total	141.7	36.0	274.5	86.2	14%
Tapping - dom.	46.4	10.0	26.6	12.1	18%
Tapping - nondom.	42.8	8.0	27.1	9.4	18%
TPT-Memory	7.3	1.6	2.50	1.4	14%
TPT-Local.	3.3	2.4	.6	.8	20%

TABLE 4

MEANS, STANDARD DEVIATIONS, AND OVERLAP ANALYSIS

HIGH I.Q. GROUP

TEST	YOUNG $\overline{X}$	YOUNG σ	OLD $\overline{X}$	OLD σ	% OVERLAP
Category	38.9	19.4	84.1	33.8	20%
Speech	3.7	1.7	8.6	5.4	12%
Rhythm	2.7	2.1	4.3	4.1	40%
Trail A	28.9	9.2	48.4	17.5	23%
Trail B	59.3	17.1	131.0	61.2	18%
Trail Total	88.1	23.0	180.5	77.3	18%
Tapping - dom.	48.0	8.3	36.1	10.6	26%
Tapping - nondom.	43.5	7.6	33.2	8.6	26%
TPT-Memory	7.8	1.2	5.3	2.1	22%
TPT-Local.	5.0	2.2	2.1	2.1	25%

Similarly, by means of overlap analysis, it was determined to what degree the variable of intelligence separated the score distributions of the young and old age groups. Tables 5 and 6 show the means, standard deviations and overlap analyses for respectively the young and old groups. For the young subjects, the test which evidences the least amount of overlap between the low and high I.Q. groups is the Trail Total test. The Tapping tests which failed to show significant I.Q. effects on the analysis of variance test show almost complete overlap of the two distributions.

For the old group (Table 6), the test most sensitive to intelligence is the TPT-Memory Test.

Interaction Effects

The overlap analysis has indicated that there may be possible differential age effects for different ability groups. Since this is a question of considerable theoretical relevance, it is important to examine whether the results obtained in the overlap analyses are statistically significant. In the previous analyses of variance, several F's for interaction approached significance. To bring out these possible interaction effects between young and old individuals and intelligence more clearly, the middle-aged groups were excluded from the analyses. The subsequent analyses of variance indicated that there were significant interaction effects at the .05 level in three of the Halstead Battery tests: Trail B, Speech Perception, and Tapping tests. Low ability subjects show a significantly greater decline due

TABLE 5

MEANS, STANDARD DEVIATIONS, AND OVERLAP ANALYSIS

YOUNG GROUP

TEST	LOW I.Q. $\overline{X}$	LOW I.Q. σ	HIGH I.Q. $\overline{X}$	HIGH I.Q. σ	% OVERLAP
Category	67.4	24.8	38.9	19.4	26%
Speech	7.4	4.8	3.7	1.7	29%
Rhythm	7.9	6.6	2.7	2.1	28%
Trail A	42.2	13.8	28.9	9.2	28%
Trail B	99.5	30.5	59.3	17.1	20%
Trail Total	141.7	36.0	88.1	23.0	19%
Tapping - dom.	46.4	10.0	48.0	8.3	47%
Tapping - nondom.	42.8	7.9	43.6	7.6	48%
TPT-Memory	7.3	1.6	7.8	1.2	43%
TPT-Local.	3.3	2.4	5.0	2.2	36%

TABLE 6

MEANS, STANDARD DEVIATIONS, AND OVERLAP ANALYSIS

OLD GROUP

TEST	LOW I.Q. $\overline{X}$	LOW I.Q. σ	HIGH I.Q. $\overline{X}$	HIGH I.Q. σ	% OVERLAP
Category	112.1	16.9	84.2	33.9	30%
Speech	17.1	7.7	8.6	5.4	27%
Rhythm	10.8	5.8	4.3	4.1	26%
Trail A	93.0	44.0	48.4	17.5	23%
Trail B	181.5	52.9	131.0	61.2	33%
Trail Total	274.5	86.2	180.5	77.3	28%
Tapping - dom.	26.6	12.1	36.2	10.6	34%
Tapping - nondom.	27.0	9.4	33.2	8.6	41%
TPT-Memory	2.5	1.4	5.3	2.1	21%
TPT-Local.	.6	.8	2.1	2.1	30%

to aging on these tests than do high ability subjects. This finding is graphically displayed in Figures 1-8, where the age curve of performance for the lower ability subjects is steeper than that for the high ability subjects on those tests in which significant interaction between age and I.Q. was found. Also from the graphs, the relative amount of age-related decline on the various tests can be assessed. The Speech Perception and Rhythm Tests show very little decline, whereas the Category and Trail B tests show a relatively large amount of decline.

Table 7 indicates the relationship between Reitan's ranking of the tests along the dimension of immediate adaptive ability vs. stored information and the results of the analyses of variance. Since several subtests of the Halstead Battery not used in the present study as well as all the subtests of the WAIS were ranked, only those subtests relevant to the present study are indicated in Table 7. This table indicates that, with one exception, the interaction between age and I.Q. corresponds to Reitan's ranking, i.e. on those tests ranked as requiring a relatively larger degree of background experience than immediate adaptive ability, the decline due to aging depends on the ability level, with high I.Q. subjects displaying a relatively smaller amount of decline due to aging than low ability subjects.

Factor Analysis

In order to determine what factors the variable of age is associated with in the young as compared to the old group, chronological age in years was included as a variable in the data matrix. Because of the unequal numbers in each of the ability groups, equal numbers of subjects were

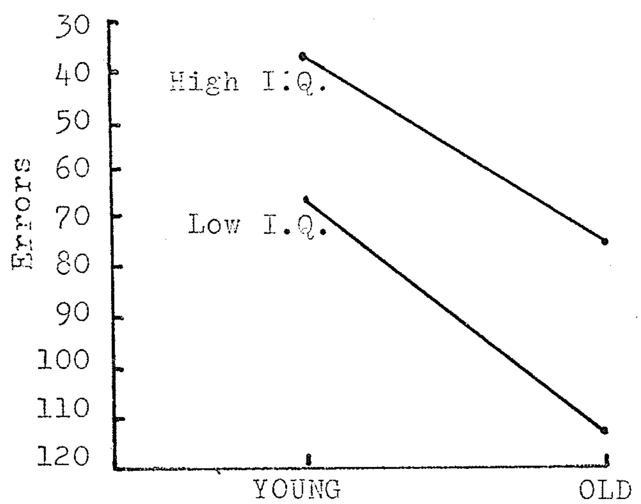

Fig.1. Decline of High and Low Ability Groups on the Category Test.

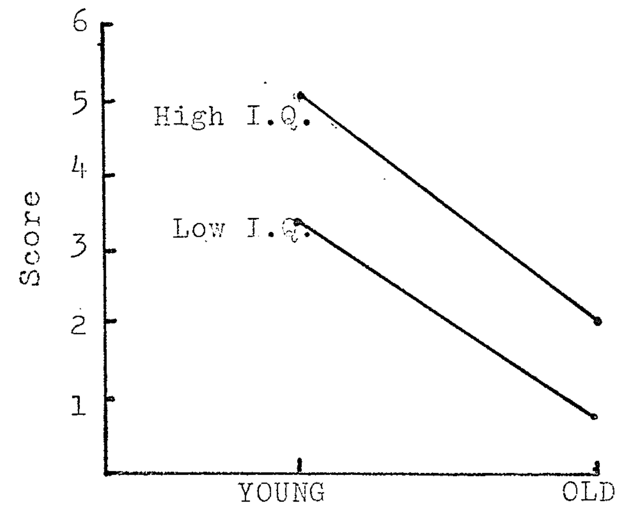

Fig.2. Decline of High and Low Ability Groups on the TPT-Loc. Test.

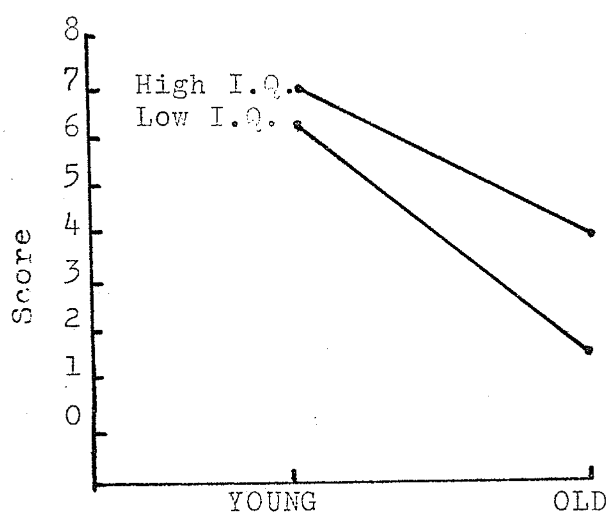

Fig.3. Decline of High and Low Ability Groups on the TPT-Mem. Test.

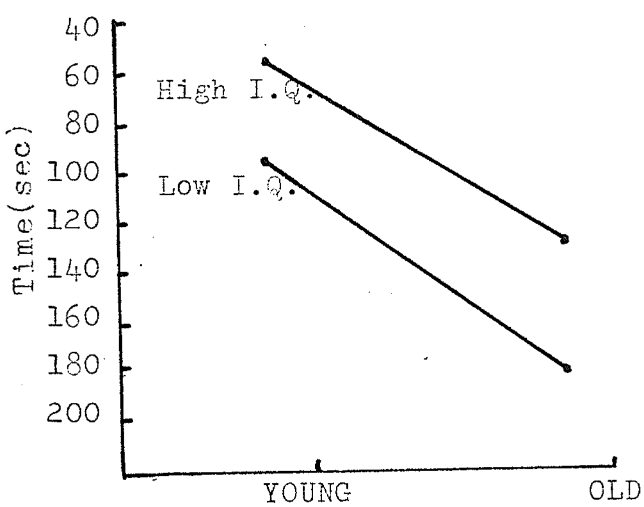

Fig.4. Decline of High and Low Ability Groups on the Trail B Test.

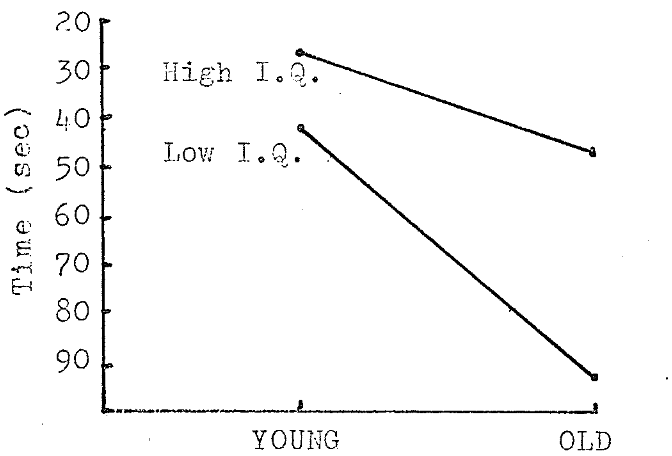

Fig. 5. Decline of High and Low Ability Groups the Trail A Test.

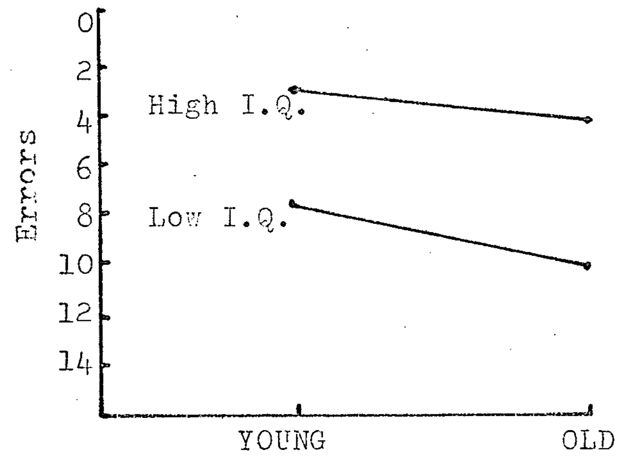

Fig. 6. Decline of High and Low Ability Groups on the Rhythm Test.

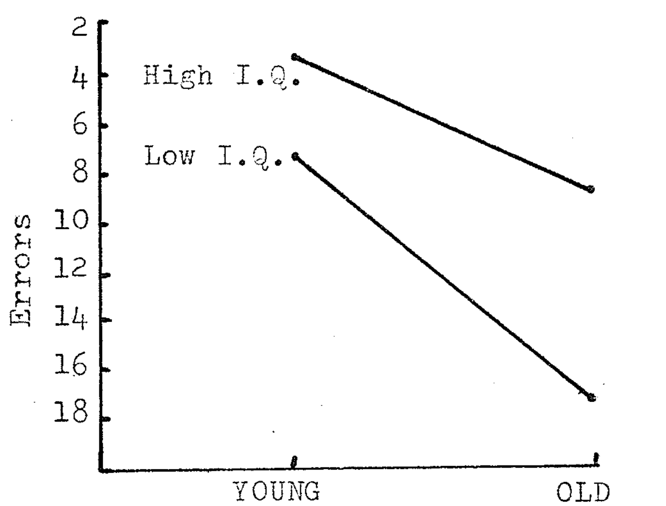

Fig. 7. Decline of High and Low Ability Groups on the Speech Test.

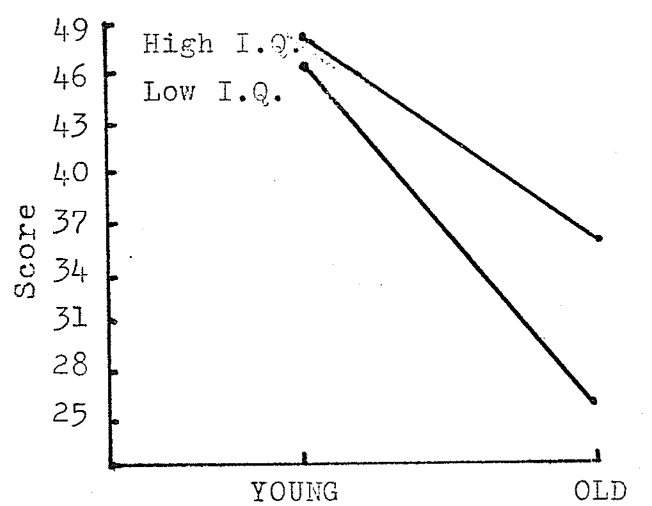

Fig. 8. Decline of High and Low Ability Groups on the Tapping Test.

TABLE 7

RELATIONSHIP BETWEEN REITAN'S RANKING OF TESTS

AND RESULTS OF ANALYSES OF VARIANCE

HALSTEADS RANKING	INTERACTION EFFECTS
Category	Not significant
TPT-Loc.	Not significant
TPT-Mem.	Not significant
Trail B	Not significant
Trail A	Significant
Rhythm	Not significant
Speech	Significant
Tapping	Significant

randomly selected from each ability group. This resulted in an N of 30 for each factor analysis.

Preliminary to the actual factor analysis, the correlation matrices were obtained. They are presented in Tables 8 and 9. The average absolute correlation in the young group was 0.242 whereas in the old group it was higher, 0.335. The test intercorrelations were then examined for statistical significance. Since a low correlation coefficient can reach statistical significance when N is large enough, differences of correlation coefficients from $r=0$ was examined using the formula $t = \frac{r\sqrt{N-2}}{\sqrt{1-r^2}}$ where t = 2.763, corresponding to the .01 level with N-2 df. In examining the correlation matrix of the young group (Table 8), it can be seen that there are only 9 tests of the Halstead Battery which correlate significantly with each other, suggesting that biological intelligence for young people consists of a large number of relatively independent abilities. Examining the correlation matrix of the old group (Table 9) the opposite seems to be true. Nineteen tests correlate significantly with other tests of the battery, and together with the higher absolute correlation coefficient, seems to suggest that biological intelligence in an older sample consists of abilities which are interdependent.

In comparing the correlational matrices of the young and old groups, it is evident that while many corresponding correlation coefficients in the comparison groups are similar in magnitude, other corresponding correlation coefficients differ to a seemingly large degree.

TABLE 8

CORRELATION MATRIX OF YOUNG GROUP

TESTS	Age	Category	Speech	Rhythm	Trail A	Trail B	Tapping - dom.	Tapping - nondom.	TPT - dom.	TPT - nondom.	TPT - both	TPT - Memory	TPT - Local.
Age	1.00												
Category	.49*	1.00											
Speech	.09	-.01	1.00										
Rhythm	.23	.22	.56*	1.00									
Trail A	.40	.59*	.03	.13	1.00								
Trail B	.33	.75*	.10	.20	.61*	1.00							
Tapping - dom.	-.20	-.26	-.27	-.40	-.04	-.10	1.00						
Tapping - nondom.	-.22	-.34	-.30	-.22	-.05	-.31	.75*	1.00					
TPT - dom.	-.04	.28	.23	-.08	.20	.25	-.06	-.07	1.00				
TPT - nondom.	.01	.14	.18	.33	.22	.28	.09	.15	.41	1.00			
TPT - both	.05	.32	.10	.30	.22	.28	-.29	-.26	.37	.71*	1.00		
TPT - Memory	-.18	-.30	.07	-.14	-.16	-.23	.27	.17	-.12	.10	-.17	1.00	
TPT - Local.	.60*	.46*	-.02	.21	.18	.17	-.26	-.15	.10	.10	.23	-.37	1.00

Average absolute correlation = 0.242

*significant difference of 5 from o evaluated by means of a t-test

If $r > .46$ $t > 2.76$ (.01 level)

TABLE 9

CORRELATION MATRIX OF OLD GROUP

TESTS	Age	Category	Speech	Rhythm	Trail A	Trail B	Tapping - dom.	Tapping - nondom.	TPT - dom.	TPT - nondom.	TPT - both	TPT - Memory	TPT - Local.
Age	1.00												
Category	.54*	1.00											
Speech	.31	.49*	1.00										
Rhythm	.32	.52*	.52*	1.00									
Trail A	.27	.45	.47*	.62*	1.00								
Trail B	.49*	.53	.29	.53*	.63*	1.00							
Tapping - dom.	.48*	.36	.34	.57*	.43	.44	1.00						
Tapping - nondom.	.30	.25	.31	.58*	.29	.37	.86*	1.00					
TPT - dom.	.04	-.26	-.26	-.17	-.37	-.18	-.06	-.01	1.00				
TPT - nondom.	.28	-.16	-.27	-.09	-.34	-.10	-.22	-.14	.65*	1.00			
TPT - both	.26	-.06	-.30	-.11	-.29	.05	-.27	-.27	.73*	.81*	1.00		
TPT - Memory	.24	.54*	.49*	.47	.41	.37	.29	.21	-.45	-.38	-.23	1.00	
TPT - Local.	.12	.41	.40	.35	.13	.29	-.07	.03	-.28	-.04	.01	.61*	1.00

Average absolute correlation = 0.335

*significant difference of 5 from o evaluated by means of a t-test

If r > .46 t > 2.76 (.01 level)

In order to test whether these differences were statistically significant, the following formula was used:

$$z = \frac{z r_1 - z r_2}{\sqrt{\frac{1}{N_1 - 3} + \frac{1}{N_2 - 3}}} \qquad \text{where} \qquad z_r = \tfrac{1}{2}\log_e \frac{1+r}{1-r}$$

A z-level of 2.58, corresponding to the 1% level of a two-tailed test, was used as the cut-off point. There were several significant differences in correlation coefficients between the two groups. The following correlations (presented in Table 10) differed significantly between the two groups: The correlations between Tapping-dom. tests and Age, and between Tapping-dom. and Rhythm tests; the correlations between Tapping-nondom. and Rhythm tests and between Tapping-nondom. and Trail B tests; the correlations between TPT-Memory and Category and TPT Memory and TPT-Local. It is significant to note that three of the changes in correlations involve that of a speeded motor test which in the young group is uncorrelated with other tests and which in the old group becomes significantly correlated with other tests. In all cases except one, the correlations changed from either a slight negative or negligible correlation in the young group to a significant positive correlation in the old group, i.e., where significant differences are observed, the change in intercorrelations with age is in the direction of increased positive correlations between test scores.

As the first step in the factor analysis, condensation of the variables was accomplished by the principal axes solution, using an eigen value of one as the criterion of when to stop factoring.

TABLE 10

SIGNIFICANT CHANGES IN CORRELATION COEFFICIENTS

BETWEEN YOUNG AND OLD GROUPS

TESTS	CORRELATION COEFFICIENTS YOUNG GROUP	OLD GROUP
Tapping - dom. + Age	-.20	.48
Tapping - dom. + Rhythm	-.40	.57
Tapping - nondom. + Rhythm	-.22	.58
Tapping - nondom. + Trail B	-.31	.37
TPT - Memory + Category	-.30	.54
TPT - Memory + TPT - Local.	-.37	.61

In the young group, the factor analysis resulted in 5 factors which explained 76.8% of the variance of the original data matrix. In the old group, the factor analysis resulted in 3 factors which explained 70.6% of the variance in the original data matrix. These percentages indicate that the obtained sets of factors efficiently explain the original variables, since only a small percentage of the original variance is unaccounted for. The principle axes solutions for the young and old groups are presented in Tables 11 and 12 respectively.

The final step in factor analysis involves the rotation of factors in order to obtain a more interpretable pattern of factor loadings. This was accomplished using the Varimax method. The rotated factor solutions for the two groups are presented in Tables 13 and 14.

Since the groups are comparatively small (N=30) for factor analysis, no attempt will be made to interpret the individual factors, rather emphasis will be focused on the general trends. For the young group, age enters as a significant variable in only 2 of the 5 factors. The other three factors are not related to age in the young group. In the old group, however, all three factors have significant loadings on age.

Also of theoretical importance is the difference in the number of factors in the two groups. Five factors are needed to explain Halstead Battery performance of the young group whereas only three are needed to explain the performance of the old group.

TABLE 11

PRINCIPAL AXES SOLUTION (UNROTATED) FOR

THE YOUNG GROUP

TEST	F1	F2	F3	F4	F5	Communality
Age	.571	.180	-.456	-.273	.322	.75
Category	.801	-.109	-.377	-.030	-.196	.83
Speech	.309	.257	.610	.467	-.044	.75
Rhythm	.512	.260	.447	-.411	.349	.82
Trail A	.596	-.341	-.334	-.324	-.210	.73
Trail B	.716	-.257	-.227	-.207	-.366	.81
Tapping - dom.	-.521	-.667	-.226	-.272	-.128	.86
Tapping - nondom.	-.523	-.616	-.137	-.194	.415	.88
TPT - dom.	.376	-.446	.278	.292	-.281	.58
TPT - nondom.	.419	-.628	.498	.036	.274	.89
TPT - both	.593	-.317	.454	.318	.094	.76
TPT - Memory	-.436	-.075	.191	-.486	-.233	.52
TPT - Local.	.561	.137	-.323	.190	.558	.78
Eigen Values						

TABLE 12

PRINCIPAL AXES SOLUTION (UNROTATED) FOR

THE OLD GROUP

TEST	F1	F2	F3	Communality
Age	.469	.630	.030	.62
Category	.725	.213	.300	.66
Speech	.693	-.033	.157	.51
Rhythm	.779	.245	-.062	.67
Trail A	.745	-.030	-.066	.56
Trail B	.683	.329	.050	.58
Tapping - dom.	.682	.237	-.614	.90
Tapping - nondom.	.599	.212	-.610	.78
TPT - dom.	-.489	.694	-.170	.75
TPT - nondom.	-.435	.791	.154	.84
TPT - both	-.406	.813	.298	.91
TPT-Memory	.714	-.140	.415	.70
TPT-Local.	.440	.007	.714	.70
Eigen Values	4.976	2.501	1.699	

TABLE 13

VARIMAX ROTATION OF YOUNG SUBJECTS

TEST	F1	F2	F3	F4	F5
Age	.492	.009	-.250	-.249	.615
Category	.799	.240	.159	.029	.336
Speech	.044	.241	.108	-.795	-.223
Rhythm	.065	.133	.121	-.853	.234
Trail A	.836	-.095	.112	-.059	.089
Trail B	.857	.141	.220	-.052	.039
Tapping - dom.	.017	-.856	-.055	.242	-.248
Tapping - nondom.	-.185	-.909	-.002	.143	-.042
TPT - dom.	.095	-.301	.830	-.308	.105
TPT - both	.099	.160	.812	-.178	.206
TPT-Memory	-.058	-.261	-.233	-.197	-.599
TPT-Local.	.163	.066	.045	.079	.864

TABLE 14

VARIMAX ROTATION OF OLD SUBJECTS

TEST	F1	F2	F3
Age	.508	.433	.415
Category	.343	.008	.737
Speech	.331	-.234	.585
Rhythm	.633	-.042	.518
Trail A	.516	-.287	.461
Trail B	.526	.087	.542
Tapping - dom.	.940	-.133	.054
Tapping - nondom.	.874	-.108	-.003
TPT - dom.	.046	.777	-.379
TPT - nondom.	-.102	.904	-.098
TPT - both	-.173	.940	.027
TPT-Memory	.132	-.296	.773
TPT-Local.	-.194	-.017	.816

CHAPTER IV

DISCUSSION

Differentiation-Integration Hypothesis

The present results are in agreement with the postulates of the differentiation-integration hypothesis. The average test intercorrelations for the old group are substantially higher than the average test intercorrelations for the young group. An increase in correlation between tests is also indicated by the fact that there are more than twice as many significant correlations among tests of the Halstead Battery in the older group. Along with the greater number of factors in the young group, this indicates that performance on the Halstead Battery for a young individual depends on several relatively independent abilities. However, for an older individual, an apparent reorganization towards greater integration takes place, and performance depends on a smaller number of abilities which are closely related.

Several factor analytic studies comparing young and old groups have been conducted on the WAIS subtests. In general the results support the findings of the present study. These studies have not been performed with the differentiation-integration hypothesis in mind, consequently there is no report of a possible change in intertest correlations. However, a decrease in the number of factors for older age groups has been reported by Maxwell (1961) and by Green, Russell and Berkowitz (1963). Cohen (1957) and Berger and Bernstein (1964) although reporting an equal number of factors in each age group, report a change in factor structure. On other intellectual tasks, it has been found that intercorrelations between tests in an old sample are quite high (Loranger & Misiak, 1960; Ross, Vincino, & Krugman, 1960).

Utilizing the results of the present study, it is possible to speculate on the nature of the change in intelligence structure. The more homogeneous factor structure in the old group is due to correlations between subtests which in the young group were negligible and which in the old group became positive and significant. Where the test intercorrelations on corresponding tests increased significantly between the young and old groups, in the three cases out of six, it involved that of speeded motor tests (the Tapping tests) becoming positively correlated with other more complex tests (Trail and Rhythm tests). In another case, performance on the Tapping tests in the old group became significantly correlated with chronological age. One of the most reliable facts known about human aging are the tendencies toward an increase in reaction time or psychomotor slowness (Birren, Riegel, & Morrison, 1962; Welford, 1959) - and since peripheral nerve function is not significantly altered with age (Birren & Wall, 1956), investigators have concluded that the increased latency in the performance of older people is the result of alterations in central mechanisms. Gerard (1959) points out that, although small alterations in function may not be too important in the performance of simple tasks, the effect will be augmented in complex tasks since performance depends on many subunits which must function efficiently together. Aging may change the functioning level of central processes which have negligible influence on behaviour in young individuals in such a way that these processes become important determinants in the behaviour of old individuals. Taking these considerations into account, the tendency towards an increase in reaction time in old people may be postulated to account not only for decreased efficiency in a simple psychomotor task, but also decreased efficiency in a complex task, where altered central functions associated with psychomotor slowing may be responsible for the failure of one of the many subunits making up the task. Central slowing, for example, may produce observable losses in performance of tasks where immediate memory is required (Rhythm, Trail tests), since information would be lost before it could be integrated and stored. It is also significant to note that the first factor in the old group has significant loadings on both the Tapping tests and the Trail and Rhythm tests.

Effects of Aging in Different Ability Groups

The results of the present research indicate that the effects of aging are different for different ability groups. It appears that high ability older subjects perform relatively more efficiently than low ability older subjects on those tests which depend on a greater amount of stored experience than immediate adaptive ability. Where immediate adaptive ability is needed, high ability subjects are not relatively better at performing the task. Reed and Reitan (1963b) found that the rankings of the tests along the dimension of immediate adaptive ability vs. stored information corresponded to the rankings of the tests according to their sensitivity to age. Taking this aspect into consideration, the present data suggest a certain functional equivalence between the performance of old subjects in general as compared to young subjects and the performance of low ability older subjects as compared to high ability older subjects. The effect of age on older people in general is to render them less proficient on tests requiring immediate adaptive ability; the effect of age on I.Q. is to render low ability subjects disproportionately less proficient on these tasks.

There is the possibility that the cognitive complexity of a task is important in determining the amount of decline due to aging (Welford, 1959; Birren et al., 1962). The importance of this aspect is demonstrated by the fact that Reitan (1963a) instructed the judges ranking the Halstead Battery tests along the stored memory vs. immediate adaptive ability dimension to also consider the complexity of the response required of the subject. However, the absence of an a priori ranking of the tests along this dimension discouraged data analysis to determine the role this variable played in the present research.

Reitan's Results

The Halstead Battery definitely is sensitive to the variable of ability level. All the tests except the tapping tests showed statistically significant I.Q. effects, indicating that ability level is a pertinent variable in evaluating the performance of individuals on the Halstead Battery. This information has practical significance with respect to the present norms for the Halstead Battery. The existing norms do not take into consideration either the age or ability level of the individual whose performance on the Halstead Battery is to be evaluated. In view of the present findings, testing of low I.Q. subjects or older subjects raises the distinct possibility of false positives.

The present findings also raise a question about the validity of some of Reitan's findings. In Reed and Reitan's 1963a study, a seemingly qualitative relationship was established between the effects of brain damage and the effects of aging. However, in view of the present finding that the Halstead Battery is very sensitive to differences in ability level, it is imperative that all groups were matched on this variable in order that the effects associated with ability level do not confound the effects associated with aging. However, Reitan's two groups which enabled him to rank the tests according to their sensitivity to aging were significantly different in terms of years of formal education completed. Although the number of years of formal education is not the best way of measuring ability level in a group of older subjects, it is very probable that if they differed significantly in years of formal education, that they would also differ in ability level. Therefore, there is the possibility that Reitan was measuring differences associated with ability as well as differences associated with aging.

Limitations of the Study and Suggestions for further Research

The results of the present study and those investigating the tenability of the differentiation-integration hypothesis seem to suggest that there is a correlation between the level of performance and the degree of differentiation of the factor structure of intelligence. The differentiation of the factor structure from childhood to adolescence corresponds to an increase in test performance whereas the integration of factor structure from adolescence to old age corresponds to a decrease in test performance. Is this change related intimately to the process of aging or is it independent of it? Or, would the factorial structure of the Halstead Battery for two groups of the same age but different ability levels show differences in the degree of differentiation? Unfortunately, due to the small N in the present study, the question of whether the factorial structure of different ability levels of the same age show different degrees of differentiation cannot be answered.

The above considerations of a possible factorial similarity between old subjects and low I.Q. subjects plus the seemingly functional equivalence between the performance of old subjects and low I.Q. subjects reported in this study, raises the question of the relationship between low I.Q. and old age. Further research might fruitfully concentrate on examining whether there are quantitative and qualitative similarities between the performance of aged subjects and the performance of low I.Q. subjects.

CHAPTER V

SUMMARY AND CONCLUSIONS

The primary purpose of this study was to investigate the relative roles of age and ability level on the performance of a group of neuropsychological tests called the Halstead Battery. The sensitivity of the Halstead Battery to age has been established by earlier studies, but little attention has been paid to its possible sensitivity to ability level either as a phenomena to be studied in its own right or as a variable which must be adequately controlled.

The design of the study also allows two questions of considerable theoretical importance to be examined. One question concerns the generality of the differentiation-integration hypothesis which states that the structure of intelligence undergoes a change with advancing age.

Another question investigated by the present study was whether there are differential aging effects in different ability groups, and whether these effects could be related to an a priori ranking of the tests along the dimension of stored memory vs. immediate adaptive ability.

One hundred and twenty-nine normal healthy subjects were selected on the basis of age and I.Q., and with the goal that there be adequate representation of subjects at the extremes of both adult age ranges and I.Q. ranges. On the basis of their age and I.Q. scores, they were placed into their respective age and ability groups (3x3 design), whose scores on the Halstead Battery were then submitted to analyses of variance in order to determine whether age and ability level produced significant effects. In order to determine whether the effects of aging were different for different ability groups, the middle-aged groups were excluded from the analyses, and it was determined whether there were significant interaction effects between age and I.Q. and on what tests this occurred. To answer the question of the tenability of the differentiation-integration hypothesis, correlational matrices and factor analyses for the young and old groups were compared. Overlap patterns were calculated in order to determine the relative sensitivity of each of the tests to age and ability level.

The results of the study provide evidence in favor of the following conclusions:

1) The Halstead Battery is very sensitive to both the effects of aging and the effects of ability level. These findings were discussed in relation to previous studies which did not adequately control for the latter variable and in relation to the need for revised norms for the Halstead Battery.
2) There is a change in factor structure of the Halstead Battery associated with aging and this change is in accordance with the postulates of the differentiation-integration hypothesis. The factor structure of intelligence appears to undergo an integration from a large number of relatively independent factors in a young individual to a smaller number of interdependent factors in an old individual.
3) The data reveal that there are differential effects of aging in different ability groups. High ability older subjects perform relatively better on those tests requiring a certain

degree of stored information. However, on tests requiring immediate adaptive ability, the performance of both high and low ability older subjects is not relatively different.

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