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INTELLECTUAL FUNCTIONING: THE NATURE AND PATTERN OF CHANGE WITH AGING

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# INTELLECTUAL FUNCTIONING: THE NATURE AND PATTERN OF CHANGE WITH AGING

by

Loren Henry Meyerink

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A Dissertation Submitted to the Faculty of the

DEPARTMENT OF PSYCHOLOGY

In Partial Fulfillment of the Requirements
For the Degree of

DOCTOR OF PHILOSOPHY

In the Graduate College

THE UNIVERSITY OF ARIZONA

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THE UNIVERSITY OF ARIZONA
GRADUATE COLLEGE

As members of the Final Examination Committee, we certify that we have read the dissertation prepared by Loren H. Meyerink

entitled INTELLECTUAL FUNCTIONING: THE NATURE AND PATTERN OF CHANGE WITH AGING

and recommend that it be accepted as fulfilling the dissertation requirement for the Degree of Doctor of Philosophy.

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| Ronald H. Pool | Date 2-17-82 |
| Robert Lansing | Date 2-17-82 |

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TABLE OF CONTENTS

## LIST OF TABLES

LIST OF ILLUSTRATIONS

ABSTRACT

We know very little about the intellectual functioning of the elderly. In the past, IQ normative data has been gathered using simple cross-sectional designs but these designs confound aging and generational effects, leaving interpretation unclear. Longitudinal studies have also been done, but the results can't be generalized because practice and sample bias effects are confounded with aging effects. In addition, nearly all the research to date either uses a very restricted age range or uses a limited number of measures, many of which have not been adequately validated with respect to predicting functional ability.

The present set of studies used tests from the Halstead-Reitan Neuropsychological Battery for Adults. The tests were organized into measures most sensitive to retention of prior learning, sensory input, motor output, language processes, visuo-spatial processes, abstract reasoning, and a combined measure of central processing. These measures allowed accurate characterization of a broad range of brain-related functions both across groups and within single individiuals.

This research was divided into two related studies. The first study measured the performance of 125

neurologically normal subjects divided into 5 equal sized age groups (20-29, 30-39, 40-49, 50-59, 60-70). The second study used 3 groups (a young neurologically normal group, an older neurologically normal group, and a young brain-damaged group).

Results of the present investigation showed that: (1) Retention of prior learning did not change across age groups. (2) Sensory input functions deteriorated with age, but the actual amount of change was modest and limited to measures using complex stimuli. (3) Simple motor output ability showed no significant change with age, but complex motor performance did deteriorate substantially. (4) Language processing ability decreased significantly with age, but the actual amount of change was small. (5) Complex visuo-spatial ability deteriotated substantially with age, and a particular decrement took place for those in their 60s. (6) Marked deterioration of abstraction ability took place with increasing age, and again those in their 60s showed a particularly large decrement of performance.

## CHAPTER 1

## INTRODUCTION

America is in the midst of a transformation which may have as profound an effect on all of us as any of the major changes of recent years. We have had the dawning of the "space age," the "computer age," the "urbanization of America," and numerous other technological and social transitions within our lifetimes. However, the change the media has dubbed the "graying of America" may cause as great a social and political upheaval as any of these developments.

The Congressional Quarterly's Weekly Report (1981) gives figures that show just how the age balance in our population has shifted and is continuing to shift. In 1900 there were only 3 million people 65 and older (4 percent of the population), now there are 25 million (11 percent of the population), and in 50 years it is estimated there will be 55 million; close to 1 out of every 5 persons will be 65 or older.

The picture is even more striking if one considers the 70 plus age group. In fact, this is the fastest growing age group in America. There were barely a million people 70 or over in 1900. Now there are 9.5 million, and by 2030 there will be an estimated 25 million (10 percent of the total population)!

The ramifications of this "graying of America" could be staggering. Already our economy is feeling the effect. Social security, which was established to build up a large fund to help provide for a secure and comfortable retirement for everyone, is facing serious financial pressures. The fact that people are retiring at the same age while living longer means they are drawing on the funds for an extended period. This is largely the cause of the social security dilema (charges of bureaucratic bungling notwithstanding). Social security funding, however, is merely the tip of the iceberg. Medical costs in general continue to soar, and the cost of medical care for the elderly is assuming gigantic proportions. Added to this is the fact that 25 percent of the 25 million older Americans require full-time care in nursing homes, placing an enormous drain on the economy.

The effect of the "graying of America" could be reduced or possibly even negated entirely if people were to continue working and functioning in proportion to the increasing life span. There have been efforts directed toward this end--the age of mandatory retirement has been raised or even eliminated entirely in many sectors of society. For this to work, however, people must continue to function normally in their 60s and 70s. If people can function productively at advanced ages, then the shift in population age presents only minor difficulties and possibly even major advantages. The education and training phase could be extended, with workers better equipped to confront the social and technological complexities of life. The productive working phase might also be extended by encouraging people to retire later than they are now doing. The extended lifespan would still allow the average person a comfortable retirement in which to enjoy the added years.

Given the fact of the changing population age ratios, either situation discussed above could be what the future holds. The ever-increasing burden on society may reach intolerable limits, or the extension of all phases of people's lives may have definite benefits. Which will it be?

"Conventional wisdom" holds two conflicting views of the elderly. One viewpoint sees people as increasing in intellectual power and wisdom throughout life. The corporation head or the wise old statesman are examples of this view. Another, equally prevalent view is that of the confused, faltering oldsters who are considered to be having a good day when they can remember their children's names. Which of these is true? If both are true, why do some elderly fit one conception and others just the opposite view? Do all people decline intellectually with age? Do some decline while others increase in competence? Does everyone continue to learn and improve until they suffer some neurologically devastating disease? What really does happen to people's intellectual powers as they pass through their adult years? The answers to these and related questions need to be answered. With the population age trends now in operation, the need for the information is not merely necessary, it is urgent! A whole new specialty area called Gerontology has emerged to address these questions. Research into the medical, physiological, and intellectual changes associated with aging has increased dramatically in the last few years. Neither the literature to date nor the present studies can give answeres to all the questions posed above or even complete answers to any one of them. The present work, however, does provide another step in the accumulation of knowledge in gerontological research and its meaning for society. Only a superficial review of the literature in these areas is within the scope of this paper, but some discussion of prior work is in order.

## Medical Risk

Epidemiological studies indicate that the incidence of quite a number of diseases related to functional ability increases with age. For example, about 33 percent of all persons over 65 have hypertension even after treatment, and the incidence is linearly correlated with age. Only 21 percent of those in the 45 to 49 age range exhibit hypertension compared to 67 percent of those age 75 to 79 (Kannel and Gordon 1980). This is particularly important since hypertension is one of the major factors associated with cardiovascular disease. When coronary heart disease, cerebrovascular accident, peripheral arterial disease, and congestive heart failure are lumped together under the heading of cardiovascular disease, the relationship is again a linear increase with age (Kannel and Gordon, 1980).

The present investigation is not directly concerned with deteriorating physical health, but the trend is noted briefly because it is one of many factors which could affect intellectual functioning.

## Physiological Changes With Age

Considerable attention has been given recently to measuring the changes in the central nervous system (CNS) neurobiology that are related to aging. This work is often quite difficult to perform and sometimes even harder to interpret, especially in human beings. For instance, it is relatively easy to perform neuron counts and measure gross neurotransmitter levels, etc. in animals, but it is a much harder task to obtain suitable biopsy and necropsy specimens from human beings of varying ages. This makes it very difficult to assess biological aging in human beings. Nevertheless, some findings seem fairly clear.

One of the earliest human aging effects noted by researchers was a systematic decline in brain weight and volume among older adults. This decline was apparent even in patients who showed no neurological or obvious psychological pathology before death. Although individuals varied widely, the mean brain weight and volume was maximal for those who died in their 30s and declined uniformly in each advancing age group thereafter (Bondareff, 1959). The average decline from patients aged 25 to those in their 90s was 11 to 17 percent for brain weight and about 10 percent for volume (Appel and Appel, 1942, Hoff and Sietelberger, 1957). It is interestng to note that this decrease is about half that reported in cases of Alzheimer's presenile dementia (Morel and Wildi, 1952). When the atrophy is visible in patients without known pathology, it is most likely to be noted primarily in the frontal lobes, while in Alzheimers disease it is much more extensive and involves the temporal and parietal lobes as well (Grinker and Bucy, 1949). A more recent study (Barrow, Jacobs, and Kinkel, 1976) using computerized tomography supports the earlier work by reporting a systematic age decrement in the thickness of the cerebral cortical mantle and an increase in ventricular volume in normal living humans. Himwich (1958), attempting to account for the decrease in brain weight in apparently normal aged concluded that brain protiens and lipids constituted the major losses.

As there are demonstrable age-related changes in the gross anatomy of the brain, there are microscopic changes also. CNS neurons are lost by all aging animals including man. The evidence indicates that not all areas of the CNS lose neurons at the same rate, and in some areas no loses are apparent at all. Critchley (1942) noted age-related loses in the number of pyramidal cells in the human cerebral cortex. He found the losses generally to be most marked in the frontal cortex with lesser effects in the basal ganglia, thalamus, cerebellum, and brain stem. Brody (1955, 1973) also reported the greatest neuronal decreases in the superior frontal and superior temporal gyri, moderate loses in the inferior temporal gyrus and precentral gyrus, and no change in the post central gyrus. There can be little doubt that age-related neuronal losses do occur, but the pattern and extent of the loss is not yet clear. A whittling away of the neuronal dendritic tree also appears to be characteristic of aged humans and animals (Schiebel, Lindsay, Komiyasu, and Schiebel, 1975). Bondareff (1980) suggests that the density of dendritic spines is reflective of an organism's functional capacity. In animals an "enriched environment" leads to both increased branching of higher-order dendrites and a higher number of dendritic spines. No one has devised a way of obtaining these measurements in humans, but it is likely true for them also. No systematic study has been done relating the number of dendritic spines or branches to specific age groups, but it is known that substantial reductions occur in both senescent animals and humans (Scheibel et al., 1976).

Brain catacholamine levels, as well as the uptake of dopamine, decreases in animals as they age (Jonec and Finch, 1975). Similar findings have not been reported in humans, but this seems to be due to difficulty in finding a suitable way to perform the studies rather than the occurrence of negative results. The same situation holds for investigating the CNS extra-cellular space. Aging rodents show a dendritic volume decrease and a corresonding 45 percent increase in astrocytic (non-neuronal) cell processes, which appear to be primarily space filling (Geinisman, Bondareff, and Dodge, 1978b). Researchers have been unable to determine if these changes occur in humans, but the age decrements are quite systematic in rodents.

The reader is referred to Bondareff (1980, pp. 90-94) where an excellent table listing anatomical and physiological age changes can be found.

Electrophysiological research also shows age-related changes in the dominant, ongoing electrical rhythms of the brain. Davis (1941) and Obrist (1954) noted a marked shift of overall electroencephalographic (EEG) activity toward the slower end of the spectrum. The shift included particularly a marked slowing of the alpha (8-12 cps) rhythm even in most neurologically normal adults 60 or older when compared to those in their early adulthood. Other researchers (Luce and Rothschild, 1953; Obrist and Henry, 1958) have found the same pattern (only more pronounced) in patients diagnosed as having generalized cerebral degenerative disease.

More recently researchers have found age-related changes in another kind of EEG measure--the charcteristic electrical potentials in the brain that accompany specific sensory and behavioral events. Smith, Thompson, and Michalewski (1980) reviewed a large number of studies which showed evidence that there is an age-related slowing of EEG recovery from one discrete sensory event to the next, meaning that rapid sensory input cannot be handled as well by the elderly as the young person. This finding also permits the prediction that information processing in general is less efficient.

The exact relationship between these structural, neurochemical, and electrophysiological age changes and behavior is still unknown, but many or all of them may reflect debilitating effects. In all cases, more severe deterioration is associated with the more severe behavioral deficits seen in degenerative cerebral diseases and cerebrovascular disease. Surwill (1962) found a .72 correlation between alpha rhythm slowing and increasing reaction time latencies in the elderly. Although the evidence linking event-related EEG age changes to decreased performance ability is still not absolute, the majority of evidence supports the view that such a relationship exists.

## Intellectual Correlates of Age

At first glance the intellectual correlates of age would seem to be much simpler to evaluate than neurobiological changes; measures are non-intrusive, they can be given repeatedly, no sophisticated equipment is needed for most, and there is an abundance of measurement devices. The task is not without complications, however. First and perhaps most troublesome of all are the emotional aspects of the issue. Most older people will agree they can't run as fast or they are not as strong as they used to be (or even that they have developed wrinkles), but very few are willing to say they have lost any intellectual competence. Researchers can also very easily fall into the trap of "defending" the elderly by only looking for evidence of preserved ability, failing entirely to investigate possible deterioration of function. Perhaps, more than most, the issue of intellectual loss in aging calls for research conducted in an objective manner. The time for compassion is in the social application of the facts, not when gathering and interpreting data.

Results of research into intellectual correlates of aging fall into two groups--those which show moderate to severe decline in function, and those which find no loss of function or even improved performance as people progress into their fifth, sixth, and even seventh decades of life. Early studies by Doppelt and Wallace (1955) and Weschler (1944, 1958) noted a progressive decline in IQ raw scores starting in early adulthood and continuing throughout life. Bayley and Oden (1955), Owens (1953, 1966) and Terman and Oden (1963), on the other hand, all consistently found increasing mean IQ scores at least up to age 50. Rhudick and Gordon (1973) noted little change in Wechsler Adult Intelligence Scale (WAIS) scores when people were tested and then retested at a later age (average test-retest interval is equal to 4 years). The subjects they used ranged in age from 55 to 90. Scores of 40 of the subjects declined while 43 improved. Blum, Clark, and Jarvik (1973) found declining scores on Wechsler Bellvue (W-B) vocabulary, similarities and digit symbol substitution subtests and on a tapping test with increasing age. They also noticed that marked decline on the three W-B subtests was often associated with a subject's impending death. In fact, the W-B scores predicted mortality within the next 5 years better than a subject's chronological age.

Reviewing results obtained with a variety of tests, Jarvik (1973) found remarkable stability of verbal language ability over time but a progressive decline of motor performance on timed tasks. Along similar lines, Granick and Friedman (1967) reported an age-related decline in broad areas of function involving "sensory efficiency, psychomotor speed, perceptual flexibility, and abstract thinking." They used 33 different tests and found that scores declined on 27 of these. Suspecting that education might be a confounding factor, they examined the scores again and reported a significant negative correlation between performance decline and educational attainment. However, with the education factor controlled, significant decline still appeared in 19 of the 33 tasks.

Taking a somewhat different tack, Welford (1959) compared psychomotor performance in younger (under 40) and older (over 40) subjects. Reviewing a number of studies, including his own, he noted moderately impaired efficiency in the older group on tasks involving both sensory input and motor output, but the major limiting factor on sensorimotor tasks was speed and accuracy of central processing.

That is, peripheral sensory or motor losses could account for only part of the decrements in sensorimotor performance. He concluded that:

> These central mechanisms may be conceived of as having a finite capacity in the sense that there is a maximum amount that can be done at any one time and in any given period of time. Compensation can to some extent be made for loss of capacity by taking a longer time, and this appears to be a major cause of slowness of performance among older people.

Birren, in a number of publications (Birren 1955, 1974; Birren and Botwinick, 1955; Birren, Riegal, and Morrison, 1962; Birren and Schaie, 1977; Birren and Wall, 1956; Birren and Williams, 1980) explored a variety of performance measures and came to a similar conclusion. On the average there are decrements in speed of performance on all kinds of tasks with advancing age. He also noted that these speed decrements might reflect deterioration in the organic integrity of older people's nervous system, including particularly the brain.

Reitan, (Boll and Reitan, 1973; Reed and Reitan, 1962, 1963a, 1963b; Reitan, 1954, 1955, 1956, 1957, 1962, 1967, 1970), using a battery of tests designed specifically to be sensitive to cerebral cortical dysfunction, found deficits in performance related to age in both normal control subjects and in patients with known brain lesions. These same subjects showed relatively little decrease in performance on tests sensitive to educational attainment or past learning.

It is necessary to take a closer look at the studies cited to understand the discrepant and sometimes contradictory results reported. These apparent conflicting results can be traced in large part to the different methodologies used.

## Methodological Issues

Methodology is necessarily related to the underlying purpose of research efforts. Some research in aging is directed towards measuring the population as it exists at the present time, and some is aimed at elucidating the basic nature of the aging process. Methodology designed for one of these aims may be imperfect for the other. For example, the studies cited in the medical risk review were designed primarily to characterize the present population, and while they may provide data useful in the study of aging processes, they were not designed specifically for that purpose. On the other hand, the neurobiology research was directed toward establishing the basic mechanisms of the aging process and tells us very little about how this might apply to the present or future populations. Research into the relationships of age and intellectual functioning has tried to answer both kinds of questions, often at the same time. This can cause real confusion, especially if the researcher fails to recognize that the two goals are not the same and does not spell out which goal he is attempting to achieve.

Two studies, one by Doppelt and Wallace (1955) and the other by Rhudick and Gordon (1973) are briefly reviewed here as examples of the two kinds of investigation. The former study is aimed at providing information about the present population and the latter about the aging process.

Doppelt and Wallace describe the procedures and findings of a special study of 475 people over 60 years of age who were tested with the WAIS. This testing was done as part of the standardization of the WAIS for those aged 16 to 75. Subjects were taken from the Kansas City metropolitan area because it was judged to be representative of America in many respects--culturally, geographically, economically, and socially. A probability sample of the metropolitan area was selected first. A stratified, systematic sample was then drawn with attention given to making it as representative as possible. Once the subjects were selected, a determined effort was made to complete testing with every one of them. Only those actually too ill or infirmed to participate and those not speaking English were excluded. Testing was done in the home or at easily available (for subjects) community locations by trained and experienced administrators. Quite a number of the subjects were initially reluctant to participate but were contacted repeatedly until they understood the purposes of the study. Only a relatively few of the subjects originally contacted were not tested by completion of the project. Subjects were tested only once. A distribution is reported for each subtest as well as for the summary scores for each age group.

Rhudick and Gordon, on the other hand, performed a study aimed at determining within subject age changes. They used only 86 subjects--the subjects were selected because they were already participants in the Age Center of New England project. All subjects lived at home in metropolitan Boston, were healthy, and were managing well. Subjects consisted primarily of white-collar and semiprofessional workers. Only subjects who had completed the WAIS twice and had also taken the Minnesota Multiphasic Personality Inventory, the Cornell Medical Index, the Leary Interpersonal Checklist, and a Current History Questionnaire were included. The amount and direction of change in WAIS summary scores from first testing to second (mean test-retest is equal to 4 years) was considered to be representative of the aging process.

Subject Selection. Subject selection procedures for normative research by Wechsler and by Doppelt and Wallace tended to be different from those of later investigators such as Rhudick and Gorden, Terman and Oden, and others. For example, Doppelt and Wallace generated a stratified sample list of subjects and then made an extremely determined effort to persuade all those on the list to participate in the research. Rhudick and Gordon, in contrast, solicited volunteers from an ongoing community project to act as their subjects. It is quite likely that Rhudick and Gordon's self-selecting subject groups were markedly biased towards the most highly-functioning elderly persons. This could also be true for Doppelt and Wallace. They excluded anyone in an institution and were not able to get everyone on the original list tested. Of course, the bias in the Doppelt and Wallace study is likely to be much less extreme. The purpose of these two studies was quite different; Doppelt and Wallace wished to establish norms for the population as it existed at the time, while Rhudick and Gordon were interested in whether IQ summary scores declined as a function of age. As one would expect, the scores of subjects selected to represent a cross-section of the total population were consistently poorer than those of subjects selected for aging research. At least a partial explanation for the discrepant findings in the literature may be suggested. Studies using representative samples show an age-related decline of function across a variety of intellectual measures, while studies using volunteer subjects tend to show a lesser decline.

Experimental design. The 2 studies used here as examples, the Doppelt and Wallace study, and the Rhudick and Gordon study, also represent 2 different research designs. The former used a cross-section (single measurement across two or more groups) design, while the latter used a longitudinal (within subjects, repeated measures) design. In general, research using cross-sectional design reports age-related deterioration of intellectual function, while studies using the longitudinal design do not. An examination of the weaknesses of each design gives clues as to why this happens. The cross-sectional design assumes that subjects born, for example, in 1900, 1930, and 1960 are equivalent on all factors affecting intellectual function except age. This confounds age effects with any generation (cohort) effects which may be present. Anastasi (1958) states:

> Differences between 20- and 40-year olds tested simultaneously (in 1940 or 1960) would reflect age changes plus cultural differentials, especially differences in the conditions under which the two age groups were reared.

The longitudinal design also has a number of flaws. Because repeated measures over time require subject participation for an extended period, this design eventually becomes biased toward the most highly-functioning members of the original sample. The problem becomes particularly acute when dealing with subjecs of an advanced age because of sample depletion (Baltes, 1968). The subjects most likely to continue participation in a study are those who are most active and competent. The selection process probably begins with collection of the original groups and continues throughout the years of the study. In many studies there is little information reported about the dropouts except that they were too ill to be tested, or that they died before completion of the study. This problem is highlighted by Blum et al., (1973), who found that deteriorating scores on some W-B subtests were significantly correlated with impending mortality. Longitudinal studies end up examining only highly-functioning, long-term survivors. This design gives results not representative of the general population or even of a particular age group; it only tests a biased segment of an age group. The segment of the population most likely to show changes may never be measured at all.

The longitudinal design also requires that subjects take the same test repeatedly and may make the assumption that there is no learning effect from one administration to the next. This is an unwarranted assumption in most cases (Baltes, 1968). The result is a bias in favor of higher scores with each retest.

Using cross-sectional comparisons within a longitudinal design only increases the bias. Eisdorfer and Wilkie (1973) used the 4 successive WAIS scores obtained in a comprehensive longitudinal study (The Duke University Center for the Study of Human Development and Aging) to examine intellectual changes with age. One unexpected result was that the group mean scores of each successive testing increased despite the fact that virtually all individual scores declined. The reason for this became apparent when the subjects were divided into those who survived the whole 10 years (and took the test 4 times), those who completed 3 testings, those who completed 2, and those who survived to complete only 1. The long-term survivors had higher scores to start with and declined less than non-survivors, so that at each successive testing the healthier and more competent subjects comprised a larger proportion of the sample group. The results represented a methodological artifact and to this extent were definitely misleading.

The types of measures used may also have an effect on age-related findings. Studies that show no age-related decline in intellectual functioning tend to be those using measures restricted to IQ scores (often restricted to summary scores or verbal subtests). As noted above, additional procedural factors leading to finding of limited decline in intellectual fuctioning include the use of volunteer subjects and a longitudinal design. Studies that find age-related decrements in performance tend to be those which use a broad range of measures, a representative subject population and a cross-sectional research design. The question of which tests instruments to use to evaluate intellectual functioning also requires more detailed consideration.

Test Instruments. The literature is replete with research which claims to measure "intellectual functioning" using only IQ tests and often only verbal subtests. This is hardly adequate, since IQ tests in general and verbal subtests in particular are more indicative of prior learning and educational attainment than they are of a person's ability to function in a day-to-day environment (Reitan and Reed, 1962). To measure intellectual ability it is necessary to use a broad range of measures, which match to some extent, the whole range of human brain-related activities. The tests need to be shown to be reliable indicators of the individual person's functional ability as well.

Human intellectual functioning can be characterized as having three components; information acquisition through sensory input, central processing of information, and overt behavior through motor output. For an individual to function normally, ability in all three areas must be intact. Ability in these areas requires that the biological integrity of the brain be preserved. In this sense, performance in these areas can be considered to be brain-controlled activity and therefore represents intellectual functioning in its broadest sense. Evaluation of intellectual functioning then requires a battery of tests capable of reliably measuring all 3 of the basic components of function, and in addition, demonstrates (validated) sensitivity to the organic integrity of the human brain.

The Halstead-Reitan Neuropsychological Battery fulfills these requirements. It is comprehensive with regard to evaluating an individual subject's present capabilities, is sensitive to the organic integrity of an individual's brain (Reitan, 1967), and is clinically useful in predicting an individual's day-to-day functioning (Heaton and Pendleton, 1981). Moreover, the individual tests in the battery can be combined in such a way as to give multiple measurements of the 3 basic functional areas.

The Present Investigation.

The present investigation was aimed at gathering information about possible age-related changes in functional ability, particularly intellectual functioning, while avoiding some of the pitfalls noted earlier. The study uses a variety of tests from the Halstead-Reitan Neuropsychological Battery arranged to give multiple measurements of sensory input, central processing, and motor output. A cross-sectional design was used to gain the advantage of measuring the population as it actually exists at present. To guard against confounding due to age group differences in education, health, and experiential history, the <u>pattern</u> of performance in the various functional areas (rather than just level of performance) was examined <u>within</u> age groups as well as across groups. Thus subjects of each age group act as their own controls for part of the study. Comparisons across groups were also made to examine how they differ on each measure.

# CHAPTER 2

## STUDY NUMBER 1

The following procedures were used to address the issues discussed above. The investigation was divided into 2 related but separate studies to provide the maximum information. Study 1 specifically tested the hypothesis that:

> Age changes progress at a comparable rate in the areas of sensory-perceptual function, motor skills, central processing abilities, and retention of prior learning and information.

Study 2 attempted to gather further information about the age-related changes found in Study 1. Study 2 specifically tested the hypothesis that:

> The deficits in performance shown by the older age groups follows the same pattern as that shown by persons having known structural cerebral damage.

The methodology and results of Study 2 will be discussed after those of Study 1.

### Method

#### Subjects

One hundred and twenty-five subjects were used in the first investigation. They were taken from a larger pool of subjects selected from the files of Dr. Ralph M.

Reitan. The majority of cases in Dr. Reitan's files were referred for a clinical neuropsychological evaluation because there was some reason to suspect cerebral diseases or damage. However, a substantial number of subjects were tested for other reasons. Some were gathered as part of the original validity studies concerning the Halstead-Reitan Neuropsychological Battery. Normal subjects were also periodically referred to evaluate the potential for discrimination of neurologically normal patients from those with brain damage. A number were examined as controls in a variety of studies. Finally, some were evaluated in a large-scale study of the relationship of serum cholesterol levels to intellectual functions.

Those selected to form the original pool of normal subjects were drawn from the latter kinds of cases--control subjects of one kind or another or neurologically normal patients with mild medical or emotional problems. All subjects either had a complete neurological evaluation with negative findings or were specifically selected as controls in earlier studies with no reason to believe they had any kind of brain damage or dysfunction. The selection process in this study consisted of the following steps:

1. Compiling a large pool of subjects originally gathered as controls or those having medical or emotional diagnoses without evidence of any compromise of brain function. A listing of all subjects in Dr. Reitan's

files was examined for diagnostic category. Names, ages, and diagnosis of those likely to be neurologically normal were determined.

2. Once this pool was formed from the larger population, the author collected the neurological evaluations of all subjects in the pool except those listed as controls.
3. Any subject who was not definitely clear neurologically was eliminated at this time.
4. The remaining subjects were then screened by Dr. Reitan, and any subjects whose neurological evaluation was not complete and reliable were dropped. These steps produced the final pool of normal subjects.

Once the pool was formed, subjects were divided by age into 5 groups (20-29, 30-39, 40-49, 50-59, 60-70). Twenty-five subjects were chosen in each group for a total of 125. Due to the difficulty in finding neurologically normal subjects in the older ranges, the 60-70 age group was chosen first and the remaining four groups were matched to the oldest group for education and "diagnostic category" (controls, medical illness, or emotional problems). The oldest group was chosen to reflect as high an education level (12.8 years) as possible. In fact, Dr. Robert Heaton and Dr. Mark Pendleton of the University of Colorado Medical Center furnished 11 cases, and Dr. James Comber of the

Tucson V.A.M.C. supplied 3 cases which were used to increase the number of highly-educated controls in the 2 oldest age groups. This high education level is reflected in the job accomplishments of many of the subjects. These groups reflect a higher ratio of subjects with professional and executive jobs than seen in their age peers in the general population. Equating on education may, in fact, have produced a bias of original intellectual functioning in favor of the older age group.

Among the 25 subjects in each age group, 6 fell in the category of "emotional problems," 8 had medical illnesses, and 11 were originally tested as control subjects. The general category of "medical illness" included: tension headache, migraine headache, paraplegia, diabetes (earliest stages), cervical fracture, rectal fissure, and hypertension (controlled). The general category of "emotional problems" included anxiety reaction, personality disorders, conversion reaction, and reactive depression.

Dependent measures used. The concept of human interaction with the environment being divided into 3 major areas was discussed at length earlier so it will not be reviewed here. The earlier discussion forms the rationale for using three major divisions of ability: sensory input, central processing and motor output, plus an additional measure related to the subjects' level of prior learning and information. Since central processing encompasses such diverse kinds of activity, it is subdivided into language processes, visuo-spatial processes, and general abstraction processes. These 7 areas are the ones investigated by both Study 1 and Study 2. The author does not intend to imply that these areas of function cover all the brain-related activities in which a human being may engage, nor that they are completely separate functions. Any person engaged in almost any behavior may use several of the functions either consecutively or simultaneously. The divisions are merely a way of conceptualizing human functioning in such a way that they may be tested. Furthermore, the tests used to measure these functions can never be said to be either pure or complete measures of any function. Nevertheless, when analyzed, a number of tests on the Halstead-Reitan Battery require predominantly one kind of function or another. The use of several test measures helps give reliable estimates of the general functional areas.

The test measures used were limited to those given with the Battery. Therefore, not all areas of function were based on an equal number of tests. For example, the area of prior learning used only three measures, while visuo-spatial functioning used six. There is no guarantee that prior learning is measured as well or as reliably as the latter area, but no such assurance would hold even if the same number of tests were used for every function. The areas of function merely provide ways of conceptualizing human interaction with the environment; the area names are descriptive rather than actual entities, and estimates of function in these areas must always be inferred rather than directly measured in any case. Nevertheless, these measures have proven useful and reliable over the years as the basis for inferences about the physical integrity of an individual patient's brains, as well as inferences about their ability to function in daily life in various environments. Clinical experience in neuropsychological evaluation indicates that valuable information about intellectual ability in these general functional areas can be obtained using the test measurements listed below.

Prior learning and information scores were based on the mean level of performance of subjects on the Information, Comprehension, and Vocabulary subtest scores from the Wechsler Bellveue (W-B) or Wechsler Adult Intellegence Scale (WAIS). Sensory-perceptual functions were measured by the mean performance on the Finger-tip Number Writing test, the Finger Agnosia test, and the Tactile, Visual, and Auditory Double Simultaneous Stimulation tests. The mean performance of the preferred hand on the finger Oscillation test and the average time-per-block for all three trials on the Tactual Performance Test were used to measure motor output. Performance on the Similarities, Arithmetic, and Digit Span subtests of the W-B or WAIS plus the subjects' scores on the Halstead Speech-sounds Perception test measured language-processing ability. Scores on the Performance subtests of the W-B or WAIS and the ability to reproduce the Greek cross on the Reitan-Indiana Aphasia Exam were used to measure visuo-spatial ability. Performance on parts A and B of the Trail making test and the Halstead Category test were used to measure abstraction ability. General ability in central processing was represented by a summary measure of the last 3 functional areas: language, visuo-spatial, and abstraction performances.

The original test batteries were administered by technicians either trained by Dr. Reitan or by his Chief Technician. The technicians had no prior knowledge of this research and administered all tests in a standardized, consistent manner. The testing was all performed between 1953 and 1980.

Appendix A gives descriptions of each of the tests used to produce the area-of-function scores. Included in this appendix are also the exact formulae used to generate the area scores.

## Analysis

All raw score measurements were subjected to McCall T-score transformations in the following manner:

1. Raw scores (scaled scores for W-B or WAIS subtest) of all 125 subjects were listed and combined for each separate measure.
2. The scores for each measure were sorted and ranked from best to poorest.
3. Percentile ranks were computed, and each raw score was assigned a T-score based on a normal probability distribution with a mean of 50 and a standard deviation of 10 for each measure.

This method of transformation gives each raw score equal probability of achieving each T-score. The actual T-score assigned to a raw score depended only on its relationship to the other raw scores obtained on that measure. T-score transformation has the advantage of always having a mean approximately equal to 50 and a standard deviation of about 10. Thus T-scores from one measure are equivalent to T-scores from other measures and so may be combined or compared regardless of the idiosyncrasies of individual test scoring procedures.

The analysis of the data followed a standard statistical sequence. First, the raw scores were subjected to the standard score conversion discussed above to make them more usable in the context of this study (McCall T transformation). The T-scores were then subjected to a Multivariate Analysis of Variance (MONOVA) using the

Statistical Package for the Social Sciences (SPSS) to determine the significance of the overall age group by dependent variables effect. Once this was shown to be statistically significant ($p < .01$), Univariate analysis tested the significance of each of the 7 functional categories. These group by variable effects that were statistically significant ($p < .01$) were then subjected to post hoc testing using the Tukey HSD (.05) to establish the pattern of change. For example, the pattern of change might be reflected by significant differences only among extreme age groups as contrasted with another measure where even adjacent age groups showed significant differences.

Discriminant analysis determined each factor's contribution to the group differences, and provided an estimate for the power of the combined factors to classify individual subjects into their correct age group.

Finally, the Multivariate, Univariate, and Discriminant analyses were also run on all individual test measures to provide additional information about the contribution of each measure to the functional areas, as well as to provide a first estimate of age corrections which may eventually be used in clinical neuropsychological interpretations. The later information included means and standard deviations for each level-of-performance measure on the Battery.

# Results of Study One

## Analysis of Variance

Multivariate Analysis of Variance showed that there was indeed a group effect when all dependent functions were considered together ($p < .01$). The actual probability of Type I error was extremely small ($p < .00001$). Univariate analysis, as shown in Table 1, demonstrated that the category of prior learning was nonsignificant while all other functional areas showed group by function differences ($p < .01$). The actual F values, given in Table 1, show the probability values for each of the functional areas. Group means and standard deviations for each dependent variable are given in Table 2. As shown, T-score means other than prior learning demonstrated a remarkably consistent progression from best to poorest performance with progression from the youngest to oldest age groups. These means were converted to graphs of performance with relation to age groups for each of the functional areas in figures 1A, 1B, 1C, 1D, 1E, 1F, 1G.

Retention of prior learning and information not only didn't change statistically with aging, there was virtually no absolute difference between the age group means in Table 2. The Table 1 F-ratios reflect this, with an F value approaching zero.

TABLE 1

Group by function F and P values (MANOVA) for the five age groups (20-29, 30-39, 40-49, 50-59, 60-70)

FUNCTION

| Value | Prior Learning | Sensory Input | Montor Output | Language Ability | Visuo-Spatial | Abstrac-tion | Combined Central |
|---|---|---|---|---|---|---|---|
| F | 0.13 | 3.73 | 8.82 | 5.57 | 27.11 | 18.94 | 20.17 |
| P | 0.96977 | 0.00679 | 0.00001 | 0.00038 | 0.00001 | 0.00001 | 0.00001 |

TABLE 2

Group by function means and standard deviations for five age groups (20-29, 30-39, 40-49, 50-59, 60-70)

GROUP

| Function | | 20-29 | 30-39 | 40-49 | 50-59 | 60-69 |
|---|---|---|---|---|---|---|
| Prior | M | 50.37 | 50.82 | 49.54 | 49.27 | 49.88 |
| Learning | SD | 5.79 | 8.56 | 9.35 | 9.91 | 8.61 |
| Sensory | M | 50.45 | 50.82 | 50.30 | 47.29 | 48.12 |
| Input | SD | 2.98 | 3.67 | 3.11 | 5.51 | 4.66 |
| Motor | M | 54.17 | 53.47 | 51.03 | 47.22 | 44.09 |
| Output | SD | 7.53 | 7.56 | 7.97 | 5.98 | 6.77 |
| Language | M | 53.04 | 53.43 | 49.49 | 47.84 | 46.02 |
| Processes | SD | 6.31 | 5.20 | 6.44 | 9.16 | 6.49 |
| Visuo- | M | 55.82 | 52.88 | 49.98 | 48.21 | 42.60 |
| Spatial | SD | 5.12 | 4.60 | 5.01 | 5.14 | 4.07 |
| Abstrac- | M | 56.58 | 54.28 | 49.22 | 47.95 | 41.94 |
| tion | SD | 7.81 | 5.28 | 6.15 | 8.00 | 5.09 |
| Combined | M | 55.15 | 53.53 | 49.56 | 48.00 | 43.52 |
| Central | SD | 5.44 | 4.29 | 4.82 | 6.42 | 4.41 |

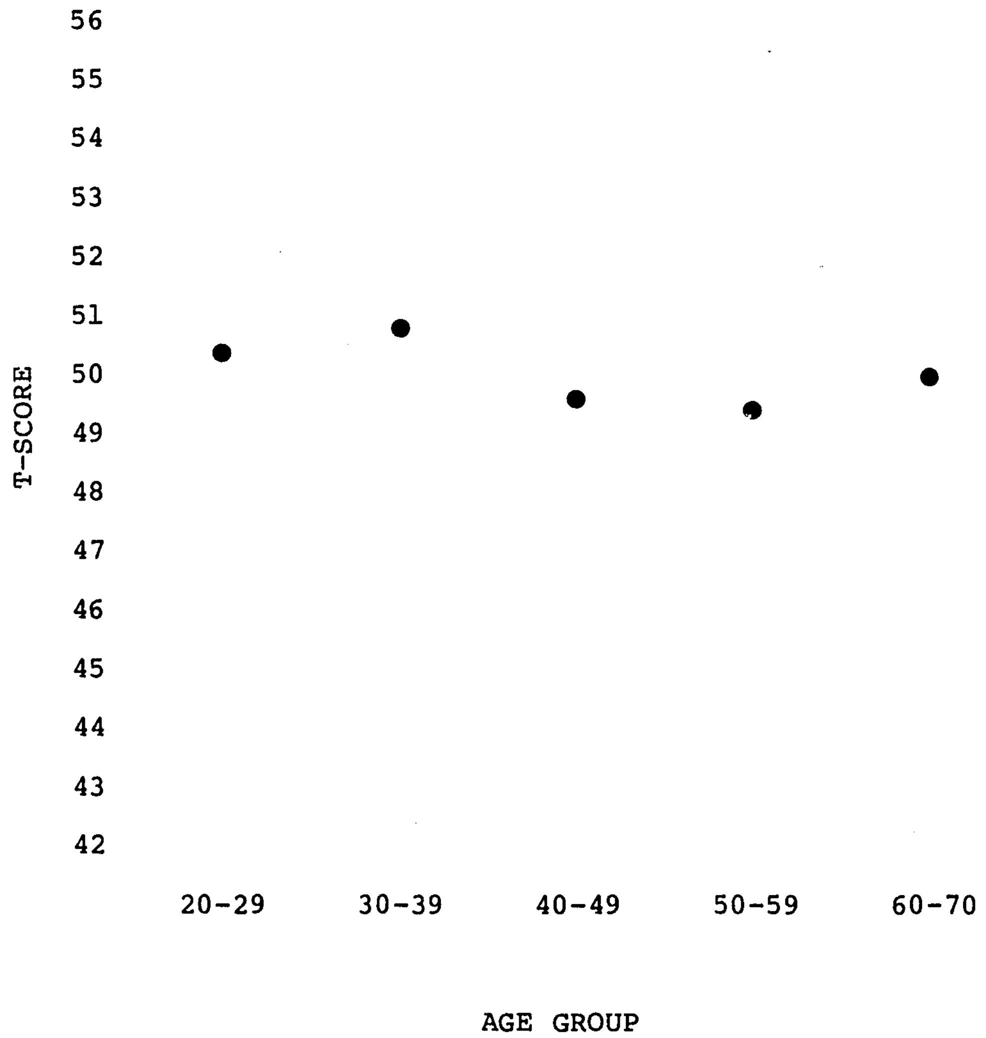


Figure 1A. Group mean T-scores for the 5 age groups for retention of prior learning and information measures.

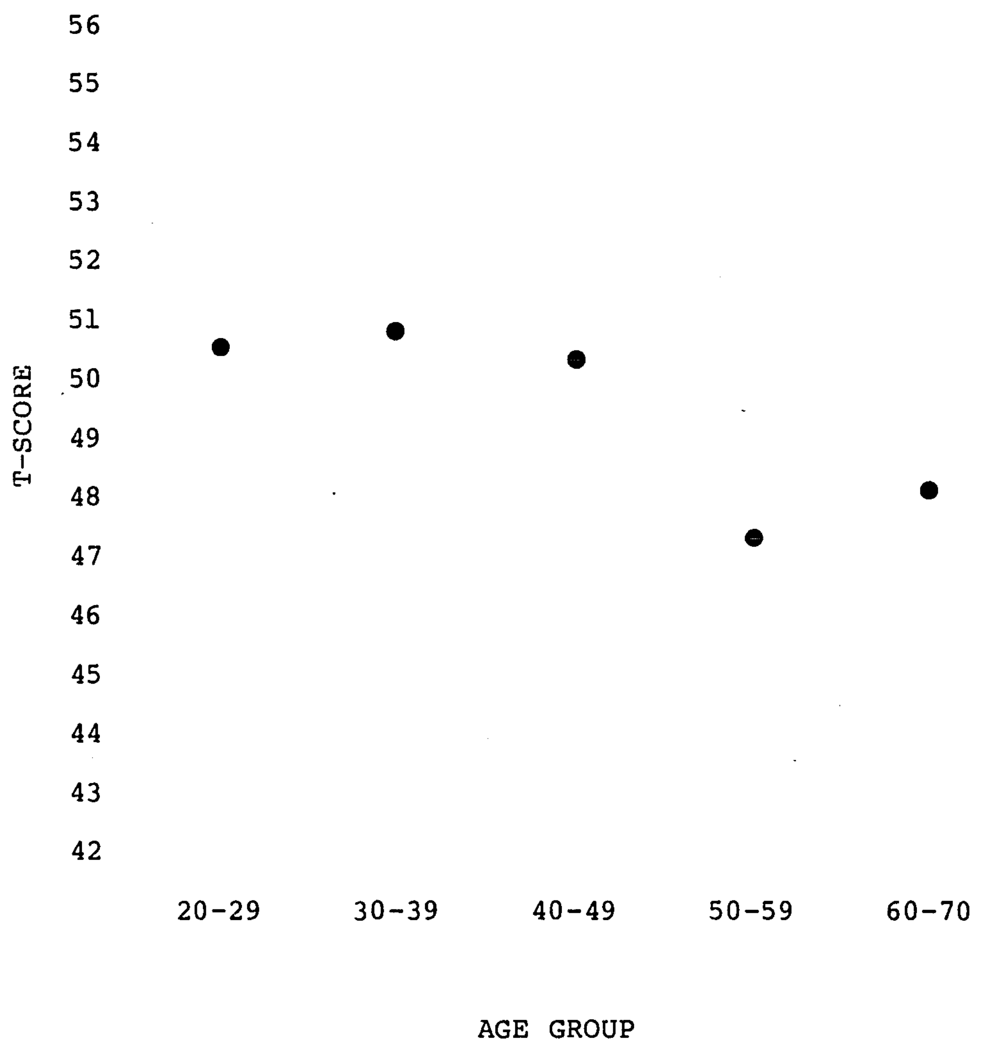


Figure 1B. Group mean T-scores for 5 age groups for sensory input measures.

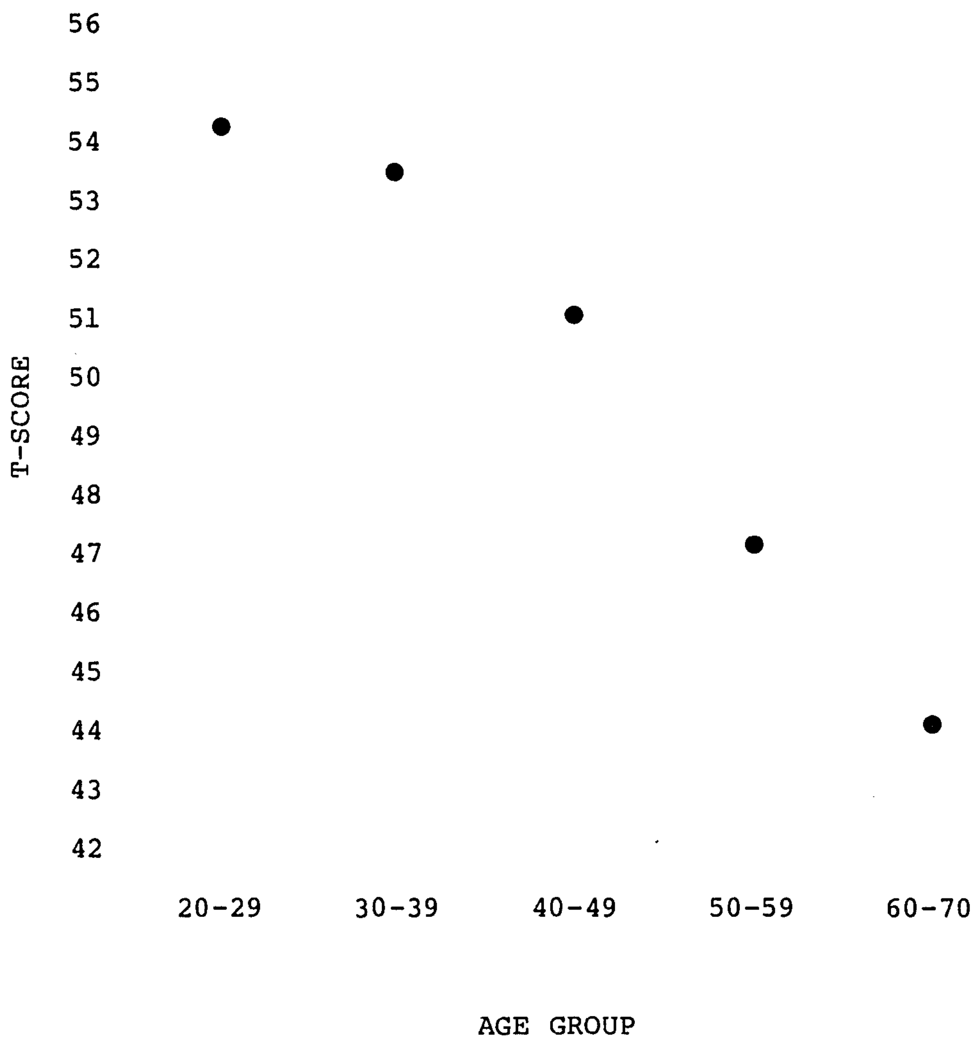


Figure 1C. Group mean T-scores for 5 age groups on motor output measures.

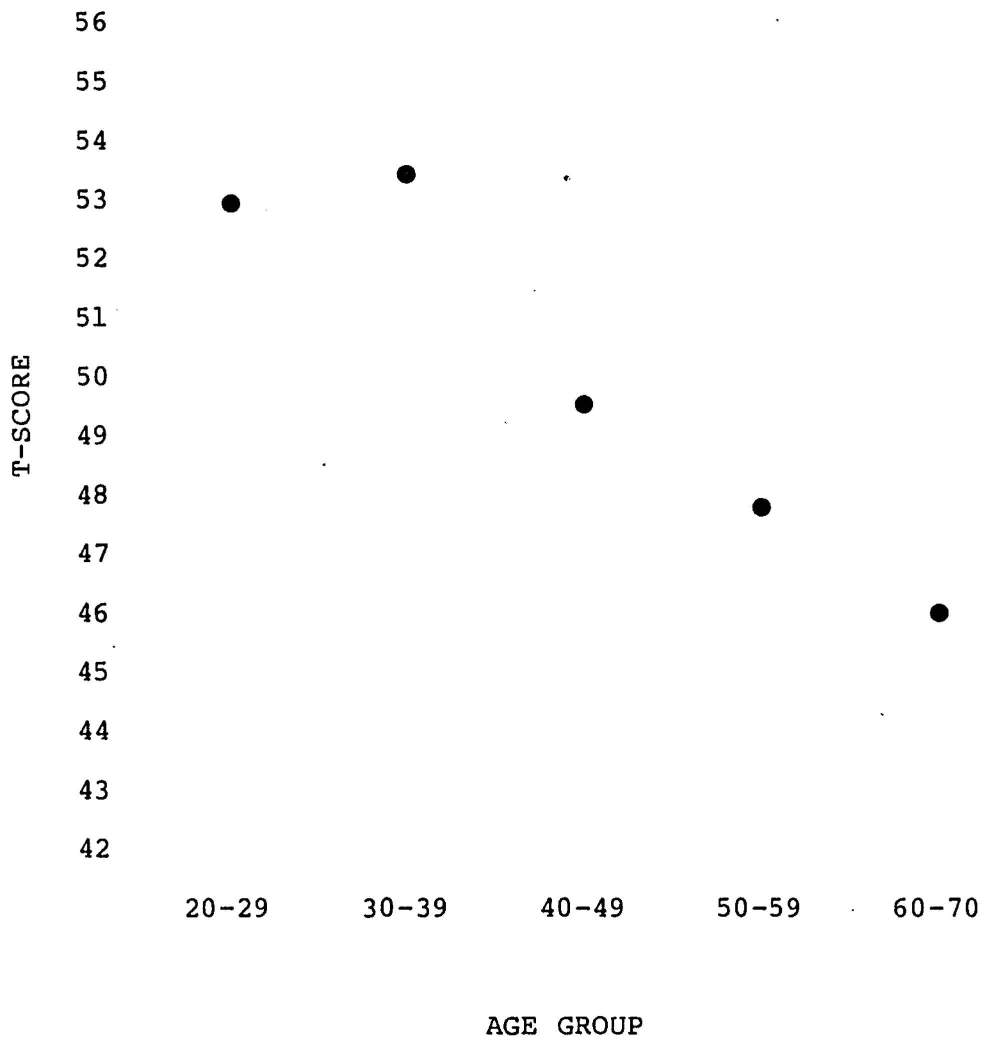


Figure 1D. Group mean T-scores for 5 age groups on language processing measures.

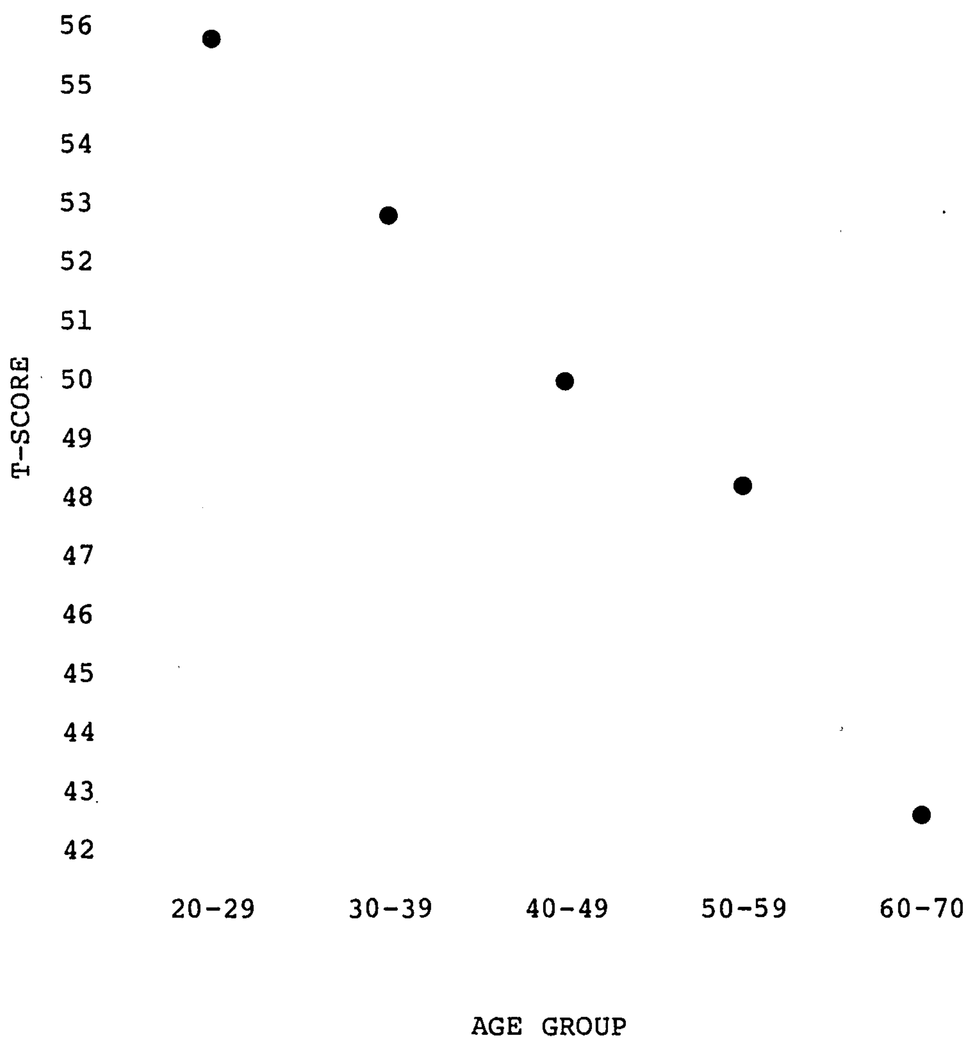


Figure 1E. Group mean T-scores for 5 age groups on visuo-spatial measures.

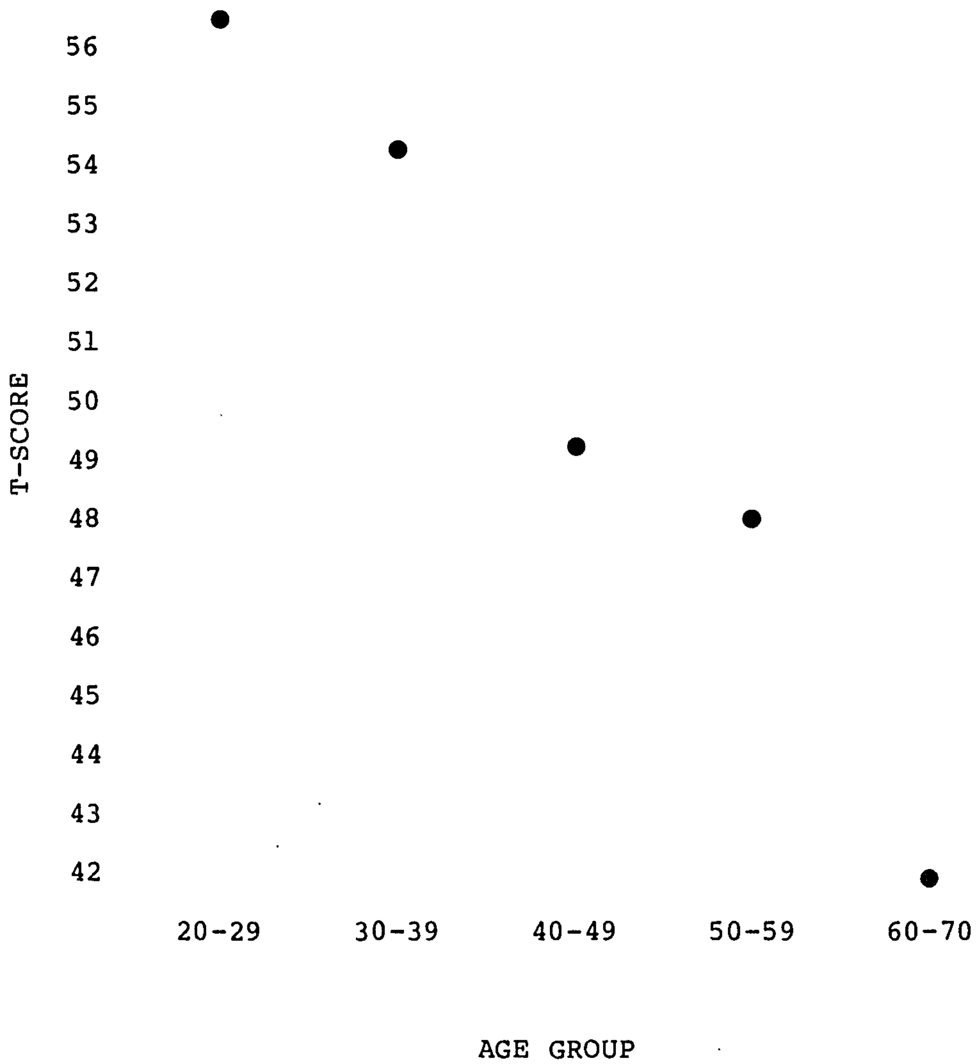


Figure 1F. Group mean T-scores for 5 age groups on abstraction measures.

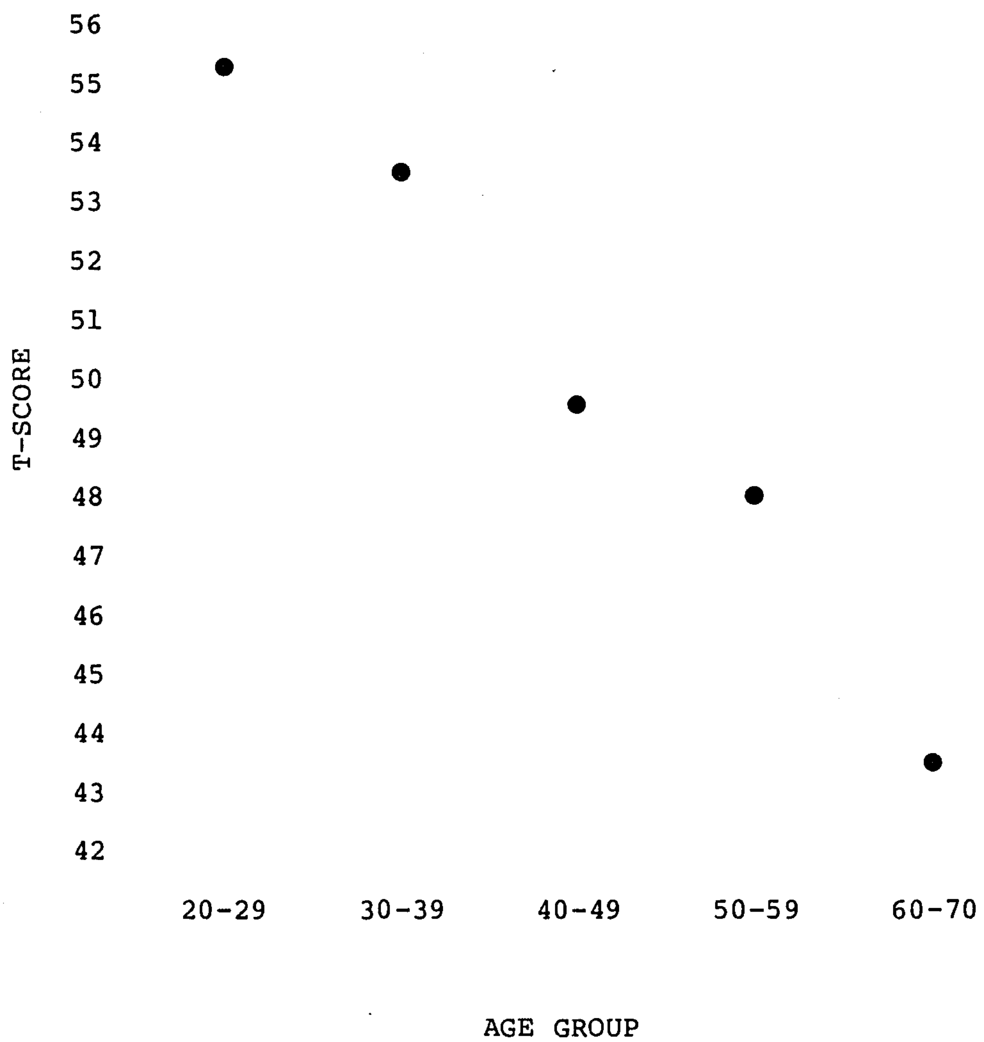


Figure 1G. Group mean T-scores for 5 age groups on composite central processing measures.

Just the opposite was true of the other functional areas. Each of them significantly related to age in a specific way--Figures 1B-G show systematically poorer group performances as age increases. The results were all statistically significant at the .01 level of confidence. Table 1 shows that motor output, visuo-spatial ability, and abstraction were statistically significant effects beyond the .0001 level of confidence (a very conservative value). The combined central processing factor was also significant at this conservative value. On the basis of these results, the hypothesis that various physical and intellectual processes change with age in a similar manner can definitely be rejected. Retention of prior learning and information showed no change with aging while all other areas did.

## Post Hoc Testing

Post hoc testing with the Tukey HSD (.05) gives additonal information about the patterns of change. Post hoc test results are listed in Table 3. There was no age effect on prior learning so, of course, no post hoc testing was done on this variable. The 30-39 and 50-59 age groups represented the extreme means on the sensory input function, and only these two groups were statistically different from each other. On the motor output variable, the 60-70 age group was significantly worse than the 3 youngest

TABLE 3

Group comparisons for each functional area.
Only group means connected By the arrows represent
significant differences (Tukey HSD).

| Function | 20-29 | 30-39 | 49-49 | 50-59 | 60-70 |
|---|---|---|---|---|---|
| Prior Learning | | | Nonsignificant | | |
| Sensory Input | 50.4 | 50.8 | 50.3 | 47.3 | 48.1 |
| Motor Output | 54.2 | 53.5 | 51.0 | 47.2 | 44.1 |
| Language Processes | 53.0 | 53.4 | 49.5 | 47.8 | 46.0 |
| Visuo-Spatial | 55.8 | 52.9 | 50.0 | 48.2 | 42.6 |
| Abstraction | 56.6 | 54.3 | 49.2 | 48.0 | 42.0 |
| Combined Central Processing | 55.2 | 53.5 | 59.6 | 48.0 | 43.5 |

groups while to 50-59 group was worse than the two youngest. These findings indicate a sharp break in performance of motor functions between the 40-49 and 50-59 age groups. The 20-29 and the 50-59 groups were the extremes on language-processing ability and only these 2 groups were significantly different from each other, indicating a modest deterioration with age without sharp breaks. Visuo-spatial functioning produced a nearly linear deterioration with aging up to the 50-59 age group. The 60-70 age group was worse than all other groups, whereas none of the differences between adjacent-group comparisons were significant. All the nonadjacent group comparisons were significant. The results showed a steady decline up till the 50s and an accelerated deterioration in the 60s. The results of the group comparisons for abstraction show the same pattern as for visuo-spatial functions. The 60-70 group performed more poorly than all others, and a linear deterioration appeared with age for the rest of the groups (adjacent-group comparisons were nonsignificant). When the 3 central processing functions were combined, the pattern was like that of the visuo-spatial and abstraction functions. The 60-70 age group was significantly worse than all others and nonadjacent group comparisons showed significant differences among the younger groups.

Discriminant Analysis

Discriminant analysis of the age groups on the 6 (omitting prior learning which was not significant) dependent variables classified all subjects in the CORRECT AGE GROUP at a level 2½ times better than chance (48 percent). Table 4 presents the outcome of the discriminant function analysis. When the "correct" classification was expanded to include the age-adjacent group(s) as well as the exact age group, the discriminant functions determined the correct age range with increased accuracy (77.6 percent). Placement into actual or adjacent groups is perhaps a more meaningful measure because otherwise the analysis must discriminate between 5 contiguous age categories. Perhaps most striking was the fact that none of the subjects aged 60-70 were placed in the 20-29 or 30-39 age groups, and none of the 20- 29-year-old subjects were placed in the 60-70 group. Chronological age was such a significant predictor of performance in these 6 areas of function that the youngest and oldest groups did not overlap.

The Discriminant analysis also provided estimates of the discriminant power of the dependent variables based on the size of the F-ratios. Table 5 lists these variables from best to least discriminant. Performance on visuospatial functions was the best discriminator of correct age group. The combined central processing measure was next

TABLE 4

Discriminant analysis placement of subjects in correct age group. Placement was based on each subject's performance in the 6 functional areas (sensory input, motor output, language processes, visuo-spatial processes, abstraction processes, combined central processes).

PERCENT PLACED IN CORRECT GROUP

| Actual Group | Predicted Group 20-29 | 30-39 | 40-49 | 50-59 | 60-70 | Correct or Adjacent Group |
|---|---|---|---|---|---|---|
| 20-29 | 60% | 16% | 16% | 8% | 0% | 76% |
| 30-39 | 36% | 28% | 28% | 8% | 0% | 92% |
| 40-49 | 16% | 12% | 36% | 16% | 20% | 64% |
| 50-59 | 4% | 24% | 12% | 40% | 20% | 72% |
| 60-70 | 0% | 0% | 16% | 8% | 76% | 84% |
| | | | | | Total | 77.6% |

TABLE 5

Discriminative power of each of the 7 functional areas to classify subjects by age. Results are listed in order from most to least powerful (based on the 5 age groups: 20-29, 30-39, 40-49, 50-59, 60-70).

| Variable | Wilkes-Lambda | F | P |
|---|---|---|---|
| Visuo-spatial | 0.52530 | 27.11 | 0.00001 |
| Combined Central | 0.59796 | 20.17 | 0.00001 |
| Abstraction | 0.61297 | 18.94 | 0.00001 |
| Motor Output | 0.77271 | 8.82 | 0.0011 |
| Language Processes | 0.84348 | 5.57 | 0.001 |
| Sensory Input | 0.88952 | 3.73 | 0.01 |
| Prior Learning | 0.99557 | 0.13 | NS |

best, abstraction third, motor output fourth, language processes fifth, sensory input sixth; and prior learning was not a significant variable.

An additional sequence of analysis provided an even further break down of age-related effects. The individual measures themselves were subjected to multivariate and univariate analysis of variance and discriminant analysis. Because of the large number of groups (5) and dependent variables (30), comparisons based on individual variables would result in a distinct loss of power due to controlling experiment-wise error. Realizing this, it was decided *a priori* not to use these individual measures as indicative of the presence or absence of age-related changes. However, this series of analyses did provide group means for each of the *individual* tests and information about how performance changes with age group on each of them. The means for each group on each measure are listed in Appendix C. The number of subjects in the age group is much too small for the results to be used as established, usable norms, but the results can eventually be supplemented by additional studies to provide reliable age norms. In addition, the analysis of individual measures may provide heuristic information about the relative contribution of each test to the functional area which it helps to measure.

Table 6 lists individual test measures from the Halstead-Reitan Battery in accordance with the size of their F-ratios. In one sense this table provides information regarding the sensitivity of possible groups of tests, as well as each individual test, to age. (Discriminant functions correctly classified 93 percent into the exact age group they belonged to, but since there were 30 dependent measures, this is actually less impressive than the results of the discriminant function analysis based on areas-of-function performed).

Based on Discriminant analysis, and considering the area of visuo-spatial function, the results suggest Block Design suffered most with advancing age, with Picture Arrangement, Object Assembly, Digit Symbol, and Picture Completion following in decreasing order of sensitivity. Reproduction of the cross on the aphasia exam was least sensitive of all on the visuo-spatial function and was not a significant discriminator of age group, largely because few of the subjects even in the older age group had any trouble with this task. The Category score was the most sensitive of the age discriminators for the abstraction function. Trails B and Trails A scores were less sensitive, but both were also powerful discriminators of age group. The overall time-per-block on the TPT test was the best single test discriminator of age group, and of course, the most sensitive of those

TABLE 6

Individual tests in order of decreasing F-ratios, which provide a general ordering of power to discriminate age groups (based on the five age groups: 20-29, 30-39, 40-49, 50-59, 60-70).

| Test | Wilkes-Lambda | F | P |
|---|---|---|---|
| Block Design | 0.57691 | 22.00 | 0.00001 |
| Tactual Performance | 0.59042 | 20.81 | 0.00001 |
| Category Test | 0.65268 | 15.96 | 0.00001 |
| Picture Arrangement | 0.66965 | 14.80 | 0.00001 |
| TPT Location | 0.69360 | 13.25 | 0.00001 |
| Object Assembly | 0.71352 | 12.05 | 0.00001 |
| Digit Symbol | 0.72738 | 11.25 | 0.00001 |
| Trails B | 0.76828 | 09.05 | 0.00001 |
| Trails A | 0.80812 | 07.12 | 0.00001 |
| Picture Completion | 0.81411 | 06.85 | 00.0001 |
| Similarities | 0.85535 | 05.07 | 00.0008 |
| TPT Memory | 0.87553 | 04.27 | 00.0029 |
| FT#W | 0.89193 | 03.64 | 00.0078 |
| Speech-Sounds | 0.89376 | 03.57 | 00.0087 |
| Arithmetic | 0.92184 | 02.54 | N.S. |
| Digit Span | 0.93216 | 02.18 | N.S. |
| Rhythm | 0.93380 | 02.13 | N.S. |
| Auditory DDS | 0.93699 | 02.02 | N.S. |
| Cross Drawing | 0.94828 | 01.64 | N.S. |
| Visual DDS | 0.95705 | 01.35 | N.S. |
| Comprehension | 0.95890 | 01.29 | N.S. |
| Tactile DDS | 0.96230 | 01.18 | N.S. |
| Finger Oscillation | 0.96526 | 01.08 | N.S. |
| Finger Agnosia | 0.96729 | 01.02 | N.S. |
| Vocabulary | 0.98067 | 00.59 | N.S. |
| Information | 0.99538 | 00.14 | N.S. |

measuring the motor output function. Finger tapping speed did not discriminate between age groups at all. Of the tests comprising the language processes, scores on the Similarities and Speech-Sounds Perception Test were both significant discriminators of age with Similarities having the higher F-ratio. Neither Arithmetic nor Digit Span discriminated significantly. None of the tests used to measure Sensory Input were significant discriminators except the Finger Tip Number Writing score. None of the four tests used to measure prior learning were able to discriminate between age groups at all. These results will be dealt with further in the discussion section after reporting the results of Study 2.

## CHAPTER 3

## STUDY NUMBER 2

Discussion of the results of Study 1 will be deferred until the methodology and results of Study 2 have been presented. Many of the implications of the first study are made more intelligable when considered in the context of the data from Study 2.

Study 2 was designed as a follow-up of the results of Study 1. The results of the first study indicated that there were indeed changes associated with aging. These changes took place in high-functioning, neurologically normal subjects in most areas of function but not in all, i.e., measures related to prior learning. The results of Study 1 required rejection of the null hypothesis. Study 2 was developed to address the question of whether the demonstrated age-related changes were similar to those seen in brain damage, or if they followed some other pattern. Study 2 specifically tested the following hypothesis:

> The deficits in performance shown by the older age group follows the same pattern as that shown by a group of persons with structural cerebral damage.

## Method

### Subjects

Study 2 used 120 subjects divided into 3 groups of 40 subjects each. One group was composed of older neurologically normal subjects, a second group was also neurologically normal but younger in age, and a third was composed of young brain-damaged subjects. The subjects were selected as follows:

Older Normal Group. Forty subjects between the ages of 45 and 70 were selected randomly from the original pool of normal subjects (which was assembled before the start of Study 1). Since the selection was random and no *a priori* decision was made to exclude subjects from Study 2 if they had been members of Study 1, 9 of the 40 older subjects had been used in the first study. All the procedures for evaluation of neurological findings had been performed in forming the original pool, so the same criteria apply to this group also.

Younger Normal Group. Forty subjects in the age range from 20 to 40 were selected randomly from the original pool of neurologically intact subjects. The stipulation was made that this group had to match the older group's educational level. The procedure used was such that if the younger group's mean education was lower than that of the older group, the subject with the least education would be dropped from the group and be replaced by the next random selection. This process was repeated until the two groups were statistically similar on education level. Had the younger group been higher on education, the reverse process would have been used; i.e., the most highly-educated young subject would have been dropped. There were 5 subjects in this group who had also been members of Study 1. All the definitions and restrictions used to form the original normal pool applied to this group also.

Brain Damage Group. Forty subjects in the age range 20 to 40 were chosen from Dr. Reitan's files to form this group. The selection process was very similar to that used to form the normal pool except for use of appropriately differing criteria. A card file listing all patient's names, age, education, and diagnoses was used to produce a list of subjects whose diagnosis indicated cerebral damage. The neurological summaries were then examined for all subjects on this list. Those whose diagnoses were questionable or whose records were not complete were dropped from the list and replaced by new subjects. Dr. Reitan then evaluated the records of all subjects on the list for completeness and reliability of neurological diagnoses. The resulting sample had a relatively lower educational level, so the subjects on the list with the least education were dropped from the list until 40 remained. The 3 groups were then statistically equivalent with regard to educational level.

The selection of subjects in this group required reliable evidence of cerebral damage, but no attempt was made to select specific kinds or locations of damage. The resulting distribution of diagnoses was not subject to systematic selection biases and probably reflected the kinds of cerebral damage one is most likely to find in a heterogeneous group of young subjects. The actual diagnostic breakdown was as follows:

Craniocerebral trauma 14

(closed head trauma 11, open head wound 3)

Cerebrovascular lesions 9

(aneurysm 3, arteriovenous malformation 5, infarct 1)

Cerebral neoplasm 8

(intrinsic tumor 5, extrinsic tumor 3)

Cerebral cyst 1

Encephalitis 2

Cerebral abscess 1

Cerebral atrophy 1

Subdural hygroma 1

Complex partial epilepsy 1

Multiple sclerosis 2

Dependent Measures Used

As in Study 1, dependent measures were divided into the 3 major functional areas, i.e., sensory input, motor output, and central processing. Central processing was again subdivided into visuo-spatial, abstraction, and language ability. The function of prior learning was used as an additional variable. The individual tests that contributed to measuring these areas of function were also exactly the same as the Study 1. To summarize, sensory input measures were Finger Tip Number Writing scores, Finger Agnosia scores, and Double Simultaneous Stimulation scores on the Tactile, Visual, and Auditory modalities. Motor output ability measures were scores on the Finger Oscillation test and the average time-per-block on the Tactual Performance Test. Visuo-spatial function was inferred from scores on the Picture Completion, Picture Arrangement, Block Design, Object Assembly, and Digit Symbol subtests, plus the score on the Greek cross reproduction. The Category test and the Trail-making test (parts A and B) scores formed the basic measures of abstraction ability. Language processes were measured by the Similarities, Arithmetic, and Digit Span subtests, along with scores on the Speech-Sounds Perception test. Central processing was again the composite of results on the visuo-spatial, abstraction, and language functions. Finally, prior learning retention was inferred from Information, Comprehension, and Vocabulary subtests. A description of the individual tests is given in Appendix A.

Analysis

The first step in data analysis (as in Study 1) was to achieve standardization of scaling and variability for each measure by conversion of raw-score distributions to McCall T-score distributions. To achieve this conversion the 3 groups were combined, and a distribution of scores with a mean of 50 and a standard deviation of 10 was formed for each test measure. The 3 individual groups were then recomposed, and intergroup comparisons were based on the T-scores. The performance estimates were then derived from the average of the T-scores on the individual test measures that contributed to each area. The exact formula for each area-of-function estimate is given in Appendix B.

The first aspect of the statistical data analysis required use of Multivariate analysis of variance with ($p < .01$) as a criterion for further analysis. Once it was established that the overall group-by-variable effect was significant, the individual variables were tested using Univariate analysis of variance ($p < .01$). The group-by-variable effects that were significant received further post hoc analysis using the Tukey HSD (.05) test. This post hoc testing determined the relative contributions of each group to the overall variance for each function.

Discriminant analysis was also performed, and it was perhaps the most important procedure performed on this data. Three separate analyses were performed. The first analysis compared all 3 groups to determine which function variables discriminated among all 3 groups: young normals, older normals, and brain-damaged patients. The first analysis also gave an estimate of each variable's discriminative power between all three groups, as well as determining the program's ability to place the subjects in their proper group using all 7 variables. The second analysis compared the young normal to the old normal group, while the third analysis compared the young normal to the brain-damaged group. These latter analyses provided information regarding the sensitivity of each variable to the age diminsion (young versus old) and the brain-damage effect (normal versus brain-damaged). These latter comparisons were relevant in the attempt to determine if the same functions deteriorate with age as with brain damage.

## Results of Study 2

### Analysis of Variance

Multivariate analysis of variance showed a significant overall group by variables effect ($p < .00001$).

Univariate analysis of variance demonstrated additional significant results for all individual variable by group effects. Table 7 lists the F values for each of the group-by-variable effects. As can be seen, each of them achieved significance beyond the ($p < .0001$) level.

Post Hoc Testing

Graphs of the mean values for each of the 3 groups are shown in Figures 2A through 2G. The results of the post hoc testing using the Tukey HSD (.05) test can be summarized as follows: Brain-damaged subjects were found to have a significantly lower score on level of prior learning than either young normal or older normal subjects. Although the older normal subjects had a higher mean score than the young normal group, the difference was not significant. The brain-damaged group's performance on the sensory input function was significantly worse than both the young and older groups. The older group did more poorly than the young, but the difference was not significant. The picture was somewhat different with motor output; each group was significantly different from the others. The young group performed best, the older group's performance was intermediate, and the brain-damaged group performed significantly worse than the older group. The pattern seen on language processing was like that of sensory input--the

TABLE 7

Multivariate analysis of variance F-ratios for group by individual area-of-function variables for three groups (young normal, older normal, and brain-damaged).

FUNCTION

| | Prior Learning | Sensory Input | Motor Output | Language Processing | Visio-spatial | Abstraction | Combined Central |
|---|---|---|---|---|---|---|---|
| F | 13.47 | 42.53 | 20.14 | 11.84 | 22.04 | 26.35 | 24.41 |
| P | 0.00001 | 0.00001 | 0.00001 | 0.00002 | 0.00001 | 0.00001 | 0.00001 |

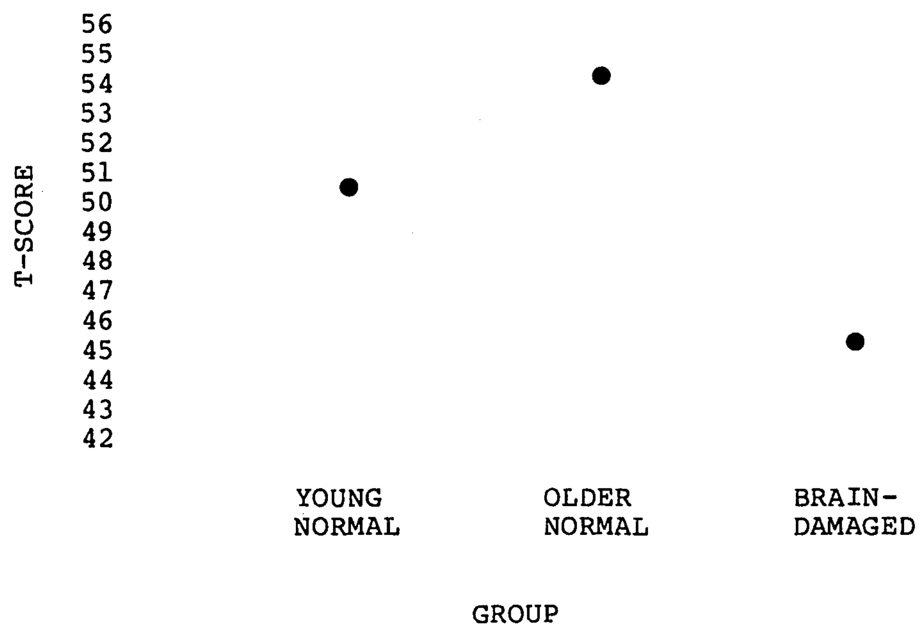


Figure 2A. Group mean T-scores for retention of prior learning and information measures.

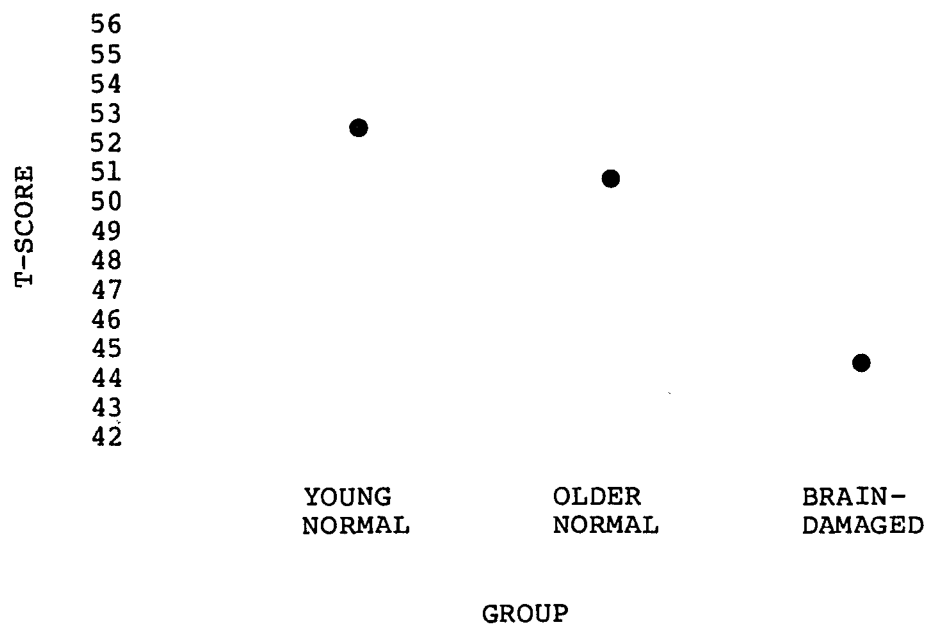


Figure 2B. Group mean T-scores for sensory input measures.

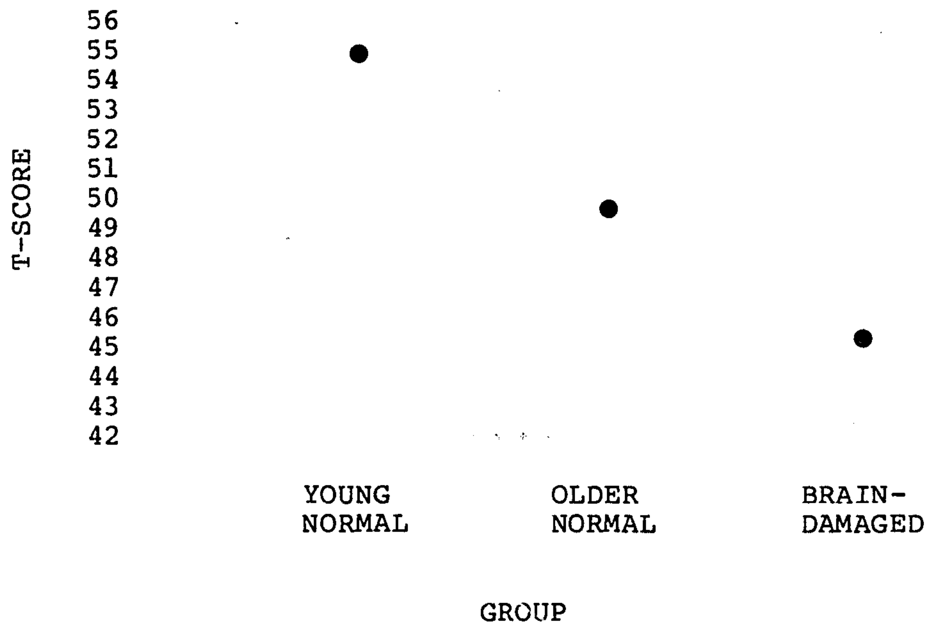


Figure 2C. Group mean T-scores for motor output measures.

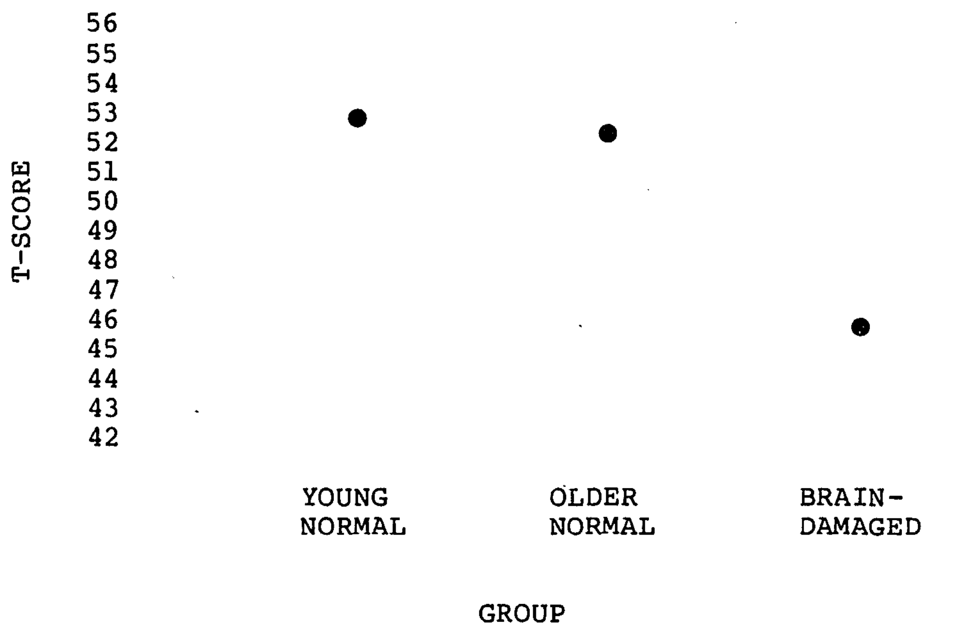


Figure 2D. Group mean T-scores for language processing measures.

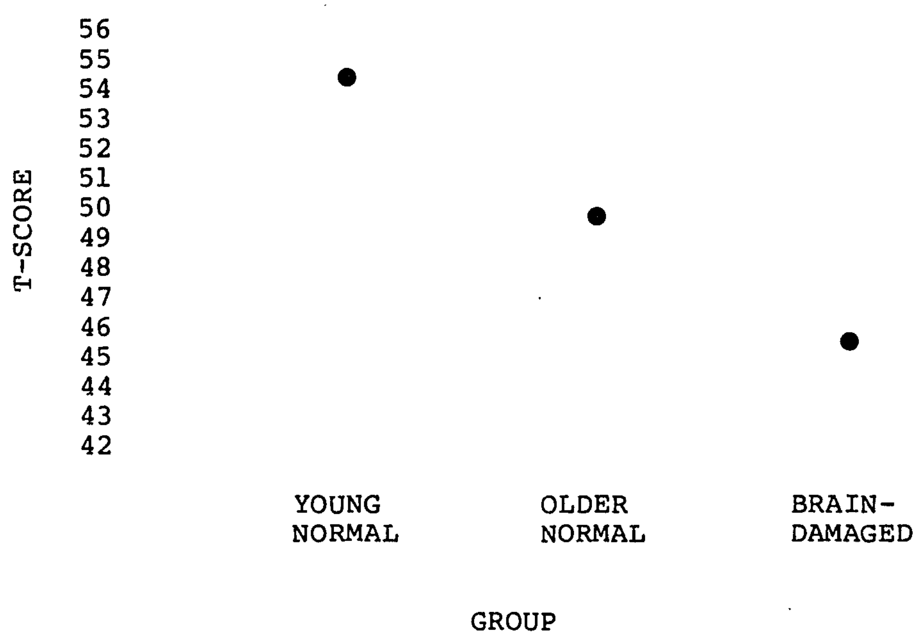


Figure 2E. Group mean T-scores for visuo-spatial measures.

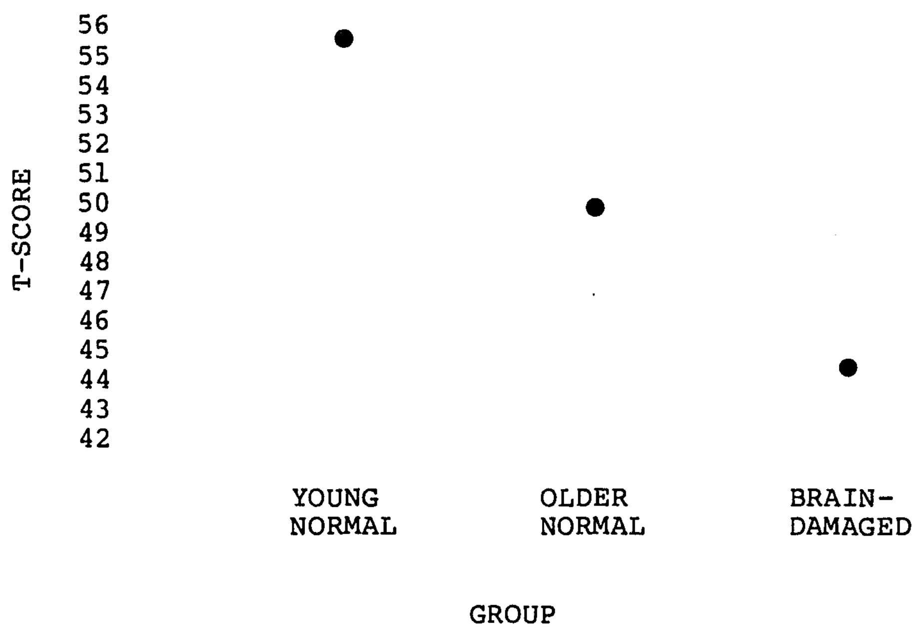


Figure 2F. Group mean T-scores for abstraction measures.

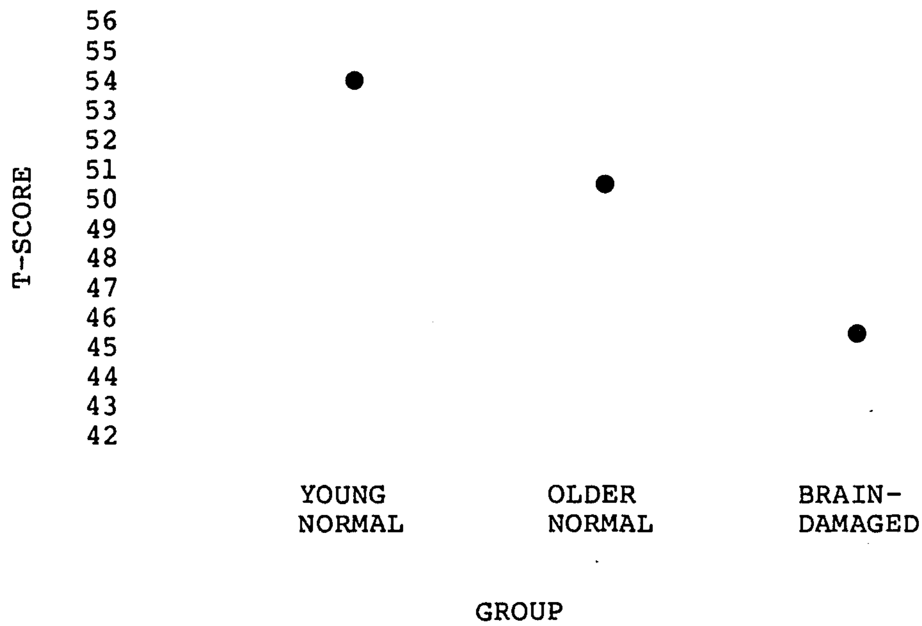


Figure 2G. Group mean T-scores for combined central processing measures.

young group performed best, the older group was poorer, but the difference was not significant, and the brain-damaged group was significantly worse than both other groups. Abstraction, visuo-spatial, and composite central processing all showed the same pattern as that of motor output--the young group performed best, the older group was significantly worse than the young group, and the brain-damaged group performed significantly poorer than both.

It is quite apparent at this point that age-related changes in function had many similarities to those seen in a heterogeneous group with cerebral damage. However, those changes were not identical in either pattern or in severity of deficit, even in the functions where there was decreased performance in both groups.

## Discriminant Analysis

Discriminant analysis based on composite scores for the 7 functional areas placed 77.5 percent of all subjects in their correct groups. Table 8A presents the classifications for each of the 3 groups. The Discriminant analysis misclassified 10 percent of the older normals as young normals, and 12 percent as brain-damaged subjects. The approximately equal number of misclassifications for the younger normal and brain-damaged groups is consistent with expectations raised by the post hoc testing. On all

TABLE 8A

Ability of a discriminnt analysis program to place subjects in their correct group using seven variables (prior learning, sensory input, motor output, language processing, visuo-spatial processing, abstraction processing, and combined central processing).

| | PERCENT PLACED IN CORRECT GROUP | | |
|---|---|---|---|
| Actual Group | Young Normals | Older Normals | Brain-Damaged |
| Young Normals | 85% | 10% | 5% |
| Older Normals | 10% | 78% | 13% |
| Young Brain-Damaged | 15% | 15% | 70% |
| | | Total | 78% |

functions except prior learning, the older normal group's performance was about midway between that of the young group and the brain-damaged. It should also be noted that all subjects in the older group who were mistakenly placed in the young group were between 45 and 50 years old, and none of the normal subjects over 50 were mistaken for young normal subjects. The reverse was also true in that no subject under 55 was mistakenly placed in the brain-damaged group by the analysis program.

The second Discriminant analysis compared only the young normal and older normal groups. In this two-group comparison (as shown in Table 8B), the analysis program classified 87.5 percent of the subjects correctly. The third discriminant analysis compared the young normal group and the brain-damaged group. The analysis program correctly placed 90 percent of the subjects, as shown in Table 8C.

Discriminant analyses 2 and 3 also provided information about the relative sensitivity of each of the 7 functional areas to the age dimension and to brain damage. The variables are listed in decreasing discriminative power for the age and brain-damage comparisons in Table 9A and 9B respectively. As can be seen, there were similarities in the discriminative power of some variable along both dimensions, but the order was not identical. In both

TABLE 8B

Ability of a Discriminant analysis program to place subjects in their correct group using 7 variables (prior learning, sensory input, motor output, language processing, visuo-spatial processing, abstraction, and combined central processing).

| | PERCENT PLACED IN CORRECT AGE GROUP | |
|---|---|---|
| Actual Group | Young Normals | Older Normals |
| Young Normals | 87.5% | 12.5% |
| Older Normals | 12.5% | 87.5% |
| | Total | 87.5% |

TABLE 8C

Ability of a Discriminant analysis program to place subjects in their correct group using 7 variables (prior learning, sensory input, motor output, language processing, visuo-spatial processing, abstraction processes, and combined central processing).

| | PERCENT PLACED IN CORRECT GROUP | |
|---|---|---|
| Actual Group | Young Normals | Brain-Damaged |
| Young Normals | 97.5% | 2.5% |
| Brain-Damaged | 17.5% | 82.5% |
| | Total | 90.0% |

TABLE 9A

Seven area-of-function variables listed in order of decreasing power to discriminate between young and older subjects. Wilkes-Lambda, F-ratio, and Probability values are given for each.

| Function | Wilkes-Lambda | F | P |
|---|---|---|---|
| Abstraction | 0.83793 | 15.09 | 0.0002 |
| Visuo-Spatial | 0.84571 | 14.23 | 0.0003 |
| Motor Output | 0.87009 | 11.65 | 00.0010 |
| Sensory Input | 0.89957 | 08.71 | 00.0042 |
| Combined Central | 0.91271 | 07.46 | 00.0078 |
| Prior Learning | 0.94421 | 04.61 | N.S. |
| Language Processing | 0.99998 | 0.002 | N.S. |

TABLE 9B

Seven area-of-function variables listed in order of decreasing power to discriminate between normal and brain-damaged subjects. Wilkes-Lambda, F-ratio, and Probability values are given for each.

| Function | Wilkes-Lambda | F | P |
|---|---|---|---|
| Sensory Input | 0.57359 | 57.98 | 0.00001 |
| Abstraction | 0.58750 | 54.77 | 0.00001 |
| Combined Central | 0.61674 | 48.47 | 0.00001 |
| Motor Output | 0.65106 | 41.80 | 0.00001 |
| Visuo-Spatial | 0.65557 | 40.98 | 0.00001 |
| Language Processes | 0.80067 | 19.42 | 0.00001 |
| Prior Learning | 0.89858 | 08.80 | 0.00400 |

comparisons, prior learning and language processes were the poorest discriminators, while abstraction ability was one of the best. Sensory input functioning, however, was the best discriminator of brain damage but only a mediocre discriminator of age. Again the pattern between age and brain damage was similar but not identical.

# CHAPTER 4

# DISCUSSION

Analysis of the findings of Study 1 and Study 2, combined with the results of relevant prior research, makes several facts clear. A number of inferences based on the findings may also be drawn. Discussion of the results and their implications is divided into 3 sections for easier understanding. The first section is limited to results that apply to the general population as it existed between 1953 and 1980 (present population). The second section deals with application of the findings to standard clinical neuropsychological assessment of individual patients. The third section discusses the implications of the current findings as they provide information useful in elucidating the aging process itself.

## The Present Population

The results of Study 1 and, to a lesser extent, Study 2 provide considerable information about the average intellectual functioning of people in the age ranges from 20 to 70. It must be clearly understood that the cross-sectional data given here represent both age and generational (cohort) effects. When age-relaged or age-group differences are discussed, they relate to the population as it stands with all the possible environmental, as well as aging-process influences in effect. To answer questions about differential functioning and especially about the functional capabilities of our society, it is advantageous initially to view the results from such a perspective.

1. Retention of prior learning showed no significant change across age groups.
2. Sensory input functions deteriorated significantly with age, but the actual amount of change was modest in this study and limited to the most complex stimuli used.
3. Complex motor output performances deteriorate significantly with age. The change was substantial and systematic up to the 50-59 age range, but then a larger decrement took place. Those in their 60s continued the downward trend. Simple motor output, however, did not change with age.
4. Language functioning decreased significantly for older age groups, but the actual amount of change was small.
5. Complex visuo-spatial performance decreased with age in a linear fashion up to the 60-70 age range, but those in their 60s did much worse than those in their 50s.

6. The pattern of fuctional loss was exactly the same for abstraction processes as for the visuo-spatial area except that the decrements were more severe. (The absolute losses across age groups in abstraction ability were the greatest of any area measured).

These findings, of course, are not unique: the results of research done by a number of other investigators are similar. A major difference between this and most prior research is in the number and type of measures used and/or the systematic application of these measures to subjects across a wide range of ages. Comparison of these results with the findings of prior research will have to be done individually for each functional area.

## Retention of Prior Learning

This experiment used the average scores of Information, Comprehension, and Vocabulary subtests to measure prior learning. The mean raw scores of all 5 age groups in Study 1 were essentially identical on all 3 scales. Wechsler (1944, 1955, 1958) and Doppelt and Wallace (1955) list results very similar to these on their large scale (1700 subjects) normative studies for the WAIS. Jarvik (1973) reported in her aging review that virtually all investigators found either no change or a slight improvement with increasing age on these measures. Study 2 also showed a nonsignificant score increase for the older group. There can be little doubt that age-related changes in retention of prior learning are minimal or nonexistent.

Sensory Input

Performance in the visual, auditory, and tactile sensory areas was used to produce an overall evaluation of the subjects' sensory input ability. The older subjects showed a small but significant decrease in sensitivity to sensory input. Young subjects all exhibited consistently perfect or near perfect scores, while performance of subjects in their 50s and 60s ranged from near perfect to poor. Most of these measures (developed to be sensitive to structural brain damage) were designed as tests that are relatively easy to perform and thus suffer from a ceiling effect when applied to normal subjects. The results, however, are quite in line with findings of other investigators. Weiss (1959) reviewed a large number of studies in visual and auditory sensitivity and noted a small but progressive decline associated with age in these modialities. Visual accommodation (Hofstetter, 1944), eye convergence (Tait 1951), pupil reactivity (Peterson, 1956), and visual field size (Bernstein and Bernstein, 1945; Mann and Sharply, 1947) all decrease systematically with increasing age.

Accuracy and/or response times of older subjects are almost uniformly poorer than those of younger subjects in the visual modiality. The differences appear to increase with the complexity of the task in that the more central processing required in a visual perception task, the more poorly older subjects compare to younger (Basowitz and Korchin, 1957; Botwinick, Robbin, and Brinley, 1959; Korchin and Basowitz, 1956).

Other investigators have noted a similar relationship in visual threshold characteristics. Montgomery (1932), O'Neill (1956), and Rósee (1953) all found a systematic loss in auditory acuity associated with age. The losses were greater at higher frequencies but extended down into the lower range also. König (1957) showed that auditory frequency discrimination deteriorates with age in essentially the same manner as acuity. Sensitivity and reactivity to pain, temperature, and vibration have all been evaluated and consistently decline with age in a manner similar to the changes in vision and hearing (Weiss, 1959).

The sensory changes that occur with age affect the different sensory modalities at slightly different rates and in different ways, but the overall results are clear. On the average, moderate but systematic decrements occur with increasing age, starting in early adulthood and continuing throughout life. In general, the more complex the perceptual processes required, the greater the decrement.

Motor Output

Only two measures were used to evaluate motor output in the current studies--Finger Oscillation speed and speed in completing the Tactual Performance Test (TPT). As a general function, motor ability decreased substantially with age, but the two test measures gave quite different results. Finger Oscillation speed dropped only 6 percent from the youngest to oldest groups in Study 1 (nonsignificant), while the TPT speed dropped 119 percent (TPT time was the best single test discriminator of age group). Considering the literature, this outcome is to be expected; indeed, results other than those obtained would be difficult to explain. Finger Oscillation speed is a simple measure of "pure" motor capability. It involves no decision making and little central processing of any kind. Performance on the TPT, on the other hand, is a complex task. It requires intact sensory input function, integration of the sensory information, and direction of the motor output based on this integration. Although the TPT is primarily a measure of motor output, it involves a considerable central processing component as well.

Sommer (1941), Wagman and Less (1952), and Norris, Shock, and Wagman (1953) all demonstrated statistically significant age differences in peripheral nerve conduction rates, but the actual change was so slight it only amounted to about 6 milliseconds for a simple motor movement. Welford (1977a) reviewed experiments examining simple reaction time across age groups and concluded that the majority of the researchers found only a very slight slowing with age. The same is true of experiments measuring tapping speed between two stationary targets (Morikiyo and Nishioka, 1966; Welford, Norris, and Shock, 1969).

Complex psychomotor tasks, on the other hand, present a very different picture than simple motor output. Welford in his 1959 review and again in a 1980 review, examined a large number of experiments involving tasks of varying complexity. He concluded that the main slowing with age was not in the execution of movements but in the central processes of decision-making. In complex choice motor tasks the increased times were not due to a simple interaction of complexity with age. Rather, they showed a progressive deterioration with age on relatively simple tasks. Complex tasks, on the other hand, showed a large decrement in performance speed appearing at about age 50 without further age-related deterioration. The TPT, however, probably requires a greater degree of central processing (problem-solving) than any of the tasks Welford reviewed. The current results suggest that very simple motor tasks show little age-related change, while very complex motor task performance deteriorates in a nearly linear fashion, starting in the 40s. The exact relationship of age to motor performance is undoubtedly quite complex, but it clearly depends very heavily on the degree of central processing required.

Language Processes

Language processing ability was measured by scores on the Similarities, Arithmetic, and Digit Span subtests, as well as scores on the Speech-Sounds Perception test. In Study 1, performance on the Speech-Sounds Perception test showed a continuous deterioration with age across the younger groups, but a sharp break occurred between the group in their 40s and those in their 50s. Overall there was a 109 percent increase in mean errors between the youngest and oldest groups. The change was highly significant but showed considerable variability within the two oldest age groups. Scores on the Similarities, Arithmetic, and Digit Span subtests showed much less absolute drop (Digit Span equal to 18 percent, Arithmetic equal to 11 percent, Similarities equal to 21 percent) in performance from youngest to oldest groups. Only the age-related change on the Similarites test was significant. Other research supports these findings quite well. Wechsler (1955) used similar age changes on his 20- to 60-year norms. The absolute values are slightly different, but the general pattern is the same. Eichorn (1973) noted slight gains in all 3

Wechsler subtests in adult subjects, but she studied an inadequte age range (16 to 36 years). Eisdorfer and Wilkie (1973) noted a small drop in these scores over a 10-year period for older subjects (aged 60 to 70 years at first testing). The Speech-Sounds Perception test has never been used before to investigate a wide range of ages, but older normal versus young normal comparisons by Reed and Reitan (1963) and Fitzhugh, Fitzhugh, and Reitan (1964) gave results that were consistent with those of this study.

Language processing ability (as opposed to measures more sensitive to prior experience and education) appears to show a mild decline with advancing age. The drop is relatively modest but statistically significant.

## Visuo-Spatial Functioning

Evaluation of visuo-spatial functioning was based upon the Wechsler Performance subtest scores and ability to reproduce a Greek cross. Subjects in their 60s dropped an average of 34 percent on their Performance subtest scores compared to subjects in their 20s. The changes across age groups were consistently linear and systematic. Wechsler's (1955) norms show a 31 percent drop for the equivalent age groups. Other investigators (Blum, Clark, and Jarvik, 1973; and Rhudick and Gordon, 1973) noted little within-subject decline over a 5- to 10-year period, but the performance scores of their subjects at first testing were consistent with those of the present study and with Wechsler's norms. It seems quite probable that the drop shown in the present study for the Performance subtests is representative of the general population.

The picture is somewhat different regarding the rather simple task of reproducing (drawing) a Greek cross. There were no age group differences at all, since most subjects were able to perform this task adequately. The few whose performances were inadequate did not fall in any particular age group. This result was supported by the findings of Study 2 in that the difference between the older normal groups and both the young normal and brain-damage groups was significant for each of the Performance subtests but not for the reproduction of the cross. The older normal group was essentially similar to the young normal group on the cross reproduction measure.

A consistent, systematic decrement in visuo-spatial function appears to occur with each advance in age group. An average drop of about 30 percent was evident for subjects in their 60s compared to subjects in their 20s for complex visuo-spatial tasks. This change was not evident in our findings for a simple visuo-spatial task.

## Abstraction Ability

Scores on the Trail-making test (parts A and B), and the Category test were used to measure abstraction ability. The older age groups showed large decrements on all 3 tasks. Overall, the oldest age groups exhibited greater decrements in abstraction ability than in any of the other functional areas. Subjects in their 60s took about 50 percent longer to complete Trails A, about 75 percent longer to complete Trails B, and made 1½ times as many errors on the Category test as subjects in their 20s. However, abstraction ability was only the second best discriminator of age groups (visuo-spatial was best), because the variability within the older groups was greater than for measures of visuo-spatial functioning. Once again, the older groups showed an increasing rate of performance decrement as task complexity increased. It should also be noted that the Category test (where older subjects showed the greatest decrement) has no time element. In fact, instructions to subjects on this test emphasize accuracy and imply that speed is unimportant.

Results of Study 2 are quite similar to those of Study 1. Abstraction showed the greatest differential between young and older normals but was second to visuo-spatial function in discriminative power due to within-group variability for older subjects. However, even with the increased variability, no subject 60 or older performed as well as the average of the 20's group. Along similar lines, Granick and Friedman (1967) noted a particular age-related decrement in abstract thinking ability even after controlling for educational attainment in their subjects. Reed and Reitan (1962) found similar results in prior research on these same measures.

Overall, the area of abstraction ability showed the greatest age-related decline of any measured.

## Central Processing

Language, visuo-spatial, and abstraction performances were combined to represent the general area of central processing. As noted above, abstraction and visuo-spatial function in particular showed marked age-related decrements. The language processing scores also showed a decline, but to a much lesser extent. Nevertheless, it is quite apparent that every aspect of central processing showed some age-related decrement. These conclusions are supported by the fact that in the sensory and motor areas, performance on complex tests with central processing components invariably declined substantially with age, while tests more reflective of relatively simple sensory or motor tasks did not. The uniformity of the results in this experiment and across the aging literature in general provide assurance that central processing requirements represent the most important factors in age-related intellectual losses.

A number of factors argue for accepting these results as representative of the general population. While 240 subjects are hardly enough to produce actual population norms, the findings of the current study are consistent with the results of prior research. Every study cited agrees with the results noted here, certainly in the pattern of performance and quite closely in absolute scores as well. The statistical analyses added to the level of assurance intrinsic to the interpretation offered. The probability values for age differences in the functional areas were either nonsignificant or else had less than a one in ten thousand probability of occurring by chance. Every statistical method used (and all of these were conservative procedures) gave consistent results within each study and across both studies. Finally, the results are internally consistent. In each case, measures that contained central processing components showed greater decrements than those without. Furthermore, the degree of central processing complexity predicted the amount of decrement. Thus it would appear that these results, at least in broad outline, are representative of the general population.

The results of these studies, when considered in the light of related research, have important implications concerning the social issues raised at the beginning of this paper. Two conflicting perceptions of the elderly were noted earlier--they are alternately seen as possessors of wisdom and as physically and intellectually incompetent. Which is true? The answer, as might be expected seems to be complex in nature. A considerble variation exists between individuals of the same age in performance across the whole range of brain-related behaviors. The incidence of both physically and neurologically debilitating diseases and accidents increases with age, so that major deficits in intellectual performance are more often seen in the elderly than in younger groups. The present studies, however, suggest that even a healthy, neurologically normal older person may be very competent in one situation and have great difficulty in another. Novel tasks or completely new environments are likely to present much greater difficulty for most (if not all) people 60 years of age or older, compared to younger people.

The strikingly decreased ability in abstract reasoning, visuo-spatial problem-solving, concept formation, and other aspects of complex central processing of information suggest that those middle aged or older should make major career changes only after careful deliberation. Even moving to a different part of the country could present serious problems for the older person, especially if the transition were abrupt and the environment drastically different. For example, an elderly person moving from a rural or small town to a large city might very well be overwhelmed by the complexities of adapting to the new location.

The sudden death of a spouse is another situation where an elderly person may be at a special disadvantage. Even without considering the emotional disruption and stress, the complexities of performing the unfamiliar tasks formerly done by the spouse could be very difficult for the elderly. In short, the elderly person is at a distinct disadvantage in any situation that calls for rapid adaptation to unfamiliar people, places, and tasks. An older person, placed in such situations, is quite likely to appear incompetent to others.

In a different set of circumstances, however, the exact opposite may be true. The older individual has a lifetime of learning and experience to draw upon. In familiar situations the older person might well perform as competently as they ever did. This is particularly true where language abilities are required since there seems to be little, if any, age-related loss in this area. In the performance of well learned (even very complex) tasks, as teachers and as advisors the elderly may be able to use their past experience and preserved language functions to advantage.

## Implications for Individual Assessment

Psychological research, while yielding interesting and significant generalizations, often fails to bridge the gap between group analysis and applications to individual subjects. The test measures used in the present research, however, lend themselves to assessing the functional capacities of individual subjects. Indeed, the Halstead-Reitan Battery was specifically designed for individual assessment and diagnosis. How the test measures may be used for assessment and the importance of the present findings for that purpose can best be illustrated by example.

The following two persons had been examined by their neurologists with no positive findings. The first case was selected to exemplify one of the best performances given by a subject in the oldest age group. Case two is representative of the other extreme, demonstrating marked decrements in brain-related performances even though evidence of neurological disease was not present.

## Case One

### Background Information

Case one was referred by a neurologist for neuropsychological evaluation because of her complaints of physical and intellectual deterioration. (For reference purposes, the actual test scores are listed in Table 10.) She had been employed for several years as a bookkeeper when the testing took place.

TABLE 10

Name Case One Age 61 Education 16 R X L ___ Date 4/29/80

Occupation Bookkeeper Sex F Diagnosis Back pain

| | |
|---|---|
| WAIS | X |
| W-B | |
| VIQ | 134 |
| PIQ | 119 |
| FSIQ | 128 |
| VWS | 75 |
| PWS | 52 |
| Information | 16 |
| Comprehension | 17 |
| Digit Span | 13 |
| Arithmetic | 14 |
| Similarities | 15 |
| Vocabulary | 15 |
| Picture Arrangement | 10 |
| Picture Completion | 11 |
| Block Design | 10 |
| Object Assembly | 9 |
| Digit Symbol | 12 |

MMPI

| | | | |
|---|---|---|---|
| ? | ___ | Pd | ___ |
| L | ___ | Mf | ___ |
| F | ___ | Pa | ___ |
| K | ___ | Pt | ___ |
| Hs | ___ | Sc | ___ |
| D | ___ | Ma | ___ |
| Hy | ___ | Si | ___ |

Constructional Dyspraxia

| | | | |
|---|---|---|---|
| □ | 0 | ✣ | 0 |
| △ | 0 | key | 0 |

| | | |
|---|---|---|
| Trails A | | 34 |
| Trails B | | 62 |
| Grip | R | ___ |
| | L | ___ |
| Category | | 55 |
| TPT | R | 7.6 |
| | L | 7.6 |
| | BH | 4.5 |
| | TOT | 19.7 |
| | MEM | 5 |
| | LOC | 0 |
| Rhythm | | 29 |
| Sp. Per | | 5 |
| Tapping | R | 45 |
| | L | 40 |
| FT#W | R | 2 |
| | L | 3 |
| Finger Recog. | R | 0 |
| | L | 0 |

Tactile Form
Errors: RH__ LH__
Time: RH__ LH__

Imp. Index ___

TAC DSS

RH 0 LH 0 B:RH 0 LH 0
RH 0 LF 0 B:RH 0 LF 0
LH 0 RF 0 B:LH 0 RF 0

AUD DSS

RE 0 LE 0 B:RE 0 LE 0

VIS DSS

U/RV 0 LV 0 B:RV 0 LV 0
M/RV 0 LV 0 B:RV 0 LV 0
L/RV 0 LV 0 B:RV 0 LV 0

APHASIA

| | |
|---|---|
| Dysnomia | ___ |
| Spelling Dyspraxia | ___ |
| Dyspgraphia | ___ |
| Letter Dysnosia | ___ |
| Number Dysnosia | ___ |
| Finger Dysnosia | ___ |
| Dyscalculia | ___ |
| Ideokinetic | ___ |
| R-L Disorientation | ___ |
| Dyslexia | ___ |
| Aud. Ver. Dysnosia | ___ |
| Visual Form Agnosia | ___ |
| General Apraxia | ___ |
| Paraphasia | ___ |
| Dysteriognosis | ___ |
| Central Dysarthria | ___ |

Evaluation of Performance

The level-of-performance measures indicate that this woman had been extremely able in the past and continued to do well when compared to her age peers. She earned Wechsler IQ scores in the superior or near-superior range. Verbal and Performance subtests were somewhat unequal, but she still performed better than her peers on even the poorest subtests.

Her scores on tests relating to past learning and education (Information, Comprehension, and Vocabulary) indicated that she has outstanding levels of information and retained the ability to produce the information on request. She performed just as well on measures of more immediate language-processing ability (Digit Span, Arithmetic, Similarities, and Speech-Sounds Perception). In fact, she not only gained higher scores than her age peers on all these measures but performed better than those in their 20s and 30s on everything except Speech-Sounds perception. Her score on Speech-Sounds perception was still equal to the average of those in their 40s. Since language-processing scores appear to drop somewhat with age, her performance in that area was outstandingly good.

The subject's scores in the sensory perceptual area were all superior. She scored perfectly by reporting all unilateral and bilateral Double Simultaneous Stimuli in the

Tactile, Auditory, and Visual modalities and correctly identifying all fingers stimulated on the Finger Recognition test. She also made fewer errors on the complex Finger Tip Number Writing test than her age peers.

Her motor output scores were not as clearly superior as her language and sensory performance. She did somewhat poorly in terms of general norms on a simple tapping (Finger Oscillation) test, but clinical observation has indicated that women are often a little slow on this measure. Her total time on the TPT (a much more complex test) was better than expected for her age. The most that can be said on the basis of her level-of-performance on these tests is that she may have been experiencing a slight deterioration of simple motor facility.

The subject's visuo-spatial function was not only intact but was superior for her age. Her scores on each measure (Performance subtests and drawings on the Aphasia Exam) are like those of a much younger person. In fact, her performances were consistently within the range expected of persons in their 20s. It is possible, of course, that she may once have had even higher abilities in this area. Nevertheless, her current scores were still well above her age peers in a function which drops substantially for most people above 50.

The measures dealing with cognitive flexibility, abstract thinking, and concept formation gave much the same picture. Her scores on Trails A, Trails B, and the Category test were all better than one would expect for a person her age. Although her performances on Trails A and the Category test were poorer than those of most young subjects, they showed less than the expected age-related drop.

Her score in the Rhythm test indicated that she could concentrate on a task extended over a period of time and maintain excellent efficiency. She did do more poorly than expected at remembering the shape of objects after handling them for an extended time, and she had a definite problem remembering the location of the objects in relation to each other (TPT Memory and Localization).

Considering her scores from the perspective of a sign approach, she made no errors indicative of any neurologically significant damage or disease, nor did right-left comparisons present any serious problems. The performance ratio for the preferred and non-preferred hands was about as expected for the tapping test. Although the WAIS Verbal and Performance scores showed a 15 point difference, this finding occurred because of superiority in the areas of prior learning and language processing rather than poor scores on the Performance subtests. The lack of practice effect on the TPT with the left hand, following performance of the task with the right hand, may indicate some mild impairment of the right cerebral hemisphere. However, her scores on this task were generally good, and without additional finding of right cerebral deficit, cannot be interpreted as having any clinical significance. Of the scores particularly sensitive to cerebral dysfunction, only the TPT Localization stood out as showing any deficit. This score, by itself, was insufficient to postulate any problem of a serious nature.

Neurological Implications

None of the results shown by this subject were suggestive of neurological disease.

Implications for Day-to-Day Functioning

The overall pattern of performance was that of someone who has had superior intellectual abilities all her life and in most areas retained the abilities better than her age peers. Considering her reservoir of background knowledge and experience coupled with generally good abilities on more immediate measures of adaptive ability, she should have been able to compete successfully in most intellectual pursuits. It is possible that she once had better motor dexterity and spatial abilities and was reacting to a mild decline in those areas. Considering her generally superior performances, the results indicate clearly that she has not experienced any significant intellectual deterioration for her age, and that the subject's anxiety and concern in this respect might be a result of other types of adjustment problems.

## Case Two

### Background Information

Case Two was referred by a neurosurgeon for a neuropsychological evaluation because of possible deterioration of brain functions. The subject himself did not feel that he had any significant difficulties. He was practicing medicine as a general surgeon at the time of testing. (For reference purposes the actual test scores are given in Table 11.)

### Evaluation of Performance

The subject's education level and job position suggest that in the past he has had abilities which were considerably above average. This inference was supported by his good performance on some of the tests. An analysis of his level-of-performance scores tells us more. He still had an IQ score that fell within the bright-normal range, and he did better than average for his age peers on both the Verbal and Performance subtests.

His scores on tests relating to retention of past learning and education (Information, Comprehension, and Vocabulary) indicate that he had the ability to produce learned information on demand. He did at least as well as

TABLE 11

Name Case One Age 67 Education 23 R 9 L 0 Date 8/6/75

Occupation Surgeon Sex M Diagnosis Normal Aging (extreme)

| WAIS | |
|---|---|
| W-B | X |
| VIQ | 118 |
| PIQ | 115 |
| FSIQ | 115 |
| VWS | 57 |
| PWS | 36 |
| Information | 8 |
| Comprehension | 15 |
| Digit Span | 11 |
| Arithmetic | 7 |
| Similarities | 16 |
| Vocabulary | 15 |
| Picture Arrangement | 9 |
| Picture Completion | 11 |
| Block Design | 8 |
| Object Assembly | 5 |
| Digit Symbol | 6 |

MMPI

| | | | |
|---|---|---|---|
| ? | 50 | Pd | 62 |
| L | 56 | Mf | 63 |
| F | 53 | Pa | 59 |
| K | 55 | Pt | 50 |
| Hs | 47 | Sc | 46 |
| D | 60 | Ma | 55 |
| Hy | 53 | Si | |

Constructional Dyspraxia

□ 1 ✚ 2

△ 1 Key 1

| | | |
|---|---|---|
| Trails A | | 41 |
| Trails B | | 178 |
| Grip | R | 11.3 |
| | L | 13.5 |
| Category | | 111 |
| TPT | R | 15(3) |
| | L | 15(5) |
| | BH | 15.5 |
| | TOT | 45.5 |
| | MEM | 2 |
| | LOC | 0 |
| Rhythm | | 26 |
| Sp. Per | | 5 |
| Tapping | R | 53 |
| | L | 49 |
| FT#W | R | 2 |
| | L | 4 |
| Finger Recog. | R | 3 |
| | L | 3 |

Tactile Form
Errors: RH 0 LH 2
Time: RH 17 LH 21

Imp. Index 0.6

TAC DSS

RH 0 LH 0 B:RH 0 LH 0
RH 0 LF 0 B:RH 0 LF 0
LH 0 RF 0 B:LH 0 RF 0

AUD DSS

RE 0 LE 0 B:RE 0 LE 0

VIS DSS

U/RV 0 LV 0 B:RV 0 LV 0
M/RV 0 LV 0 B:RV 0 LV 0
L/RV 0 LV 0 B:RV 0 LV 0

APHASIA

| | |
|---|---|
| Dysnomia | |
| Spelling Dyspraxia | |
| Dysgraphia | |
| Letter Dysnosia | |
| Number Dysnosia | |
| Finger Dysnosia | |
| Dyscalculia | |
| Ideokinetic | |
| R-L Disorientation | |
| Dyslexia | |
| Aud. Ver. Dysnosia | |
| Visual Form Agnosia | |
| General Apraxia | |
| Paraphasia | |
| Dysteriognosis | |
| Central Dysarthria | |

the average person his age. However, there was considerable variation between the 3 subtest scores.

The same pattern held true for the measures of more immediate language processing ability (Digit Span, Arithmetic, Similarities, and the Speech Perception test). He did extremely well on the Similarities subtest and quite well on the Digit Span subtest; the Speech-sounds Perception test compared to his age peers. His score on the Arithmetic subtest, however, was poor even allowing for his age. Again, there was considerable variability between the different measures. Nevertheless, his overall performance on language processing measures was still better than average for his age peers.

The subject's scores on the sensory perceptual measures were also generally quite good. He made no errors in perceiving either the unilateral or bilateral simultaneous stimuli in the Visual, Auditory, or Tactile modalities. He did make 6 errors each on the Tactile Finger Recognition test. This was about average for his age on the latter test but was much poorer than expected on the Finger Recognition test, especially since performance on this test does not appear to decline much with age.

Motor output scores (Finger Oscillation and TPT total time) showed a great discrepancy of performance. He did very well on the simple Finger Oscillation test and very poorly on the more complex TPT, even allowing for age effects.

His visuo-spatial functioning was quite poor. All of the Performance subtests scores except Picture Arrangement were below the expected level for his age, and he had serious problems reproducing the drawings on the Aphasia Exam.

The measures dealing with cognitive flexibility, abstract thinking, and concept formation showed significant deterioration of the subject's ability in this general area. The Trails B and Category scores were quite deficient, even allowing for age-related changes.

His score on the Rhythm test showed that he was capable of close concentration over an extended period. He did more poorly than expected, however, in remembering the shape of objects and remembering their position in relation to each other (TPT Memory and Localization).

Considering his scores from a sign-approach perspective, he showed no aphasic symptoms and made no errors on the Sensory-perceptual Exam indicative of a neurological disease. His drawings on the Aphasia Exam were sufficiently poor to be considered pathological.

Right-left comparisons did not give evidence of a focal or lateralized deficit. The Finger Oscillation, TPT, Tactile Finger Recognition, and Finger Tip Number Writing right-left comparisons, as well as the Verbal-Performance subtest scores were all in about the expected ratios. The right hand was weaker than the left on Strength of Grip, but the left hand was poorer on the Tactile Form Recognition test.

No consistent evidence pointed to a lateralized cerebral lesion, although deviations from the expected relationships, such as shown by this man, are often present in persons with generalized impairment of the cerebral hemispheres.

Neurological Implications

A number of results which might be considered definitely pathological in a younger person (Category score, TPT scores, Impairment Index, and drawings) are probably not indicative of brain disease subject to specific diagnosis in this case. Rather, they are an extreme example of age related deficits. The deficits are sufficiently pronounced, however, to raise the possibility that the subject may be experiencing the early stages of a generalized degenerative process. The pattern of results in aging and general cerebral degenerative processes overlap so that it is not always possible to distinguish between them.

Implications for Day-to-Day Living

Overall, the pattern of the subject's performance indicated that he once had superior intellectual ability. It is likely that those who who worked closely with him noticed a decrease in work efficiency since he experienced a great deal of difficulty with most tasks involving complex central processing. His verbal ability was still good, but this finding, considered by itself, is misleading. The striking deterioration of ability in abstract reasoning, complex motor skills, and spatial relationships is likely to interfere with his functioning in many day-to-day situations.

The results are of particular significance in consideration of the subject's professional occupation. His ability to process information was seriously impaired--especially in situations where there were a number of things to consider simultaneously. He had difficulty analyzing situations in a logical manner. He was also very impaired in the ability to use his hands in complex manipulatory tasks without the aid of vision, even though his simple motor ability was still quite good. He was impaired in visual-spatial and performance problem-solving tasks. These dificits would seem likely to interfere substantially with his ability to perform as a general surgeon.

## Implications Concerning the Aging Process

The aging process itself is very difficult to pin down. It is relatively easy to take measurements concerning attributes of the current population, but much harder to separate out the environmental (generational) influences from aging influences on any measure. Conclusions about the aging process require additional inferences beyond those needed to relate data to age groups. Unfortunately, it is nearly impossible to construct an adequate experiment to study the aging process in humans. Certainly no one has done so yet. Simple cross-sectional designs confound the aging and environmental differences. Any longitudinal or repeated measures design confounds both sample survival and practice effects with the aging process effects. Cross-sectional studies using lower animals, however, can control environment across generations and therefore provide useful information about the basic biology of aging.

Numerous extensive studies have been done which find decreases with age in the total brain weight of rhesus monkeys (Horrocks, Sun, and D'Amato, 1975); the number of neurons in the mouse (Johnson and Erner, 1972), rhesus monkey (Brizee, 1975; Brody, 1955, 1973), and the number of synapes in the rat brain (Bondareff and Geinisman, 1976; Glick and Bondareff, 1979). Others have noted deterioration of neuron components and neurochemical activity in animals. All of these same effects have been noted in humans when young groups are compared to older groups. Even though the data lacks environmental control in humans, the consistency of a gross pattern of biological deterioration across species makes it seem likely that the deterioration is, in fact, a result of the aging process itself.

Tentative links between biological changes and behavior are provided by the two types of EEG studies discussed in the introduction. Since EEG measures reflect actual physiological events, they provide a way of tying biological changes to behavioral changes. The fact that the kind of EEG changes noted with increasing age are also correlated with decreased behavioral performance of various kinds then becomes important. These findings are entirely consistent with the notion that the performance decrements seen in aging are due, in large part, to biological deterioration. This notion is also consistent with the finding that the above correlations hold for patients with a diagnosis of dementia. The severity of biological deterioration, EEG changes, and behavioral deficits are all greater, but the general relationship is the same.

The present study also sheds some light on this problem. Measures were used which are relatively insensitive, as well as those which are very sensitive, to the biological condition of each subject's brain. Young subjects performances on both kinds of measures were uniformly good. Each successively older age group showed increasing deterioration of performance on measures sensitive to loss of the biological integrity of the brain while at the same time retaining or even improving on measures of prior learning. It should be noted that this pattern was not merely a reflection of comparisons across age groups but was present on many variables for virtually every individual subject also. Since education level was controlled in these studies, it is possible that some of the associated nonbiological environmental effects were also diminished in their influence on group comparisons. The present results, however, suggest that the age-related differences were strongly affected by biological factors. Of course, these biological factors themselves are subject in certain respects to environmental influences and there may be cohort differences which affect them. Nevertheless it is the measures sensitive to biological condition that show age decrements while less biologically sensitive measures show relatively little or none. The behavioral deficits seen here, while appearing to be biologically based, are not identical in either pattern or degree of severity to those seen in a group of subjects with brain damage. These brain-damaged subjects all had diagnosed structural damage of the cerebral cortex, so one can say that the effects of the aging process do not completely mimic those of structural lesions, although the two have a number of similarities.

## Implications for the Future

If one accepts that CNS deterioration takes place with advancing age, this does not mean that the effects on intellectual function are inevitable or immutable. If the biological deterioration has its roots in environmental conditions, the causal agents may eventually be discovered and steps taken to remedy the causes. Even if the biological changes are an inevitable part of the aging process, the picture may not be entirely bleak. Neuropsychologists have been doing intellectual retraining of patients with structural lesions on a clinical basis for some time. A number of researchers in neuropsychology are expressing interest in developing formal programs along this line. Much research needs to be done before the best retraining techniques are found and evaluated, but principles discovered in this area may be very useful in the field of Gerontology. In the future it is quite possible that all aspects of intellectual functioning in the elderly may be maintained or even recovered after deterioration has already occurred.

## Summary and Conclusions

The results of Study 1, believed to be representative of the general population, showed:

1. No age-related changes in measures sensitive to prior learning and education.

2. Significnt age-related changes in the functional areas of sensory input, motor output, language processing, visuo-spatial processing, and abstraction ability.
3. The consistent pattern was of decrements in central processing ability, with greater deficits seen in tasks with the largest central processing components.
4. The test which showed the greatest age-related decrements Category test is not a timed task and has no speed component.
5. The results are useful in clinical assessment of individuals, even though the sample size is not sufficient to consider the results as reliable norms.

The results of Study 2 indicated:

6. Age-related changes show some similarities to changes seen in structural brain-damage, but the age deficits are less severe in all areas and do not appear in retention of prior learning, simple sensory ability, or simple motor output ability.
7. The age-related intellectual deficits may be the result of biological CNS deterioration, but it is still unclear whether the biological changes are due to generational environmental differences, increased incidence of undiagnosed CNS disease, or effects of the aging process itself.

## APPENDIX A

The following is a brief description of the tests used to measure the 6 areas of intellectual functioning. The descriptions are taken from the test manual and various publications of Dr. Reitan's.

Halstead Category Test

This test uses a projection apparatus to show 208 successive slides. Each slide contains four stimulus figures. The slides are divided into 7 subtests, each with its own single organizing principle. The principle in one subtest may be either the same or different from that of the preceeding subtest.

The subject is informed of the nature of the test and instructed to try to find the organizing principle behind the subtest he is working on. He does this by relating the stimulus pattern of a slide to a number between 1 and 4 on the apparatus that represent alternative answers. He is given feedback by means of a bell and buzzer about "right" and "wrong" answers. On the first item in each subtest the subject can only guess at the right answer, but with each successive slide, he can test out various possible organizing principles until he finds the one that always gives him the right answer.

Once the principle is found, the correct response for each slide in the remainder of the subtest is generally apparent, except for the requirement that the principle be applied to modified stimulus configurations.

This test requires psychologic processes (reasoning, abstraction, and concept-formation) that are fundamental to practical intelligence. The subject must observe the similarities and differences in the stimulus material, both within a single slide and across successive slides. He must be able to ignore irrelevant stimulus aspects while recognizing and using the pertinent information.

The test is scored by counting the total number of errors made by the subject in all 7 subtests--a measure of competency in discerning the various principles.

Halstead Tactual Performance Test (TPT)

A formboard with 10 different geometrically-shaped slots is set up on a stand, and the subject is required to place the correct block in each slot as quickly as possible. The subject is blindfolded before the task is begun and uses first the "preferred" hand, then the "non-preferred" hand, and finally, both hands to correctly place the blocks in each consecutive trial. This test requires subjects to deal with problem-solving elements, as well as integrate sensory and motor functions. Since the subject is blindfolded, a good performance requires that the subject adjust to a novel situation and organize his (her) efforts within this situation.

The subject is not notified in advance that three trials will be required. This allows the incidental learning from trial to trial to be measured also.

Performance may be scored either in terms of the time required to complete the individual tasks and toal test, or the mean time required for placing each block.

The subject is asked to draw a picture of the board, reproducing all blocks and placing them in their correct positions. This drawing is then scored (TPT Memory and TPT Localization).

<u>Trail Making Test (Part A)</u>

This paper-and-pencil test requires the subject to connect circles, numbered 1 to 25, in their proper order.

<u>Part B</u>. This test is like Part A except that the circles contain both numbers and letters. The subject is required to alternate between numbers and letters, aking them both in their proper order (i.e., 1 to A to 2 to B etc.). Subjects must be able to locate the correct circle on the paper, and in Part B keep track of letter and number sequences.

Scores are determined by the time taken on each part individually, and a total time is also recorded.

Speech-Sounds Perception Test

Subjects listen to a tape recorded voice saying a series of 60 nonsense syllables and underline the matching sound on a corresponding sheet of paper. They must pick the correct sound from printed alternatives

There is no time pressure in this task. All that is required is the ability to recognize the speech sounds when given orally and when written on paper.

Scores are the number of errors made on the 60 items.

Finger Oscillation Test

This is a simple tapping test where the subject is required to depress and release a small lever with his (her) finger as rapidly as possible. Five consecutive 10-second trials are given for each hand. The test measures simple motor speed, and scores are the average number of taps per trial.

APPENDIX B

1. Retention of prior learning measures were derived according to the following formula: (Information + Comprehension + Vocabulary T-scores) ÷ 3.
2. Sensory input measures were derived according to the following formula: (Tactile DSS + visual DSS + Auditory DSS + Tactile Finger Recognition + Finger Tip Number Writing T-scores) ÷ 5.
3. Motor output measures were derived according to the following formula: (Finger Oscillation test T-scores) ÷ 2.
4. Language processing measures were derived according to the following formula: (Digit Span + Arithmetic + Similarities + Speech-Sounds Perception test T-scores) ÷ 4.
5. Visuo-spatial measures were derived according to the following formula: (Picture Arrangement + Picture Completion + Block Design + Object Assembly + Digit Symbol + cross reproduction T-scores) ÷ 6.
6. Abstraction measures were derived according to the following formula: (Category test + Trails A + Trails B T-scores) ÷ 3.

7. Combined central processing measures were derived according to the following formula: (Language score + visuo-spatial score + abstraction score) ÷ 3.

TABLE 10

Name Case One  Age 61  Education 16  R X  L ___  Date 4/29/80

Occupation Bookkeeper  Sex F  Diagnosis Back pain

| | | | | |
|---|---|---|---|---|
| WAIS | X | Trails A | 34 | **TAC DSS** |
| W-B | | Trails B | 62 | RH 0 LH 0 B:RH 0 LH 0 |
| VIQ | 134 | | | RH 0 LF 0 B:RH 0 LF 0 |
| PIQ | 119 | Grip R | ___ | LH 0 RF 0 B:LH 0 RF 0 |
| FSIQ | 128 | L | ___ | |
| VWS | 75 | | | **AUD DSS** |
| PWS | 52 | Category | 55 | RE 0 LE 0 B:RE 0 LE 0 |
| Information | 16 | | | |
| Comprehension | 17 | TPT R | 7.6 | **VIS DSS** |
| Digit Span | 13 | L | 7.6 | U/RV 0 LV 0 B:RV 0 LV 0 |
| Arithmetic | 14 | BH | 4.5 | M/RV 0 LV 0 B:RV 0 LV 0 |
| Similarities | 15 | TOT | 19.7 | L/RV 0 LV 0 B:RV 0 LV 0 |
| Vocabulary | 15 | MEM | 5 | |
| Picture Arrangement | 10 | LOC | 0 | |
| Picture Completion | 11 | | | |
| Block Design | 10 | Rhythm | 29 | **APHASIA** |
| Object Assembly | 9 | Sp. Per | 5 | |
| Digit Symbol | 12 | Tapping R | 45 | |
| | | L | 40 | Dysnomia ___ |

**MMPI**

| | | | |
|---|---|---|---|
| ? | ___ | Pd | ___ |
| L | ___ | Mf | ___ |
| F | ___ | Pa | ___ |
| K | ___ | Pt | ___ |
| Hs | ___ | Sc | ___ |
| D | ___ | Ma | ___ |
| Hy | ___ | Si | ___ |

| | |
|---|---|
| FT#W R | 2 |
| L | 3 |
| Finger Recog. | |
| R | 0 |
| L | 0 |

**Tactile Form**
Errors: RH__ LH__
Time: RH__ LH__

Imp. Index ____

**Aphasia (continued)**

| | |
|---|---|
| Spelling Dyspraxia | ___ |
| Dyspgraphia | ___ |
| Letter Dysnosia | ___ |
| Number Dysnosia | ___ |
| Finger Dysnosia | ___ |
| Dyscalculia | ___ |
| Ideokinetic | ___ |
| R-L Disorientation | ___ |
| Dyslexia | ___ |
| Aud. Ver. Dysnosia | ___ |
| Visual Form Agnosia | ___ |
| General Apraxia | ___ |
| Paraphasia | ___ |
| Dysteriognosis | ___ |
| Central Dysarthria | ___ |

<u>Constructional Dyspraxia</u>

□ 0   ✣ 0

△ 0   ⚷ 0

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