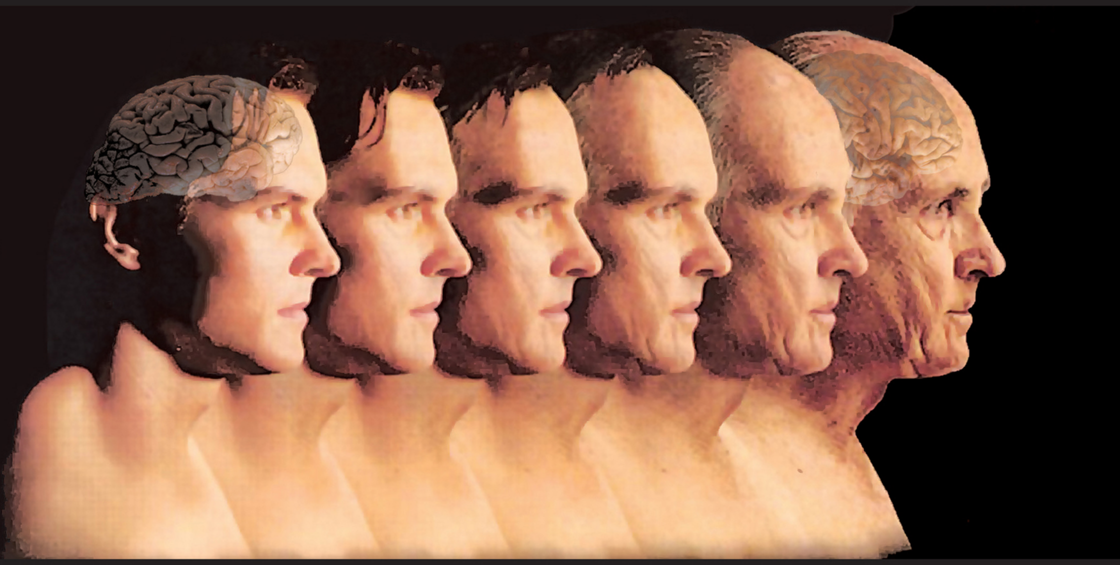
Process of Aging

Social and Psychological Perspectives

Volume 1 and 2



Richard H. Williams,
Clark Tibbits,
Wilma Donohue, editors

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Volume 1

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Volume I

PREFACE

Processes of Aging: Social and Psychological Perspectives is based on studies prepared for an international seminar on the psychological and social aspects of aging in relation to mental health. The seminar was convened to give scientists from North America, Western Europe, and other countries an opportunity to explore together the concepts, methodological problems, and conclusions of their researches in the rapidly growing field of gerontology. Much editorial work has been done in an attempt to present this material in sequential and systematic fashion. Original work of sixty-six research workers from twelve countries is represented in these volumes. They are an inventory of the principal fields of gerontological research, except in the purely biological and medical areas, in the countries where most of the work is currently being done.

Human aging, in its many ramifications, is becoming one of the major areas of research interest among an increasing number of students in the biological, behavioral, and social sciences. Although the phenomena of aging were largely overlooked as subject matter for research during the early stages in the development of all the basic sciences, it was inevitable that students would eventually become curious about the final processes of maturation. What are the causes of decline in the organism? What are the characteristics of psychological capacities, personality, and social adjustment over the life span? What influences do older people exert in creating social norms and expectations? What societal adjustments are being adapted to the increasing number of old people?

Events of recent years have hastened the need for social action on behalf of older people and, consequently, the need for scientific knowledge about their characteristics, circumstances, and requirements. The first half of the century witnessed a great increase in the number and proportion of older people in all highly developed societies of the world and in almost all other countries. Simultaneously, economic changes, stemming largely from the exponential growth in the use of inanimate energy and machines in the production of commodities and services, and changes in culture patterns have altered the status and roles of older people and created many new personal and social problems.

Thus, over the past twenty or more years, all Western nations have shown increased concern over the changes in the age structure of their populations and in the dislocations, problems, and accommodations associated therewith. All affected countries have developed or are developing programs of income maintenance, medical facilities and services, institutional care and housing, and social services designed to enable older people to live as healthy, secure, and satisfied members of society. At the same time, knowledge about the processes of aging, about older people and their needs, and about the impact of older people on social institutions and practices has become a necessity. Research has, in fact, been initiated in virtually every country of the Western world and in the more developed countries elsewhere. The scientific literature on aging has grown enormously, particularly over the past ten to fifteen years. There is increasing evidence of the willingness of public agencies to support research and teaching in gerontology in order to increase understanding of the processes of aging and to provide a firm basis for social planning. It was against this background that the seminar and the two meetings that preceded it took place.

The seminar was a joint undertaking of the Social Research Committee of the International Association of Gerontology, represented by Drs. E.W. Burgess and Clark Tibbitts; of the Professional Services Branch of the National Institute of Mental Health, represented by Dr. Richard H. Williams; and of the Division of Gerontology of The University of Michigan, represented by Dr. Wilma Donahue. The seminar had its origin in a meeting of social and psychological scientists held in Sheffield, England, under the auspices of the Nuffield Foundation, just prior to the Third International Congress of Gerontology (1954). The Foundation's guess that researchers would have common interests was borne out in the enthusiastic response to the conference and in the subsequent establishment of the Social Research Committee with European and American branches in the framework of the International Association of Gerontology. The first seminar organized by the committee took place in Merano, Italy, in 1957.

The first two seminars produced positive results in the form of international acquaintances which led to discussion of mutual research interests, international visits and exchanges, and development of parallel or cross-national studies. The seminar for which the materials in the present volumes were prepared was an extension of the enthusiasm engendered at the first two meetings. The National Institute of Mental Health became involved because it had been cooperating in and supporting several important American studies in some of the areas proposed for consideration in the third seminar. The Professional Services Branch of the National Institute of Mental Health collaborated with the Division of Gerontology at The University of Michigan because of the Division's long experience in organizing conferences, symposia, and seminars on aging and because of its chairman's knowledge of research and research personnel in Europe as well as in her own country.

The National Institute of Mental Health financial support (Grant MHO1962-02) made it possible to bring four Europeans to the United States almost a year before the seminar in order to plan with the American branch of the Social Research Committee. From Europe came Henning Friis of Denmark, Martin Roth and Alan T. Welford of England, and Jean-René Tréanton of France; from the United States the planners were E. Everett Ashley, III, Walter M. Beattie, Jr., James E. Birren, Leonard Z. Breen, Ernest W. Burgess, Ewald W. Busse, Wilbur J. Cohen, Wilma Donahue, Margaret S. Gordon, Robert J.Havighurst, Robert W. Kleemeier, Bernice L. Neugarten, Harold L. Orbach, Klaus F. Riegel, Leo W. Simmons, Alexander Simon, Clark

Tibbitts, Richard H. Williams, Seymour L. Wolfbein, and Marian Radke Yarrow. Maria Pfister attended as a representative of the World Health Organization.

The planning group selected four general topics for the discussions and appointed leaders for each one, as follows: psychological capacities, Alan T. Welford and James E. Birren; personality, life styles, and social roles, Jean-René Tréanton and Robert J. Havighurst; mental health and rehabilitation, Martin Roth and Wilma Donahue; and income, employment, and retirement, Henning Friis and Seymour L. Wolfbein. The seminar was held in Berkeley, California, over a five-day period during August, 1960. The National Institute of Mental Health support, along with National Institute of Health travel grants for the Congress itself, made it possible to defray the travel and subsistence costs of the Europeans. These, with sixty-three American and Canadian contributors and discussants, brought the number of participants to ninety.

Invited papers were prepared in advance of the seminar and made available to all participants. Seminar sessions were conducted as four simultaneous roundtables on specific research problems in each of the areas mentioned above. A final general session gave rise to repeated expressions of the continuing need for interdisciplinary conferences of an international character.

Alan T. Welford, James E. Birren, Marian Radke Yarrow, and Harold L. Orbach participated in the early phases of the editorial work. Final editorial responsibility was taken by Richard H. Williams for Volume I, Parts I and II, and Volume II, Part V; by Wilma Donahue for Volume I, Part III, and Volume II, Part VI; and by Clark Tibbitts for Volume II, Part VII. In Volume I, the focus is largely on individual aging processes. Volume II is concerned largely with social factors and influences on the individual and with the effects of aging on family and social relationships and the larger institutions and norms of society.

Processes of Aging: Social and Psychological Perspectives will be of interest to research workers, teachers, and advanced students concerned with the psychological, psychiatric, psychosocial, and socioeconomic aspects of aging. Many of the theoretical and analytical discussions and the specific studies offer guidance for top-level planners and administrators in public agencies and voluntary organizations.

—Richard H. Williams
—Clark Tibbitts
—Wilma Donahue

CONTRIBUTORS

Volume I

John E. Anderson, professor emeritus of psychology, University of Minnesota, Minneapolis

Seymour Axelrod, assistant professor of medical psychology, Duke University Medical Center, Durham, North Carolina

Louise S. Barker, University of Kansas Midwest Psychological Field Station, Oskaloosa, Kansas

Roger G. Barker, professor of psychology, University of Kansas, Lawrence, Kansas

James E. Birren, chief, Section on Aging, National Institute of Mental Health, Bethesda, Maryland

François Bourlière, M.D., professor, Faculty of Medicine, University of Paris; director, Claude-Bernard Center of Gerontology, Paris

Dennis B. Bromley, lecturer, Department of Psychology, University of Liverpool, England

Ewald W. Busse, M.D., director, Regional Center for the Study of Aging; chairman, Department of Psychiatry, Duke University Medical Center, Durham, North Carolina

Sheila M. Chown, psychologist, Medical Research Council, Unit for Research on Occupational Aspects of Ageing, University of Liverpool, England

Wilma Donahue, chairman, Division of Gerontology, Institute for Human Adjustment, and lecturer in psychology, The University of Michigan, Ann Arbor

Stephen Griew, research associate, Department of Psychology, University of Bristol, England

Ward C. Halstead, director of medical psychology, Department of Medicine, Medical School, The University of Chicago, Illinois

Robert J. Havighurst, professor of education, The University of Chicago, Illinois

Alastair Heron, deputy director, Unit for Research on Occupational Aspects of Ageing, University of Liverpool, England

James Inglis, assistant professor of clinical psychology, Department of Psychiatry, Queen's College, Kingston, Ontario, Canada

Werner Janzarik, M.D., lecturer in psychiatry and neurology; chief physician, Neurology Clinic, University of Mainz, Germany

D.W.K. Kay, M.D., Department of Psychological Medicine, King's College Medical School, Newcastle upon Tyne, England

Bertha Klien, M.D., Section of Ophthalmology, Department of Surgery, Medical School, The University of Chicago, Illinois

Martin Lakin, assistant professor of psychology, Departments of Psychology and Psychiatry, Duke University, Durham, North Carolina

Morton A. Lieberman, psychologist, Department of Psychiatry, The University of Chicago, Illinois

Pat Merryman, Medical School, The University of Chicago, Illinois

Donald F. Morrison, Section on Biometrics, National Institute of Mental Health, Bethesda, Maryland

Christian Muller, Psychiatric Clinic, University of Zurich, Switzerland

Miron W. Neal (deceased), psychologist, Geriatric Research Project, Langley Porter Neuropsychiatric Institute, San Francisco, California

Bernice L. Neugarten, associate professor, Committee on Human Development, The University of Chicago, Illinois

Suzanne Pacaud, research associate, National Center of Scientific Research; assistant director, School of Advanced Studies, Sorbonne, Paris

Felix Post, M.D., physician, The Maudsley Hospital, London

Klaus F. Riegel, assistant professor of psychology, The University of Michigan, Ann Arbor

Martin Roth, M.D., professor of psychological medicine, King's College Medical School, University of Durham, Newcastle upon Tyne, England

Peter Sainsbury, Medical Research Council, Clinical Psychiatry Research Unit, Graylingwell Hospital, Chichester, England

Barry M. Shmavonian, chief psychologist, Psychological Laboratory, Duke University, Durham, North Carolina

Alexander Simon, M.D., medical director, Langley Porter Neuropsychiatric Institute, San Francisco, California

Jean-René Tréanton, research associate, Faculty of Letters and Humane Sciences, University of Lille, France

Alan T. Welford, lecturer in experimental psychology, Cambridge University; fellow, St. John's College, Cambridge, England

Richard H. Williams, chief, Professional Services Branch, National Institute of Mental Health, Bethesda, Maryland

Marian Radke Yarrow, chief, Section on Social Development and Family Studies, National Institute of Mental Health, Bethesda, Maryland

PART ONE

Psychological Capacities

INTRODUCTION

JAMES E. BIRREN

As an adult moves forward in age, there are changes in his thinking, in the way he feels about himself and the world, and in the way he behaves in relation to others. There are also simultaneous physiological changes. These changes may not all be related, and yet most people who have worked in psychology have the clear impression that, to some unknown extent, aging should be considered as the joint product of physiological, psychological, and social factors.

The intention of the seminar on psychological capacity was to follow the relations among these factors in a series of papers and discussions embracing all three. Such a seminar was thought to be especially suitable as an activity of the Gerontological Association, an organization which includes representatives of many sciences and professions.

The planning committee—J.E. Birren, E.W. Busse, A.T. Welford, and Marian R. Yarrow—regarded the seminar as both an inductive and a deductive exercise aimed, on one hand, at making inferences about the likely consequences of physiological factors for health and psychological characteristics and, through these, for social behavior; and attempting, on the other hand, to analyze the factors of environment and individual performance and capacity which affect behavior during later life. The plan was realized by having the seminar participants discuss current research findings and from them to outline likely relationships with other sets of data.

In Part One of this book, the papers have been divided into three sections: (1) those mainly concerned with the analysis of individual behavior in psychological terms, as these were felt to be central to the whole theme; (2) those on the physiological side; and (3) the environmental.

Taking the three sections in turn, Section I deals mainly with problems of cognition ranging from simple perceptuomotor skills, through more complex performances and memory functions, to thinking and problem-solving. The emphasis in these papers is on individual performance, although the authors have been aware of physiological background and possible social influences at work.

Section II contains papers more especially concerned with the attempt to tie behavior to physiological models and to relate age changes in behavior to known physiological changes. Our ability to do this is still rudimentary, but here is a field which is attracting considerable thought and research. The studies range from those which, as far as physiology is concerned, are avowedly speculative, to those dealing with assessments of health in old age using both physiological and behavioral criteria.

Section III attempts to discuss and define the nature of psychological environment in relation to aging. The contented older person who behaves productively and adequately in relation to others and is free from psychopathological symptoms does so not only as the result of sound constitutional and psychological capacities, but also because of a facilitative social environment. This environment has not often been explored, and it was the particular desire of the seminar to examine the ways in which the psychological environment of the older person can be conceptualized as a prelude to effective research in this area.

The form and coverage of the seminar reflect the belief of the planning committee that, although research in psychology, physiology, and sociology inevitably proceeds separately, each has much to gain by keeping in touch with the others and, on occasion, working closely with them. Research on aging has developed in a way that fosters this kind of cooperation, and it is hoped that the present seminar will indicate some of its potential advantages in a practical form.

SECTION I

Studies of Cognition

CHAPTER 1

Intellectual Capacities, Aging, and Man's Environment

JAMES E. BIRREN,
KLAUS F. RIEGEL, and
DONALD F. MORRISON

Whereas we have made significant advance in summarizing what we know about aging, the field is still backward in the sense that it does not have a detailed, articulated map on which one can go from facts about the nervous system to consequences for behavior or from psychological capacities to personality. Since few disciplines in the past have considered extensively the principles which might elucidate the phenomenon of aging, our discussions must still be conducted in a mixture of common-sense language and borrowed terms and concepts.

Generally we tend to be cautious in speculating about the psychology of aging because of the danger that the implications of speculation can become unmanageable in so vast a topic, and obfuscation, rather than clarification, results. My present intent is to steer a middle course between speculation about the subject matter and adherence to results of two recent studies.[1] A usual, though not necessarily stated, intent of speculation is to secure a better understanding of the context of the subject under discussion and of how it might be "articulated." Cornfield (1959) has used the term "articulation" in describing the extent of organization of fields of research: "The degree of articulation of a field is measured by the extent to which the phenomena with which the field is concerned are potentially capable of being explained and predicted in terms of a small number of fundamental concepts and constants" (p. 240). It would seem that the principal function of psychological research on aging is to reduce the great variety of changes in behavior associated with age to a smaller number of concepts.

The word "important" is so often used to describe problems of aging that we might examine a few of its implications. "Important" may connote implied action—do something about important problems, but not about unimportant ones. Another meaning of "important" is frequency; an important problem is characteristic of many people in the population. Severity of consequences is also an aspect of importance. Rare, but severe, diseases may be regarded as important because of the consequences for an affected individual. The meaning of "important" in the sense of pervasiveness lies close to that often found in scientific discussions in which an important problem is one which is central or antecedent to a great variety of related problems and one whose solution would facilitate solution of related problems —it leads to articulation. The psychologist tends to use the word "important" in relation to aging in a mixture of meanings, since he is not frequently in a position of knowing exhaustively the importance of frequency, severity, or pervasiveness.

ENVIRONMENTAL CHANGE FOR PSYCHOLOGY

Although the dramatic changes in man's environment in the past century are subjects for historians, sociologists, and anthropologists, the trends in man's relation to his environment have some

[1] Parts of this paper have been previously published in Birren, J.E., & Morrison, D.F. *J. Geront.*, 1961, **16,** 363-369, and Birren, J.E., Riegel, K.F., & Morrison, D.F. Age differences in response speed as a function of controlled variations of stimulus conditions: Evidence of a general speed factor. *Gerontologia,* 1962, **6,** 1-18 (Basel and New York: S. Karger).

fundamental implications for psychological research. Fewer than one hundred years ago, muscle power of men and animals was the main source of energy in transforming the environment and performing the essential activities of life; motors now do the heavy work. Next, after strength and endurance were made obsolete, man's fine handicrafts began to be replaced by machines. Many fine serial movements requiring precision and careful timing can now, for the most part, be better done by machines. Most of the essential psychomotor skills of our great-grandfathers and grandfathers are irrelevant to the requirements of contemporary life, and only nostalgia keeps some skills alive. Man's role has become that of a long range administrator of his environment in the sense that he programs long range decisions, but no longer carries out these decisions. There are special sensing devices to keep track of events and either inform him or, within limits, directly effect a response.

The question may be raised as to what implications this trend has for psychology and our concepts of intelligence. If we pursue a description of man's emerging role as a decision-maker, we soon find ourselves discussing topics like thinking and consciousness, phenomena of suspicious repute in past psychological research. As a decision-maker and long-term programmer, man must make choices among a variety of possible actions. Reasoning and decision-making about alternatives seems to take place in a period of aroused, but deferred, action, in a state of maximum focused attention or awareness. Few psychologists have found it attractive to study the crucial interval between input and output. Experimental psychologists in general, and particularly those concerned with phenomena of aging, should seriously consider recovering the discarded concept of consciousness and trying to develop methods for studying more closely the associated phenomena. Decision-making in the light of experience and circumstances implies a conscious individual who can tell you what he is doing. If the evolution of our environment is placing us more in the position of decision-makers and programmers and less in the role of effectors, it seems desirable that more attention be given to what goes on between input and output—unless, of course, we wish to assume that the consciousness has no function as an independent variable in determining behavior. The authors prefer to believe that some transformations of information take place in and are fostered by the conscious mind and that these transformations are the antecedents of new behavior.

It would be convenient if we had a measure of reasoning capacity independent of or uninfluenced by that which is reasoned about. The history of psychology, however, shows limited success in obtaining absolute measures of intellectual capacity. In order to estimate the mind's capacities, we seemed to require samples of the mind doing characteristic operations. Perhaps the information theorists may help by suggesting ways in which absolute information-handling capacity of the organism can be measured, but one suspects they are faced with the same limitations in that the content of what is being processed affects the size of the unit being measured. In complex skills the transition from early to advanced levels is often brought about by simplification of the process so that the individual can attend to increasingly large units, as in reading; the highly skilled person attends only to certain critical parts of the task by learning essential cues.

ENVIRONMENT AND MEASUREMENT

It is difficult to maintain that man's capacities as a receiving, processing, and effecting system can be characterized independently of some environment in which he functions. In practice, we have to infer potential capacities from some sample of observed behavior in a particular environmental context; it is most difficult to divorce a description of function from the context in which the function is to be employed. Issues long present in mental measurement are currently being emphasized because of concern about interpretations of data from older adults who are functioning in a constantly changing environment. As long ago as 1906, a committee of the American Psychological Association was appointed to standardize testing methods. In 1954, a subsequent committee made some statements which are relevant here although not specifically pointed at aging (American Psychological Association, 1954):

> Validity information indicates to the test user the degree to which the test is capable of achieving certain aims. Tests are used for several types of judgment, and for each type of judgment, a somewhat different type of validation is involved. We may distinguish four aims of testing:
>
> 1. The test user wishes to determine how an individual would perform at present in a given universe of situations of which the test situation constitutes a sample.
>
> 2. The test user wishes to predict an individual's future performance (on the test or on some external variable).
>
> 3. The test user wishes to estimate an individual's present status on some variable external to the test.

4. The test user wishes to infer the degree to which the individual possesses some trait or quality (construct) presumed to be reflected in the test performance.

The article continues, "To determine how suitable a test is for each of these uses, it is necessary to gather the appropriate sort of validity information" (p. 213). Much emphasis is given to the question of how well the test samples the situation to which reference is being made. One may be impressed, if not depressed, with the lack of evidence about validity of tests for older adults.

FACTOR ANALYSIS

Accounting for age changes in mental abilities in elementary processes is a highly analytical task. One is faced with an array of age changes in mental test scores, and the task is to explain these changes in a minimum of elementary processes. An early task consists of grouping the age-related behaviors according to their common antecedent. One way of proceeding would be to sample a large range of behaviors in a wide range and then to subject the total correlation matrix to a factor analysis which would indicate the clusters of age-related variance. Such an approach allows for the identification of incremental age factors that might result from increased experience and simultaneously allows for the identification of decremental age factors that might result from sensory limitations. The analysis of data from large samples of subjects and measurements is now feasible with machine methods, although gathering data in such a scheme is not so feasible, for it requires that the same subjects be measured on all variables.

A longitudinal study could be analyzed in a similar manner, but the basic datum now becomes a difference value. Correlations would be determined for the differences among measurements separated in time. The factor analysis would identify the common variance among the changes which occur in individuals. A convenient assumption might be that the changes are linear with age. Although not necessarily valid, the assumption is an expedient one for initiating analysis. The day is still distant when fitted individual curves on a variety of measurements will be available so one can analyze the dependencies among the parameters of fitted complex functions which correspond to our verbal statements about aging.

Statistical analysis of individual differences is not usually appealing to the experimental scientist, who prefers to explain relationships he can manipulate, yet the results of factor analyses can be used to point out the cluster of measurements of greatest change with age for more detailed experimental analysis. These clusters can also be examined in order to generate hypotheses which can lead to experiments in which the antecedents can be manipulated.

The results of two studies which were designed to help isolate the nature of age changes in a limited sample of intellectual abilities follow.

PART A: FACTORS IN THE ORGANIZATION OF MENTAL ABILITIES WITH ADVANCING AGE

James E. Birren and Donald F. Morrison

The primary purpose of this study was to apply a statistical method, principal component analysis, to help clarify aging of mental abilities. The subject matter partially resists clarification, because probably there is not one phenomenon, but a group of processes, of aging, and methodologically the separation of these processes is not simple. The recent comprehensive review by Jones (1959) identifies most of the unresolved issues, some of which are under investigation here. The present analysis was based on data obtained with the WAIS (Wechsler Adult Intelligence Scale). Previous studies have been concerned with age changes in scores on the WAIS or the Wechsler-Bellevue (Balinsky, 1941; Birren, 1952; Cohen, 1957a; Cohen, 1957b; Doppelt & Wallace, 1955; Eisdorfer, Busse, & Cohen, 1959; Kallmann & Jarvik, 1959; Wechsler, 1955a; Wechsler, 1955b). The important difference between previous studies and the present one is that this one includes both age and educational attainment as continuous variables in an analysis of intercorrelations of mental test scores.

With advancing age, the cumulative effect of experience presumably leads to increased scores on tests which have a large component of achievement like vocabulary and general information. In contrast, negative correlations are found between chronological age and certain sensory and perceptual functions. To the extent that a test involves a mixture of achievement and perception, the scores should correlate to varying degrees positively or negatively with age. There is also an effect produced by the lower educational attainment of older generations; in the present adult population, educational level is somewhat negatively correlated with age. Other issues remain to be elucidated, like the effect of change in content of education. Is a year of schooling today equivalent to that of thirty years ago?

To discuss the effects of aging, it is useful to have a system of description independent of any particular measurements. The concept of structure of mental abilities embodies the idea of an invariant system of description. Guilford (1960) used the title "A Morphological Model for Human Intelligence" for a paper in which he described a set of logically related factors which may be used to account for individual differences in performance of intellectual tasks. The choice of the term "morphological" is, to our mind, a good one, for it emphasizes the conceptual scheme used in descriptions of the intellect independent of any particular data. If we are required to shift our frame of reference for intellectual abilities every time we change our study population, we are precluded from drawing some of the most important inferences, such as what the major changes with advancing age are in the organization of intellectual function.

For simplicity we might pose an initial hypothesis that an analysis of age and mental test data should show at least one incremental factor reflecting increased experience and one decremental factor reflecting changed functioning of the nervous system. Although suitable for testing, such a simple hypothesis, the principal component analysis of the present study, does not preclude the possibility of identifying larger numbers of mutually independent incremental and decremental age factors in intellectual performance.

The data on which the present analysis is based are part of the standardization data of the Wechsler Adult Intelligence Scale (Wechsler, 1955a). These data were used because they were, perhaps,

TABLE 1
DISTRIBUTION BY AGE AND EDUCATION

	Years of schooling			
Age	0-8	9-12	13+	Total
25-34	58	118	37	213
35-44	151	52	99	302
45-54	54	133	40	227
55-64	85	87	19	191
Total	348	390	195	933

the most adequate available from a population of a wide age span and known characteristics of educational and occupational background. Their use is made possible through the kindness of David Wechsler and the Psychological Corporation. To avoid the problems of language and educational equivalence and opportunity, only data from male and female native-born white subjects were used. Nine hundred thirty-three male and female subjects from twenty-five to sixty-four were used in the analysis (Table 1).

Product moment correlations were computed for thirteen variables—the eleven WAIS subtests, age, and education (Table 2). Correlations were initially determined for men and women separately, but the sex differences were judged to be of impractical significance, so the data were combined. From the data in Table 2 it is possible to compute partial correlation matrices with the subtests intercorrelated with the separate or joint effect of age and education held constant. Table 3 shows the results of removing the effects of education by partial correlation. The correlation and partial correlation matrices were subjected to principal component analyses by Hotelling's method. To conserve space, only the results of the two most pertinent analyses are reported here, that of the original matrix and that with the effect of education held constant.

As might be expected from the size of the correlation coefficients in Table 2, the variance attributable to the first component was rather large (Table 4). Component I accounted for 51 per cent of the total variance in the correlation matrix. This component was identical with the first factor extracted by a centroid factor analysis and can be regarded as the common factor (G) measured to some extent by all subtests of the WAIS. Of interest is the relatively small coefficient associated with age, –.13, in contrast to the higher coefficient for education, .29. In fact, the relation between the first component and education is about as high as that between the first component and any other single subtest; thus, as a single variable, educational attainment is about as good as any other single subtest in estimating the level of ability as measured by the common variance of the WAIS.

When the principal components were extracted from the partial correlation matrix of Table 3, which holds education constant, the first component accounted for only about 37 per cent of the total variance (Table 5). In this analysis the relation of age to the first component becomes trivial in comparison with the WAIS subtests.

In contrast to the first component where age was of little importance, the second component was intimately associated with age.

TABLE 2
WAIS CORRELATION MATRIX
(Decimal points omitted)

	1	2	3	4	5	6	7	8	9	10	11	12
1. Information												
2. Comprehension	67											
3. Arithmetic	62	54										
4. Similarities	66	60	51									
5. Digit span	47	39	51	41								
6. Vocabulary	81	72	58	68	45							
7. Digit symbol	47	40	41	49	45	49						
8. Picture completion	60	54	46	56	42	57	50					
9. Block design	49	45	48	50	39	46	50	61				
10. Picture arrangement	51	49	43	50	42	52	52	59	54			
11. Object assembly	41	38	37	41	31	40	46	51	59	46		
12. Age	−07	−08	−08	−19	−19	−02	−46	−28	−32	−37	−28	
13. Education	66	52	49	55	43	62	57	48	44	49	40	−29

Note — In tables 2-3 *N* is 933 native-born white males and females from twenty-five to sixty-four.

TABLE 3
WAIS PARTIAL CORRELATION MATRIX:
EDUCATION CONSTANT
(Decimal points omitted)

	1	2	3	4	5	6	7	8	9	10	11
1. Inf.											
2. Com.	50										
3. Arth.	46	38									
4. Sim.	48	43	32								
5. D.S.	28	21	38	22							
6. Voc.	68	60	40	52	26						
7. D. Sy.	15	15	18	25	27	21					
8. P.C.	44	39	30	40	27	39	31				
9. B.D.	29	29	33	34	25	26	34	50			
10. P.A.	29	32	25	31	27	32	34	46	41		
11. O.A.	21	22	22	25	17	21	31	40	51	33	
12. Age	17	08	08	−04	−.08	22	−38	−.16	−22	−27	−19

In fact, chronological age was the largest single contributor to the common variance identified in Component II for the analyses reported in tables 4 and 5. In contrast with Component I, Component II accounts for a much smaller proportion of the variance and is narrower in scope in that it involves few subtests. Components III and IV are too small in proportion of variance and relation to age to be discussed here.

If we call Component I the "general ability component" and Component II the "aging component," we would be correct in a descriptive sense, yet the term "aging component" does not imply much in an analytical sense, for we find that the tests are positively or negatively related to the component. The largest negative value was associated with the digit symbol test, known to lower with advancing age; apart from chronological age, the largest positive value was associated with the vocabulary test, known to rise with age in some populations. Thus, in Component II both aspects of the original simple hypothesis—incremental and decremental processes—are demonstrated.

One might choose to look on the age component as bipolar.

However, if one were to interpret Component II literally as a bipolar factor, then high vocabulary scores would necessarily be associated with low digit symbol scores, and conversely. It is difficult to see why low digit symbol scores should necessarily be associated with high vocabulary scores. About the only plausible bipolar factor which could exist in aging would be a use-disuse dimension, in which the degree of use determines the extent to which a function improves, remains unchanged, or atrophies. If selecting the functions we exercise precludes use of other functions, a negative relation would necessarily develop. In this manner, if a high verbal comprehension factor was gained through speaking or reading at the expense of increasing a spatial perception factor, then we would indeed have correlations resulting from the fact that an adult is time-limited—if he does some things, he cannot do others. Because of what we know about changes in sensation and perception with age, the major consideration is not likely to be such a simple, bipolar, use-disuse dimension. Rather, it seems that there are at least two essentially independent processes simultanously operating in opposite directions.

TABLE 4
WAIS CORRELATION MATRIX: PRINCIPAL COMPONENTS
(Decimal points omitted)

	I	II	III	IV	$\Sigma 1_i^2$
1. Inf.	32	28	–04	–12	.199
2. Com.	29	26	08	–20	200
3. Arth.	28	21	–09	42	305
4. Sim.	30	12	00	–25	170
5. D.S.	24	00	–42	69	713
6. Voc.	32	32	–03	–19	242
7. D. Sy.	28	–30	–29	–09	254
8. P.C.	30	–08	–28	–01	173
9. B.D.	28	–22	40	21	336
10. P.A.	28	–19	05	–06	123
11. O.A.	25	–25	53	15	428
12. Age	–13	67	29	21	591
13. Ed.	29	01	–33	–27	266
Latent roots	6.69	1.42	.80	.71	
Variance	51.47%	10.90%	6.15%	5.48%	
Σ variance	51.47%	62.37%	68.52%	74.01%	

TABLE 5
PRINCIPAL COMPONENTS WAIS PARTIAL CORRELATION MATRIX: EDUCATION CONSTANT
(Decimal points omitted)

	I	II	III	IV	$\Sigma\, l_i^2$
1. Inf.	34	32	–03	–07	220
2. Com.	32	25	–16	–16	212
3. Arth.	29	17	41	33	387
4. Sim.	32	11	–15	–32	238
5. D.S.	23	–04	76	11	645
6. Voc.	34	34	–08	–21	285
7. D. Sy.	23	–36	21	–36	357
8. P.C.	34	–12	–20	05	174
9. B.D.	31	–25	–16	41	354
10. P.A.	30	–23	–06	–17	172
11. O.A.	26	–27	–30	51	492
12. Age	–.06	59	–05	34	464
Latent roots	4.39	1.83	.95	.83	
Variance	36.57	15.27	7.90	6.94	
Σ variance	36.57	51.85	59.75	66.69	

To compute component scores for a subject, one cross multiplies scores, coefficients, and sums for each component, thus the individual's standard scores on the subtests are multiplied by the normalized coefficients in columns I, II, III, and IV of tables 4 and 5. These coefficients differentially weight the subtest according to its contribution to the common variance of the components. In a more general manner, one could devise an age index for adults by differentially weighting all subtests according to their correlation with chronological age. This is a less analytical way of proceeding, since the inferences one could draw from a single age index would be less precise than those drawn from component scores. For example, a multiple correlation between age and the eleven subtests can be computed as was done for this sample, yielding the multiple correlation 0.60. If education is held constant, the multiple R between all subtests and age is 0.57. Since this is for the age range twenty-five to sixty-four, the multiple R is somewhat lower than it would be if subjects over sixty-five were included. The opposite trend of digit symbol and vocabulary scores is seen in the multiple regression weights of Table 6. These two tests are weighted about the same in extent, but opposite in sign. This result we had already seen in the principal component analysis, so it seems clear that the two tests are different in their relation to age.

TABLE 6
MULTIPLE REGRESSION OF AGE ON WAIS SUBTESTS:
WEIGHTS BASED ON STANDARD SCORES

Subtest	*Weight*	*Weight, education held constant*
1. Inf.	.08	.12
2. Com.	.00	.01
3. Arth.	.10	.09
4. Sim.	−.11	−.09
5. D.S.	−.04	−.02
6. Voc.	.40	.35
7. D. Sy.	−.43	−.32
8. P.C.	−.08	−.08
9. B.D.	−.09	−.08
10. P.A.	−.25	−.21
11. O.A.	−.04	−.04

Multiple correlation coefficient R = .60 R = .57

One could proceed with the analysis in a different manner by computing the canonical correlations of age and education and the eleven WAIS subtests. This analysis would answer the question: Given two sets of variables (education and age and the eleven subtests), what is the linear combination of the scores in the first set which will have maximum correlation with some linear compound of the other set's variables? The results of the canonical correlations are presented in Table 7. Of the larger values, positive weights with age are seen for vocabulary, information, and arithmetic subtests; negative weights for digit symbol, picture arrangement, picture completion, block design, and similarities.

These findings support the impression one gains from an examination of the graphs of each subtest plotted against age. In Fig. 1 it is seen that educational level makes a difference for all subtests for all age groups. The age trends are less marked, and, for

TABLE 7
CANONICAL CORRELATIONS AND VECTORS FOR AGE AND EDUCATION AND THE ELEVEN SUBTESTS OF THE WAIS

I.

Variable	*Canonical vectors* 1	2
1. Education	1.000	.452
2. Age	−.187	1.000
Canonical correlation	.737	.564

II.

Variable	*Canonical vectors* 1	2
1. Information	.908	.505
2. Comprehension	.115	.036
3. Arithmetic	.014	.244
4. Similarities	.239	−.185
5. Digit span	.138	−.039
6. Vocabulary	.073	1.000
7. Digit symbol	1.000	−.686
8. Picture completion	−.109	−.227
9. Block design	.036	−.192
10. Picture arrangement	.332	−.477
11. Object assembly	.135	−.096

most tests, the age effect is much lower than educational level. Even in the digit symbol test, the effect of educational level is maintained despite the manifest age decline; the educational effect is also seen in vocabulary scores concomitant with the rise in score with age.

DISCUSSION

The fact that education was found to be much more significant for the first component (the *G* factor of the WAIS) than chronological age in the age range from twenty-five to sixty-four is encouraging for improving the intellectual performance of future

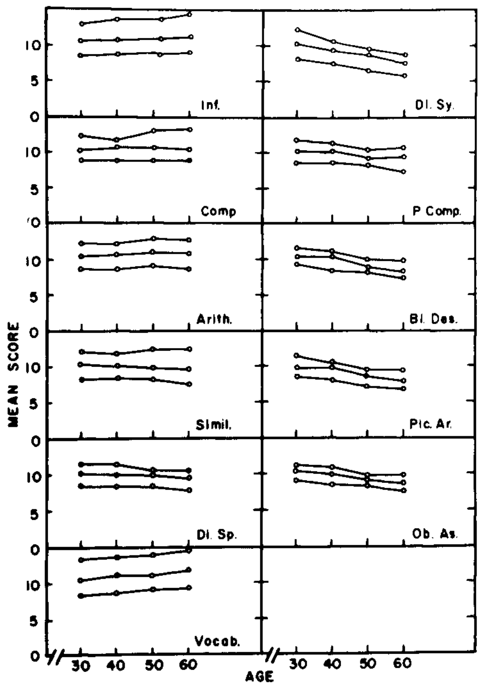

Fig. 1. Mean scores on the WAIS subtests as a function of age and education. Upper curves for education thirteen years and above, middle curves for eight to twelve years, and lower curves for fewer than eight years. Age intervals are twenty-five to thirty-four, thirty-five to forty-four, forty-five to fifty-four, and fifty-five to sixty-four years.

generations of older adults. It is not likely, however, that all the variance removed in the analyses of this study by holding education constant could be attributed to years of education alone. An unknown part is related to educability since, to some extent, the people most likely to profit by further education are selected, or decide to receive more of it. A partial correlation, therefore, removes a mixture of the effects of education and an ability to profit from education. The effect of education may, therefore, be somewhat exaggerated, just as the effect of aging is exaggerated in an opposite direction if the covariance of differing educational attainments of the generations is left uncorrected.

One of the most intriguing aspects of the results is the opposite effects seen in the vocabulary and digit symbol tests. Although these two measures go in opposite directions over the adult years, in childhood they show a concurrent advance. Some hints about such opposite age effects may come from the nature of the tests.

The vocabulary test of the WAIS requires the subject to define an unambiguously presented word. Neither the stimulus, the word, nor the operation of searching for the response seems particularly important. For the most part the subject either can or cannot identify the word. This view does not deny the effects of aging on language functions, but merely indicates that the WAIS vocabulary test is largely a test of stored verbal information which may be increased by living in an advantageous environment. In contrast to the vocabulary test, the digit symbol test consists of an unfamiliar task, translating symbols according to a numbered system. Although the task is timed, the timing seems less important than other features. In a sample of forty-seven elderly men previously studied (Birren, Botwinick, Weiss, & Morrison, 1958), the correlation between the digit symbol test and simple auditory reaction time was .53, whereas its correlations with the block design and the object assembly subtests in the same population were .65 and .72 respectively; thus it is doubtful that inability to record answers quickly is the pertinent variable. Performance on the digit symbol test seems to involve remembering a perceived unfamiliar symbol while performing a decoding operation. Since the digit span test of the WAIS does not show appreciable change with age, it is not likely that the digit symbol performance is low because of inability to retain simple perceptions. It may be, however, that the limiting variable is the ability to keep the symbol in mind while searching to decode it; this would be somewhat analogous to memory through distraction or to task set. Equally plausible, however, is the notion that the decoding operation itself is the critical factor. Beyond this we cannot go at present; future experiment will have to reveal whether the critical element is the operation of transforming symbols or retaining information while the relevant operation is developed.

The principal component method of analysis seems to have had considerable value in this study, for it helped identify the larger sources of variance as well as the effects of age and education. As a consequence of the analysis, the decremental aspects of aging now appear to be more specific in their consequences. We will not attempt to decide whether the principal component method is the only or best method of procedure. The same data were also analyzed by centroid factor analysis with subsequent rotation of axes. The two analyses were comparable in major results; the interpretation of components which involve slight variance was not attempted in either instance, since the reliability of several subtests would not lend itself to having more than a 50 per-cent common variance at the most.

PART B: AGE DIFFERENCES IN RESPONSE SPEED

James E. Birren and Klaus F. Riegel

Previous work has shown that with age there are both incremental and decremental changes in intellectual performance. In language functions older adults perform better, whereas measures involving psychomotor speed and perception frequently favor young adults. The problem is determining the extent to which the incremental or decremental changes associated with age are large or small and whether they are general. The present study compares the performance of young and old adults on tasks in which the symbolic content was varied while the manner of presenting stimuli and registering responses was held constant. Most responses show some increase in latency of response with age, although it is not known what implications extended latencies of a possible neurophysiological basis have for intellectual activity. Slowing down may primarily affect processes of specific response, although, on the contrary, the change in latency of response may represent such a general alteration in the nervous system that no behavior could be expected to be independent of its influence. In this connection, the quality of and capacity for thinking might be limited by the speed of the mediating processes which simultaneously manipulate and synthesize information for appropriate response; slowing down here would reduce the information which can be received. This might be illustrated in listening to a conversation in which a grasp of the issues depends on adequate speed in perceiving and integrating the words.

In addition to assumed biological antecedents, another group of determinants are those of experience. Thus, with age, word associations may differ in strength of habit as a consequence of selective use of certain word combinations. Different response speeds may presumably arise from experience of a special sort. These two general determinants probably overlap; thus, avoiding certain classes of words would not necessarily reflect an experiential determinant since it could also compensate for increased cognitive strain incurred by attempts to grasp certain abstractions. A preference for certain words can arise, and with age there is very likely a unique pattern of word habits typical of a given individual. The individual may also share some general tendency in word usage common to most persons of his age group. Such phenomena may be largely limited to social relations, but they might also have consequences for thinking. Word choices represent not only patterns of expression, but also of thought.

The apparatus used in this study was the psychomet. Its general features were patterned after the apparatus previously developed by Dr. Harry Kay in the psychological laboratory of Oxford University. The present apparatus was designed by Dr. Michael Davis in consultation with Dr. Conan Kornetsky and J. Birren. It consists of a subject's panel on which the light and key associations are programmed and the speed and accuracy of the responses are registered. Fig. 2 shows the physical arrangement of the subject's and experimenter's panels. The experimenter can pair any light with any response button and also present the stimulus lights in any predetermined order. The time the subject takes to respond to the onset of each light by pressing the appropriate button is recorded on 1/100 second electric timers. A total of twenty-two stimulus-response conditions were studied; each condition consisted of ten light-button pairings, and each series was presented twice.

All subjects went through the experimental conditions in the order given below. Each condition was repeated as soon as the data were recorded from the experimenter's panel; the two successive series are designated *A* and *B*. The specific instructions given the subjects are found in Appendix A.

1. *Simple movement time.* The subject presses the buttons as fast as he can from left to right, turning off the lights in the same order.

Lights (L):	1	2	3	4	5	6	7	8	9	0
Buttons (B):	1	2	3	4	5	6	7	8	9	0

2. *Serial simple movement time.* Subject presses the buttons and turns off the lights as above, but begins a new cycle after completing the last response. Each trial consisted of three cycles (thirty responses).

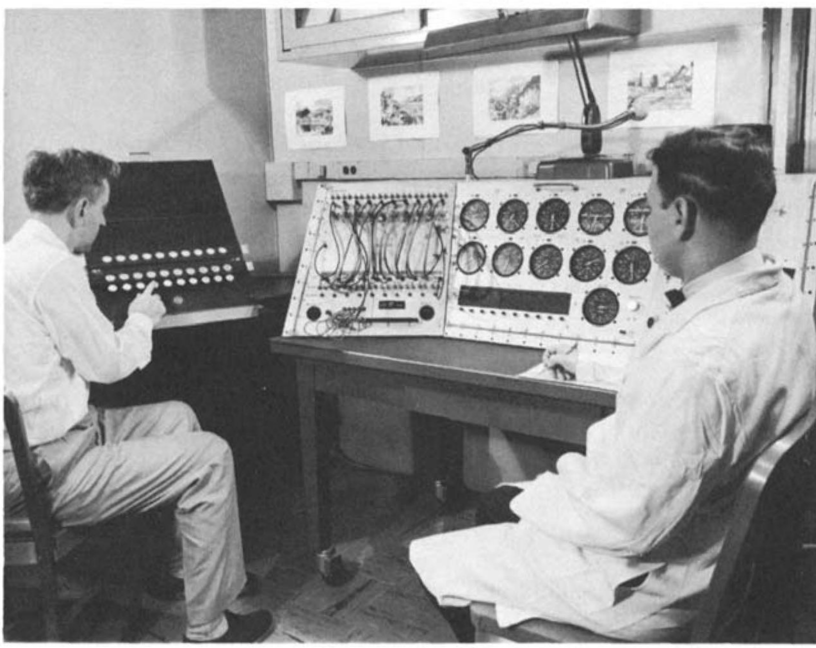

Fig. 2. The psychomet apparatus with the subject's panel on the left and the experimenter's control panel on the right. The subject has been photographed in an askew position in order to show the arrangement of the lights (upper row) and buttons (lower row). Above each button is its coded designation. Start button is placed in the lower center of the subject's panel.

3. *Choice reaction time.* Lights and buttons were regularly paired, but presented in a random order: Light 5 was first, 4 was second, and so on.

L: 5 4 8 9 6 7 2 0 3 1
B: 5 4 8 9 6 7 2 0 3 1

4. *Choice reaction time.* Same as Test 3, but with a different random order.

L: 9 1 8 5 7 4 3 6 0 2
B: 9 1 8 5 7 4 3 6 0 2

5. *Numbers.* The lights and buttons were numbered from 1 to 0. Buttons turn off lights with corresponding numbers. Lights are presented regularly from left to right, but designated with random numbers from 1 through 0; buttons are ordered regularly from left to right.

L: 2 5 7 1 6 0 9 4 3 8
B: 1 2 3 4 5 6 7 8 9 0

6. *Numbers.* Both lights and buttons were numbered from 1 through 0 as in Test 5. Button designations as well as lights were randomized.

L: 0 5 6 9 3 1 8 2 7 4
B: 2 4 7 0 9 3 8 6 5 1

7. *Letters.* Lights and buttons were designated with letters of the alphabet: A through K except J, an ambiguous letter in the style used. Lights were presented regularly from left to right, but designations were randomized; buttons were in alphabetical order from left to right.

L: I D G A F H E K C B
B: A B C D E F G H I K

8. *Letters.* Both light and button designations were randomized.

L: A I G D B K E C F H
B: H F I K B D A C E G

9. *Colors.* Lights and buttons were designated with colors, five with single colors, five with two colors each. Lights were presented in

random order. Y = yellow, G = green, R = red, B = blue, O = orange.

Order:	7	10	2	3	9	6	8	1	4	5
L:	Y	OG	B	GR	O	YR	G	BO	R	YB
B:	R	GR	O	B	BO	G	Y	YR	YB	OG

10. *Colors and symbols.* Lights and buttons were designated with one of two symbols, X or O, and with one of five colors. A correct response consisted of the proper selection of both color and symbol.

Order:	5	8	9	4	6	10	1	7	3	2
L:	YO	RX	GO	OX	RO	YX	BX	GX	BO	OO
B:	RO	GX	BO	OX	YX	OO	YO	BX	GO	RX

11. *Digit symbol.* Lights were designated with numbers 1 through 10; buttons were designated with symbols which had to be decoded by reference to a card placed on the subject's panel; lights were presented regularly from left to right.

L:	5	2	10	3	6	1	7	9	8	4
B:	D	S	P	V	C	U	Y	T	L	H

Decoding card:

1	2	3	4	5	6	7	8	9	10
P	L	S	H	U	V	C	Y	D	T

All the verbal relations stimuli (lights) were presented from left to right in regular sequence. See Appendix A for instruction details.

12. *Syllable matching.*

L:	be	cor	ex	tab	ans	gard	den	sold	morn	im
B:	ex	gard	tab	morn	im	den	be	ans	sold	cor

13. *Word matching.*

L:	short	cold	foot	girl	light	blue	head	joy	bed	salt
B:	bed	blue	foot	salt	cold	girl	short	joy	head	light

14. *Word association.* Button with the word which goes best with the stimulus is pressed.

L	B
table	flower
man	woman
slow	bird
hard	soft
eagle	short
bread	butter
long	fast
hammer	chair
king	queen
blossom	nail

15. *Word association.*

L	B
hand	fear
whistle	mind
wish	stop
earth	grass
memory	foot
bath	tiger
child	baby
lion	clean
green	want
afraid	round

16, 17, 18. *Word relations.* The same stimulus words are used for response words of three kinds—coordinates, superordinates, and parts.

L	B coordinates	B superordinates	B parts
scissors	adult	animal	page
fruit	ant	tool	tone
baby	beer	edifice	blade
house	Koran	liquid	feeler
whiskey	earth	art	angle
moon	tongs	person	orbit
music	hotel	planet	arm
square	meat	figure	peel
spider	poetry	scriptum	alcohol
Bible	rhombus	food	walls

19. *Word completion: adjectives and adverbs.*

L	B
al	haps
hap	py
rath	ant
pleas	ten
pret	deed
sud	el
in	er
of	most
per	ty
cru	den

20. *Word completion: concrete nouns.*

L	B
val	en
win	tain
mon	ley
kitch	nal
moun	ion
farm	ey
jour	dow
bu	ny
po	reau
on	er

21. *Word completion: verbs.*

L	B
ap	ter
fol	pear
ad	fer
ar	get
ex	mit
for	turb
suf	rive
dis	low
flat	tain
main	pect

22. *Word completion: abstract nouns.*

L	B
pow	ner
sys	ces
af	er
ef	fair
man	lem
meth	tion
na	od
prob	it
spir	tem
suc	fort

Thirty young and twenty-three elderly adults were studied. The young group consisted of fifteen men and fifteen women between eighteen and thirty-three years. Their mean education was 14.0 years. Thirteen were religious volunteers for research in the Clinical Center of the National Institutes of Health; the remainder were volunteer employees. The elderly group consisted of women and men in the age range of sixty to eighty. Their mean education was 12.9 years. These subjects were all volunteers and either retired government employees or spouses of retired employees.

Under all experimental conditions the elderly subjects were slower in their responses than the young subjects. In Table 8 the mean values of the two groups are shown; the means of the older group were, in almost all instances, more than one standard deviation greater than those of the younger group. The differences in response time can be considered in both absolute and relative terms. The smallest absolute age difference in the mean values for the two age groups was in simple movement time, about .14 seconds, and choice reaction time. The differences in choice reaction times were .18 and .16 seconds. The largest differences were in work relationships; superordinate, part, and coordinate association times differed by 1.75, 1.99, and 1.86 seconds respectively. Several of the word association measures did not show such large relative age differences as some of the simpler tasks.

The experimental conditions showing a large absolute and a large relative difference in mean response time were color matching; color and symbol matching; digit symbol; superordinate, coordinate and part word associations; and word completion using verbs. Those showing least absolute and relative age difference were the choice

TABLE 8
INTERCORRELATIONS OF PSYCHOMET VARIABLES:
YOUNG SUBJECTS ($N = 30$), MEDIAN VALUES, FIRST TRIAL
(Decimal points omitted)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1.		53	15	23	−01	−18	−07	05	−23	−17	−26	04	−05	−44	−16	−12	−32	−10	−26	−33	−10	−08
2.			41	45	16	−04	10	30	−05	09	−05	13	10	−19	−03	08	−25	19	−15	−02	−04	−04
3.				77	52	07	41	04	−12	30	20	12	30	02	−13	−07	−16	17	17	18	22	33
4.					60	09	57	13	−12	44	39	27	35	−13	03	02	−15	26	12	08	20	30
5.						14	55	30	29	58	33	56	49	22	30	10	02	30	23	04	15	29
6.							16	42	08	37	28	23	10	−02	33	34	39	34	12	42	14	42
7.								34	29	53	20	52	40	07	33	20	24	12	05	30	36	34
8.									26	37	−10	36	36	16	35	52	30	25	03	19	07	16
9.										47	−07	34	25	23	22	39	11	25	08	31	11	05
10.											10	37	37	23	43	34	12	42	12	41	12	21
11.												11	02	23	25	−11	05	38	35	06	27	40
12.													44	13	42	31	43	25	22	16	37	47
13.														31	22	42	17	27	45	12	16	35
14.															58	33	27	38	65	28	34	30
15.																43	30	44	41	30	33	35
16.																	52	48	40	42	38	41
17.																		26	26	30	37	31
18.																			54	47	44	46
19.																				38	53	56
20.																					62	45
21.																						79

TABLE 9
PRINCIPAL COMPONENT ANALYSIS
OF CORRELATIONS IN TABLE 8
PSYCHOMET RESULTS: YOUNG GROUP, MEDIAN VALUES,
FIRST TRIAL

Variable	*Component**				
	I	II	III	IV	V
1	−.33	.71	−.23	1.00	−.48
2	.13	80	−.24	.89	−.45
3	.49	88	.56	−.01	.24
4	.60	1.00	39	−.05	.16
5	.84	.63	−.08	−.85	−.07
6	.66	−.17	−.22	.52	1.00
7	.85	.48	−.26	−.43	.45
8	.67	.10	−.99	.43	−.04
9	.55	−.21	−.81	−.64	−.10
10	.90	.28	−.53	−.61	29
11	.51	.08	1.00	−.43	.47
12	.88	19	−.43	−.04	.04
13	.81	25	−.26	−.33	−67
14	.72	−.55	.31	−.61	−76
15	.88	−33	−19	−16	−19
16	87	−.38	−58	64	−35
17	65	−58	−29	36	39
18	94	−11	.26	37	−.23
19	85	−38	.76	−.02	−.69
20	83	−.33	.11	.45	39
21	89	−.21	.66	65	3
22	1.00	−.04	.63	.62	11
Latent roots	6.47	3.16	2.13	1.60	1.39
Proportion of variance in component	29.4	14.4	9.7	7.3	6.3
Cumulative proportion of variance		43.8	53.5	60.8	67.1

*Largest variable set equal to 1.00; others adjusted proportionately.

reaction time measurements. In view of the work that has established the fact that reaction times show significant differences with age, it is surprising that reaction time is not necessarily the task in which the largest difference in speed appears, either absolutely or relatively. In a general way, the difference in speed appears to increase as the task requires more manipulation of the stimulus before a response is given.

The effects of randomizing the numbers or letters on response buttons can be examined by comparing the performance of the subjects on experimental conditions 5 and 6 (numbers) with 7 and 8 (letters). In both instances the essential difference between succeeding experimental conditions is between a regular order and a scrambled order of response buttons. In both instances the elderly subjects showed a greater difference in response time than did the young when responses were randomized in position (number .38 versus .56 seconds; letters .46 versus .68 seconds, respectively). In percentage terms, however, both groups increased their response time to approximately the same extent in the scrambled response order. This suggests that for both age groups the time required with increased complexity is in proportion to the time required in the more regular stimulus response associations.

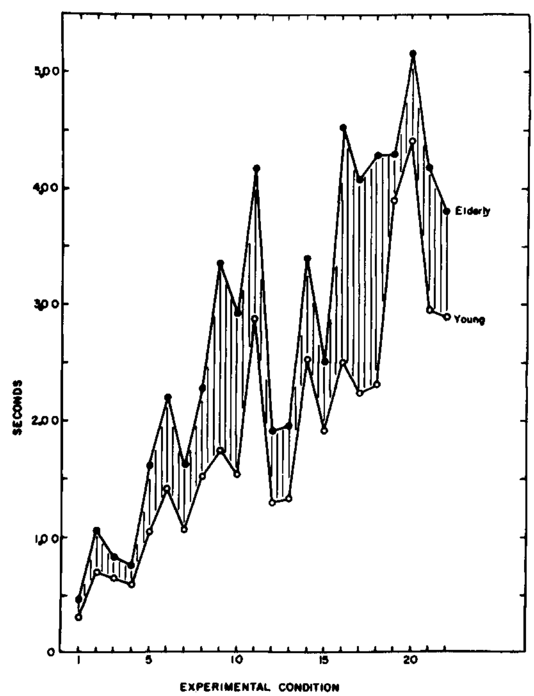

FIG. 3. Performance time for elderly and young subjects on twenty-two experimental conditions.

TABLE 10
MEAN TIME OF CORRECT PERFORMANCE OF YOUNG AND ELDERLY SUBJECTS ON THE PSYCHOMET: INDIVIDUALS, MFDIAN VALUES, FIRST TRIAL
(In hundredths of seconds; decimal points omitted)

		Experimental condition																					
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16S	17P	18C	19	20	21	22
Young	Mean	32	70	64	58	104	142	105	151	174	153	288	129	133	252	181	250	223	230	389	442	294	279
	σ	9	12	8	6	12	27	11	27	40	21	49	22	22	80	53	82	65	52	23	251	124	122
	N	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	29	30	29	29	25	28	29
Elderly	Mean	46	105	82	74	161	220	162	228	336	292	418	190	195	340	250	453	408	428	428	516	418	380
	σ	18	34	10	10	29	51	31	47	160	96	65	41	38	89	59	136	124	104	205	256	159	97
	N	21	21	21	21	21	21	21	20	21	20	21	21	21	21	21	21	21	21	21	20	21	20
Old-young		14	35	18	16	57	78	57	77	162	139	130	61	62	88	69	203	185	198	39	74	124	101
Per-cent difference		144	150	128	128	155	155	154	151	193	191	145	147	147	135	138	181	183	186	110	117	142	136

The median response times of the subjects were all intercorrelated for the twenty-two experimental conditions. This yielded two correlation matrices, one for the young and one for the old. Each matrix was analyzed by the principal component method.

The analysis suggests two differences between the age groups. The young group has a smaller first component which is not so consistent as that of the elderly. The first component for the elderly accounted for 46 per cent of the total variance, whereas in the young it accounted for 29 per cent (tables 9 and 10). Furthermore, in the young group the simple movement time measurements showed little relation to the first component. Thus, how quickly the young make simple movements has little relation to the time they require in making responses when various symbolic manipulations are involved. By contrast, the results on the older subjects show both simple and complex speed measurements to be related.

Of particular interest is the fact that the digit symbol condition correlated very highly with the first component in the elderly group, as high as that for choice reaction time. The digit symbol test, when given as a part of an adult intelligence test, has been found closely related to chronological age. The present findings suggest that it shares an important common process with speed measurements, which grow in pervasiveness with advancing age.

SUMMARY

1. The purpose of this study was to compare the speed of performance of young and elderly subjects in a standardized experimental context, varying the nature of selected stimulus and response associations. The subject's task was to respond to one of ten signal lights by pressing one of ten buttons. There was always a predetermined association between lights and buttons. The subject turned off the ten lights serially by pressing the correct buttons as rapidly as possible. A total of twenty-two experimental conditions were used, ranging from simple movement and reaction times through numbers, letters, colors, symbols, and word associations of a predetermined nature.

2. Thirty young subjects, between eighteen and thirty, and twenty-three elderly subjects, between sixty and eighty, were studied. Under all experimental conditions the elderly subjects were slower than the young. The largest relative and absolute differences appeared for the superordinate, coordinate, and part word associations, and the

color and color symbol associations. The smallest differences were found for reaction time and adjective word associations.

3. It is apparent from these results that differences between young and old in speed of response are not limited to the simple motor aspects of tasks, but involve, to a greater extent, the associative processes. Even if one were to dissociate the time required for simple reaction time from the response times for complex associations, only about 10 to 15 per cent of the differences between age groups would be removed. Furthermore, it is not obvious that this is a justifiable computation, since the difference may involve processes common to any stimulus-response association, including relatively simple choice reactions and complex verbal associations.

4. The increased common variance with differences in speed of association requires further analysis, since some generality of process is implied.

APPENDIX A

Psychomet Instructions

1, 2. This we call a psychomet. You notice here that there are lights and keys. You may press one of these buttons or keys. You see it depresses and clicks. Now what I am going to do is to have these lights light up, and your task is to turn them out as fast as you can by depressing the key beneath each light. Just like this. You see? Every time you press a key, a light will go out, and another light will come on. When you are ready, press the green button. That will turn on the first light, and then do the task as fast as you can. Press the keys just as fast as you can. Are there any questions? Try to make no errors. If there are no further questions, sit there comfortably, and, as soon as you are ready, press the green button and go. Ready?

3, 4. *Reaction time.* Instead of the lights coming on in a regular order, this time they will come on in a somewhat random order. However, the key beneath each light is a key which turns the light off. Understand? When you are ready to go again, press the green button. As soon as you press the green button, the first light will come on. Turn that light off by pressing the key beneath it. The lights will come on in a random order. Just like before, I want you to do this as fast as you can without making errors. Any questions? As soon as you are comfortable, press the green button and go. Ready? Now I am going to have you do another series, but this time the lights will come on in different order. The task is the same. As soon as the light comes on, turn it off by pressing the key beneath it. Ready?

5. *Numbers.* This time it's going to be a little different. When the lights come on you will see a number there, and each key is also numbered. You see there is a number above each key. The number

above each key will tell you which light it turns off. That is, suppose this first light had a number 2 on it. Key number 2 would turn that light off. In some of these procedures the lights will not be numbered in order from 1, 2, 3, 4, 5, up to 0, but may be randomized; always remember the key with the same number as the light, turns off that light. No matter how they come on, you press the key with the corresponding number, and that will turn off the light. Are there questions?

6. This time the task is just about the same for you. The difference this time is that the numbers in the lower set, or the key numbers, are not in regular order but are scrambled. Would you read aloud for me the numbers above the keys? I want to impress upon you the fact that the numbers are scrambled. Read. If there are no further questions, get comfortable and press the green button when you are ready to go. Ready?

7. *Letters.* This time instead of having numbers for the lights and keys, there will be letters, but the same principle holds. That is, if the light has a letter A, Key A turns off that light. Light B is turned off by Key B and so on. In the first case you will see that the lights will come on in regular order from left to right except the letters do not come in any particular order but are scrambled. You will notice that the keys are lettered regularly A, B, C, D, and so on. Are there any questions? Remember the key with the same letter as the lights turns off that light. When you are comfortable and ready to go, press the green button. Ready?

8. This time the task is almost the same except that the letters above the keys are now scrambled. I would like to have you read to me the letters above the keys to show how they are scrambled. Please read.

9. This time, instead of having numbers or letters, the lights will come on showing different colors. The principle, though, is still the same. The key with the same color as a light turns off that light. For example, a light with red will be turned off by a key with red. To be sure you see the colors the same way I do, I would like to have you name the colors in the lower row or the key colors from left to right. This is what? Please read. That's right. As before, when you are ready to go, press the green button, and the first light will come on showing a color. Turn that light off by pressing the key with the same color. All right? Ready; go.

10. This time the task is almost the same except that we have added a symbol over a color. That is, you will see the symbol X or O placed over a color. The principle is the same, however. The key which has the same color and symbol as the light turns off that light. For example, Symbol O on top of the color green would be turned off by the key with Symbol O on green above it. This time then you have to use two facts to decide which key to press, the color and the symbol—whether it is a cross or a circle. When you are ready to go, press the green button and the first light will come on. Match the color and the symbol with the proper key. Ready? Go. Please read the lower row or the key colors and symbols from left to right.

11. *Symbols.* This time the task remains the same but has an additional feature in it which I will explain to you. Each light will turn on a number. On the card above the lights row you will see a row of numbers. For example, if the light came on lighting up Number 1, below Number 1 you will see a symbol. This is the symbol which you look for in the lower row, or the key row. This symbol will turn off that light. The task thus consists of looking at the light which has come on, reading the number, looking for the number in the top row of the symbol key, finding the symbol below it, and then looking for that symbol in the key row and turning off the light. Let me show you an example. Suppose the light came on lighting up Number 9. What key would you press to turn off Light 9? That's correct. Suppose the light came on illuminating Number 2. What symbol key would you press to turn off Light 2? That's correct. As soon as you are comfortable, press the green button and go. Ready?

VERBAL RELATIONS

Controls

12. This time we will have a syllable in every window or circle. The syllables above the keys tell you which light they turn off. That is, suppose the first light had the syllable "tab" on it, then *this* key would turn off the light. The lights will come on one after the other in a regular order. The left light will come on first after you have pressed the green button. Before we begin, please read all syllables on the lower row aloud to me.

13. This time we will have a word in every window or circle. The word above each key tells you which light it turns off. That is, sup-

pose the first light had the word "girl" on it, then *this* key would turn off the light. The lights will come on one after the other in a regular order. The left light will come on first after you have pressed the green button. Before we begin, please read all words on the lower row aloud to me.

Word Association

14, 15. This time there will be words again on the circles which may help you to find the correct button. *Select always that word on the lower row which seems to go best with that on the upper row.* Before we begin, read all the words in the lower row aloud to me.

Word Relations

16, 17, 18. The next task needs a short explanation. If you take any word, there are always a number of others which belong to it which are coordinates to the word. For instance, coordinates to the word "chair" are table, bed, cabinet, desk, couch, bookshelf, bench.

All these coordinates have something in common; all denote parts of the household—products, furniture, equipment. One calls such a word as "furniture" a superordinate to the word "chair." It includes more or embraces more. Finally, all the things named above consist of many parts. Thus parts of a chair are the legs, the wood, the seat, the back.

Altogether we have three groups of words: coordinates, superordinates, and those which denote parts. (The instruction may be repeated.)

Now, in the first (second, third) problem it will be your task *to select always that word in the lower row which is a coordinate to the word which will appear in the upper row.* Make as few errors as possible, and work as fast as you can. Before we begin, read all the words in the lower row aloud to me.

In the second (first, third) problem, it will be your task *to select always that word in the lower row which is a superordinate to the word which will appear in the upper row.* Make as few errors as possible and work as fast as you can. Before we begin, read all the words in the lower row aloud to me.

In the third (first, second) problem, it will be your task *to select always that word in the lower row which denotes a part of that thing which will be named in the upper row.* Make as few errors as possible and work as fast as you can. Before we begin, read all the words in the lower row aloud to me.

Word Completion

19. In the last task, only syllables will be presented in the circles. *One syllable in the upper row and one syllable in the lower row will make up a word.* The first syllable will be always in the upper row. In the first problem these words will be adjectives or adverbs like clev-er, ex-tra, ear-ly, charm-ing. Before we begin, read all the syllables in the lower row aloud to me.

20. In the second problem, the words will be concrete nouns; that is, they will denote something which you can touch, see, smell, or hear, like brid-ge, fin-ger, la-ke, bro-ther. Before we begin, read all the syllables in the lower row aloud to me.

21. In the third problem, the words will be verbs like re-main, pre-tend, pun-ish, en-ter. Before we begin, read all the syllables in the lower row aloud to me.

22. In the fourth problem, the words will be abstract nouns; that is, they will denote something which one can just think of, which are mere ideas like beau-ty, de-gree, ac-tion, mo-ment. Before we begin, read all the syllables in the lower row aloud to me.

REFERENCES

American Psychological Association. Technical recommendations for psychological tests and diagnostic techniques. *Psychol. Bull. Suppl.,* 1954, **51,** 1-38.

Balinsky, B. An analysis of the mental factors of various age groups from nine to sixty. *Genet. Psychol. Monogr.,* 1941, **23,** 191-234.

Birren, J.E. A factorial analysis of the Wechsler-Bellevue scale given to an elderly population. *J. consult. Psychol.,* 1952, **16,** 399-405.

Birren, J.E., Botwinick, J., Weiss, A.D., & Morrison, D.F. An analysis of perceptual and mental tests given to healthy elderly men. *J. Geront.,* 1958, **13,** 444. (Abstract)

Cohen, J. A factor-analytically based rationale for the Wechsler adult intelligence scale. *J. consult. Psychol.,* 1957, **21,** 451-457. (a)

Cohen, J. The factorial structure of the WAIS between early adulthood and old age. *J. consult. Psychol.,* 1957, **21,** 283-290. (b)

Cornfield, J. Principles of research. *Amer. J. ment. Defic.,* 1959, **64,** 240-252.

Doppelt, J.E., & Wallace, W.L. Standardization of the Wechsler adult intelligence scale for older persons. *J. abnorm. soc. Psychol.,* 1955, **51,** 312-330.

Eisdorfer, C., Busse, E.W., & Cohen, L.D. The WAIS performance of an aged sample: The relationship between verbal and performance IQ's. *J. Geront.,* 1959, **14,** 197-201.

Guilford, J.P. A morphological model for human intelligence. Paper read at the National Academy of Sciences, Washington, D.C., April 25, 1960.

Jones, H. Intelligence and problem solving. In J.E. Birren (Ed.), *Handbook of aging and the individual: Psychological and biological aspects.* Chicago: The University of Chicago Press, 1959. Pp. 700-738.

Kallmann, F.J., & Jarvik, Lissy F. Individual differences in constitution and genetic background. In J.E. Birren (Ed.), *Handbook of aging and the individual: Psychological and biological aspects.* Chicago: The University of Chicago Press, 1959. Pp. 216-263.

Wechsler, D. *Manual for the Wechsler adult intelligence scale.* New York: Psychological Corporation, 1955. (a)

Wechsler, D. The measurement and evaluation of intelligence of older persons. In *Old age in the modern world,* Edinburgh: E. &. S. Livingstone, 1955. Pp. 275-279. (b)

CHAPTER 2

Psychological and Psychomotor Functions in Aging

SUZANNE PACAUD

To the present, research in biometrical and psychological gerontology has tended to be separate from research in general or comparative psychology and biometrics. This is to be deplored. None of the problems raised by the latter investigations has yet found its place in any gerontological research except A. T. Welford's works on age and skill (Welford, 1951; Welford, 1958). This is easy to understand considering the lack of data which would lead gerontological research in that direction, but it seems that it is a particular turn of mind, rather than lack of data, which has prevented researchers in gerontology, whose scope was exclusively observation of the aged, to use their investigations on senescence to clarify the fundamental problems of biometrics and psychology. So doing, they deprived gerontological research of the possibilities of formulating its own theoretical foundations. I wished to contribute to another way of thinking in gerontology by studying whether intellectual and psychomotor functions underwent changes in aging. For this purpose I chose the method of factor analysis.

The fundamental object of all the sciences is unique; the form of expression, nevertheless, changes with the methodology of the disciplines. In this research we shall apply only the techniques in Thurstone's *Multiple Factor Analysis* (Thurstone, 1947). I believe it necessary to recall, at the start, the definition which Thurstone (1955) proposed at the Factor Analysis Colloquium in Paris. The fundamental object of each science, according to Thurstone, is the accumulation of data and the determination of principles which enable one to draw precise predictions in a particular discipline. The factor analysis contributes to the realization of this aim in two ways: (1) directly, by condensing and identifying the sources of variance, thus attempting a conceptual frame which could make possible the understanding of behavior; (2) indirectly, by isolating factors, making it possible to suggest variables and patterns of variables which might be studied more intensively by other methods. It seems to me this study finds its justification in this definition.

For a long time studies using factor analysis have shown that psychological and psychophysiological functions tend to group into constellations though the structure of such groupings is still under discussion. These discussions, however, are usually concerned with the superiority of one or another technique—the naming of factors, their independence or hierarchical order, or, in the latter case, the primacy of one factor. The factorial structure of the functions has never been questioned. Its study, in connection with age, has given rise to numerous works, mostly related to children, where the *G* factor has been identified many times with the factor of intellectual maturation. Besides, whatever the significance given it, the *G* factor does not seem to vary in the course of development, even in children from ten to fourteen years old, who have outgrown the stage when tests in which the *G* factor does not predominate may be used almost exclusively.

Thus I decided to reconsider the problem which is essential for elaborating in psychology a valid theory of the structure of psychological functions. We believe gerontological research can shed new light on the problem, which we phrased this way: Whatever the factorial structure observed in a group of young adults, is it modified in older groups and, if it is modified, in which direction?

TABLE 1
CLUSTERS AROUND CENTERS OF GRAVITY

Number of test	*Name of test*	*Designation of the function corresponding to the cluster*
1 2 3 4 8	Instructions Apprehensive memory Associated words evoking memory Oral text evoking memory Logical intelligence test	Function A: Cluster of intellectual tests
5 9 12	Speed of sign-barring in the concentrated-attention test (free rhythm) Speed in adjusting simple motions in the pointing test (rhythm under stress) Speed in coordinating motions in the turning test (free rhythm)	Function B: Cluster of speed tests at free rhythm or under stress
6	Accuracy in sign-barring in the concentrated-attention test	Function C:* Concentrated attention (isolated test)
7	Recognition of preliminary heard auditory images	Function D: Mnemonic (isolated test)
 10 11	Precision in coordinating motions in the turning test: Number of errors Duration of errors	Function E: Cluster of tests setting in action precision in coordinating motions (free rhythm)
13	Learning psychomotor choice reactions (number of errors in the diffused-attention test)	Function F: Learning (isolated test)
 14 15	Precision of psychomotor choice reactions in the diffused-attention test: Visual stimuli Audiovisual stimuli	Function H: Cluster of tests setting in action precision of psychomotor choice reactions at rhythm under stress

*Later eliminated from the study.

We carried out a multiple-factor analysis of fifteen tests (Table 1). The subjects formed two samples of the same social and professional group. The only difference, a very small one, was the level of education. All the subjects in the first sample had an elementary school certificate; all the subjects from the second had only a few years' schooling and no examination certificate. All applicants for S.N.C.F. (French National Railway) jobs, however, have to pass an examination corresponding to three years of schooling so the samples were homogeneous.

Each sample contained a large number of subjects. The least numerous group had about one hundred subjects for each test, the most numerous nearly one thousand. The subjects ranged from twenty to fifty-five years of age, and we fixed an interval of five years to divide the groups. The whole study included about four thousand subjects. All of them were examined at the S.N.C.F. Laboratory of Applied Psychology under strictly controlled conditions to eliminate, as far as possible, experimental errors. To carry out the factor analysis, we chose a pilot group—the youngest adults—who ranged from nineteen years and six months to twenty-four years and five months in age and who had elementary school certificates. It is on this group that all rotations of the axes were performed.

I started from the following hypothesis: If the constellations of the studied functions remain constant with aging, the axial rotations performed on the pilot group, when automatically carried to the other groups, must show constellations consistent with those observed in the pilot group. If, on the contrary, modifications in the functional constellations take place in aging and if these modifications obey certain rules, I should be able to discern a certain regularity in the variations, in either the saturation of the functions by the factors or the displacing of the functions from one factor to another. Lastly, if in aging the constellations obey only the law of disorderly fluctuations, I should not find the pattern of the pilot group's constellations in any group that had been submitted to the automatic rotations.

The five first rotations performed on the pilot group showed many clusters. The first cluster was composed of the instructions (also called immediate memory of digits), apprehensive memory, associated words evoking memory, oral text evoking memory, and logical intelligence test (Table 1, tests 1, 2, 3, 4, and 8). The second cluster was composed of speed of sign-barring in the concentrated-attention test, speed in adjusting simple motions in the pointing test (rhythm under stress), speed in coordinating motions (free rhythm) in the turning test [1] (Table 1, tests 5, 9, and 12).

Although it appeared isolated, the accuracy of sign-barring in the concentrated-attention test showed disorderly placement and hindered the choice of axes, which should lead to a distinct separation among the other clusters, so I decided to eliminate this test after many fruitless attempts at rotations (Table 1, Test 6). In contrast, the form of memory explored by the test of recognition in preliminarily heard auditory images appeared isolated, but was regular in its relations with the other clusters (Table 1, Test 7). Another cluster was composed of the number and duration of errors in the turning test, precision in coordinating motions in the turning test (Table 1, tests 10-11). Learning psychomotor choice reactions (number of mistakes in the diffused-attention test) still appeared isolated, with a noticeable distance from the other clusters (Table 1, Test 13). Lastly, another cluster emerged, composed of the precision of psychomotor choice reactions to visual and audiovisual stimuli in the diffused-attention test, the stimuli appearing rhythmically under stress (Table 1, tests 14-15).

So it appeared, with evident clarity, that it was not necessary to continue isolated tests for the research, but that, on the contrary, it was of great interest to constitute clusters according to the psychological functions the observed clusters measured. Guided by these considerations, I composed six new elements—four clusters and two isolated tests—for the objects of further axial rotations. The third column of Table 1 indicates each of the seven elements, which are designated by the functions they seem to concern. Each function is designated by a letter, and hereafter I shall call it by that letter. Let me mention again that Function C was eliminated from the investigation.

We studied the six functions in Table 1, and, when a cluster was involved, the subsequent rotations were carried out on the mean calculated from the coordinates of the tests composing it. For instance, regarding Function E, Axis I has been chosen to pass by the intersection of the abscissa and ordinate respectively, representing the mean of abscissas and ordinates in tests 10 and 11. I proceeded in the same way for the other functions.

I must insist on the following: my first concern is not to discuss the particular configuration of the functions; whatever the

[1] In France this is a well-known test devised by Professor J.M. Lahy to assess complex coordination of hand movements.

TABLE 2
FUNCTION A: DEFINITIVE COORDINATES

Educational level	*Age groups**	*Factors*				
		I 4	II 4	III 6	IV 5	V 5
I.P. (Little schooling, no certificate)	19-6 to 24-5	.20	.28	−.03	.21	.48
	24-6 to 29-5	.08	.33	.05	.30	.40
	29-6 to 34-5	.20	.39	.01	.31	.41
	34-6 to 39-5	.05	.32	.16	.30	.40
	39-6 to 44-5	.14	.46	.14	.32	.41
	44-6 and over	.20	.28	−.04	.29	.43
C. E. P. (Elementary school certificate)	19-6 to 24-5	.15	.30	−.02	.17	.51
	24-6 to 29-5	.15	.31	−.13	.32	.44
	29-6 to 34-5	.23	.18	−.08	.33	.36
	34-6 to 39-5	.20	.36	−.03	.16	.42
	39-6 to 44-5	.20	.32	−.09	.21	.35
	44-6 and over	.16	.47	.07	.23	.44

*In tables 2-7, age groups are by years and months (19-6 to 24-5 signifies nineteen years, six months, to twenty-four years, five months).

TABLE 3
FUNCTION B: DEFINITIVE COORDINATES

Educational level	*Age groups*	*Factors*				
		I 4	II 4	III 6	IV 5	V 5
I.P.	19-6 to 24-5	.12	.41	.17	.27	.05
	24-6 to 29-5	.34	.27	.17	.12	.29
	29-6 to 34-5	.17	.19	.34	.04	.32
	34-6 to 39-5	.34	.35	−.24	.05	.18
	39-6 to 44-5	.27	−.01	−.14	.29	.49
	44-6 and over	.46	.22	.21	−.10	.14
C.E.P.	19-6 to 24-5	.05	.40	.26	.45	.01
	24-6 to 29-5	−.03	.11	.21	.25	.44
	29-6 to 34-5	−.06	.43	.20	.13	.28
	34-6 to 39-5	−.09	.09	.25	.35	.20
	39-6 to 44-5	.11	.14	.25	.29	.32
	44-6 and over	.29	−.03	−.02	.13	.54

TABLE 4
FUNCTION D: DEFINITIVE COORDINATES

Educational level	*Age groups*	*Factors*				
		I 4	II 4	III 6	IV 5	V 5
I.P.	19-6 to 24-5	.21	.32	–.06	.69	.29
	24-6 to 29-5	–.15	.13	.23	.71	.08
	29-6 to 34-5	.40	.18	–.25	.44	.29
	34-6 to 39-5	.08	.29	.12	.55	.41
	39-6 to 44-5	.22	.62	.05	.17	.18
	44-6 and over	.18	.43	–.28	.44	.20
C.E.P.	19-6 to 24-5	.08	.72	.12	.48	–.03
	24-6 to 29-5	.37	.36	–.28	.17	.28
	29-6 to 34-5	.22	.28	–.32	.21	.10
	34-6 to 39-5	.28	.35	–.39	.37	.10
	39-6 to 44-5	.10	.48	.19	.48	.07
	44-6 and over	–.10	.40	.04	.31	.32

TABLE 5
FUNCTION E: DEFINITIVE COORDINATES

Educational level	*Age groups*	*Factors*				
		I 4	II 4	III 6	IV 5	V 5
I.P.	19-6 to 24-5	.92	.21	.12	–.02	–.19
	24-6 to 29-5	.77	–.32	.24	.03	.41
	29-6 to 34-5	.83	.18	.08	–.15	–.04
	34-6 to 39-5	.79	–.36	.32	.19	.25
	39-6 to 44-5	.95	.16	.16	–.08	.05
	44-6 and over	.75	–.26	.36	.35	.35
C.E.P.	19-6 to 24-5	.97	0	.41	0	0
	24-6 to 29-5	.83	.56	.71	–.06	–.20
	29-6 to 34-5	.78	–.09	.50	–.26	.24
	34-6 to 39-5	.86	.63	.53	.06	–.20
	39-6 to 44-5	.76	.39	.77	.16	.08
	44-6 and over	.93	.22	.63	–.07	.02

TABLE 6
FUNCTION F: DEFINITIVE COORDINATES

Educational level	*Age groups*	*Factors*				
		I 4	II 4	III 6	IV 5	V 5
I.P.	19-6 to 24-5	.29	.24	.63	.13	.45
	24-6 to 29-5	.55	.56	.49	.04	.36
	29-6 to 34-5	.32	.32	.55	.30	.01
	34-6 to 39-5	.44	.56	.39	.34	−.12
	39-6 to 44-5	.30	.23	.60	.18	.54
	44-6 and over	.35	.55	.44	.30	.15
C.E.P.	19-6 to 24-5	.27	.29	.44	.10	.17
	24-6 to 29-5	.55	.05	.32	.25	.30
	29-6 to 34-5	.25	.24	.66	.42	.04
	34-6 to 39-5	.55	.01	.36	.13	.31
	39-6 to 44-5	.61	.01	.22	.25	.21
	44-6 and over	.49	.10	.71	.30	−.06

TABLE 7
FUNCTION H: DEFINITIVE COORDINATES

Educational level	*Age groups*	*Factors*				
		I 4	II 4	III 6	IV 5	V 5
I.P.	19-6 to 24-5	.20	.18	.57	.14	.27
	24-6 to 29-5	.41	.30	.39	.21	.41
	29-6 to 34-5	.23	.05	.59	.43	.02
	34-6 to 39-5	.48	.40	.27	.15	−.32
	39-6 to 44-5	.37	.07	.61	.33	.30
	44-6 and over	.29	.45	.45	.40	−.12
C.E.P.	19-6 to 24-5	.25	.28	.50	0	0
	24-6 to 29-5	.50	−.06	.39	.04	.30
	29-6 to 34-5	.30	.44	.36	.27	−.17
	34-6 to 39-5	.56	−.16	.31	.30	.07
	39-6 to 44-5	.73	−.02	.57	.35	−.04
	44-6 and over	.33	.07	.69	.35	.06

observed configuration, I want to know only how it may be influenced by aging. From that point of view, two phenomena which are central in any factorial analysis were examined: (1) the contribution of each factor to each function (the degree of saturation of each function in each factor); and (2) the constellation of functions in relation to each factor. From the gerontological point of view, the two phenomena interested me not so much in their essence as in their evolution with age. The second interested me more.

THE CONSTELLATION OF FUNCTIONS IN CONSIDERATION OF EACH FACTOR

We isolated five factors for the six functions mentioned above. The value of the definitive coordinates for the six age groups and the two samples characterized by level of education will be found in tables 2-7. Thus we have a table of twelve groups of subjects for each function.

In certain functions it can immediately be seen which factor holds each of them. For instance, Factor V controls Function A (the intellectual) and is maintained whatever the age and education of the sample. Similarly, Factor I controls Function E (coordinating motions), and this also holds whatever the age and education of the sample.

For the other functions the patterns are not so clear so synoptical tables (tables 8-13) were formed to show, for each function and group of subjects, the factors in decreasing order of saturation. I decided to take twenty-five as the significant limit of saturation, thus the factors which did not reach that limit for a given function are not in the tables.

Function A

In Table 8 Factor V has primacy in ten out of twelve groups concerning Function A. As for the two other groups, although Factor II is in first place, it is immediately followed by Factor V, and the differences in saturation are very slight. It is to be noticed that Factor IV concerns Function A to a significant degree, though much less than Factor II. Factors I and III are not on Table 8 since they did not reach the limit of significance. Thus Factor V is the chief "controller" of Function A, and the position of Function A is maintained despite age and education.

In relation to aging, the second statement is important. Another phenomenon is also worth discussion here. It seems normal that a factor which is saturated to a high degree should show constancy of saturation in all age groups, but factors which have low, or, practically speaking, no saturation should show disorderly fluctuations at different ages and levels of education. But for Function A, a remarkable phenomenon appears—whatever degree of saturation a factor has, the degree shows surprising constancy for all age groups and either level of education.

Function B

The regularity found in Function A does not appear in Function B (Table 9). Five factors take first place in the twelve groups here, and the positions of the other factors offer no suggestion about this change. Speed does not seem to concern one factor more than it does any other. In regard to gerontology, it is difficult to assign a constant constellation to this function.

Function D

As for Function D (Table 10), a remarkable regularity appears again. Factors II and IV are very clearly involved in this func-

TABLE 8
FUNCTION A

Age group	*Educational level*	*Factor saturations*					
1	I.P.	V	.48	II	.28		
	C.E.P.	V	.51	II	.30		
2	I.P.	V	.40	II	.33	IV	.30
	C.E.P.	V	.44	IV	.32	II	.31
3	I.P.	V	.41	II	.39	IV	.31
	C.E.P.	V	.36	IV	.33		
4	I.P.	V	.40	II	.32	IV	.30
	C.E.P.	V	.42	II	.36		
5	I.P.	II	.46	V	.41	IV	.32
	C.E.P.	V	.35	II	.32		
6	I.P.	V	.43	IV	.29	II	.28
	C.E.P.	II	.47	V	.44		

TABLE 9
FUNCTION B

Age group	*Educational level*	*Factor saturations*					
1	I.P.	II	.41	IV	.27		
	C.E.P.	IV	.45	II	.40		
2	I.P.	I	.34	V	.29	II	.27
	C.E.P.	V	.44	IV	.25		
3	I.P.	III	.34	V	.32		
	C.E.P.	II	.43	V	.28		
4	I.P.	II	.35	I	.34		
	C.E.P.	IV	.35	III	.25		
5	I.P.	V	.49	IV	.29	I	.27
	C.E.P.	V	.32	IV	.29	III	.25
6	I.P.	I	.46				
	C.E.P.	V	.54	I	.29		

TABLE 10
FUNCTION D

Age group	*Educational level*	*Factor saturations*					
1	I.P.	IV	.69	II	.32	V	.29
	C.E.P.	II	.72	IV	.48		
2	I.P.	IV	.71				
	C.E.P.	I	.37	II	.36	V	.28
3	I.P.	IV	.44	I	.40	V	.29
	C.E.P.	II	.28				
4	I.P.	IV	.55	V	.41	II	.29
	C.E.P.	IV	.37	II	.35	I	.28
5	I.P.	II	.62				
	C.E.P.	II	.44	IV	.48		
6	I.P.	IV	.44	II	.43		
	C.E.P.	II	.40	V	.32	IV	.31

TABLE 11
FUNCTION E

Age group	*Educational level*	*Factor saturations*			
1	I.P.	I .92			
	C.E.P.	I .97	III .41		
2	I.P.	I .77	V .41		
	C.E.P.	I .83	III .71	II .56	
3	I.P.	I .83			
	C.E.P.	I .78	III .50		
4	I.P.	I .79	III .32	V .25	
	C.E.P.	I .86	II .63	III .53	
5	I.P.	I .95			
	C.E.P.	III .77	I .76	II .39	
6	I.P.	I .75	IV .35	V .35	III .30
	C.E.P.	I .93	III .63		

TABLE 12
FUNCTION F

Age group	*Educational level*	*Factor saturations*			
1	I.P.	III .63	V −.45	I .29	
	C.E.P.	III .44	II .29	I .27	
2	I.P.	II .56	I .55	III .49	V .36
	C.E.P.	I .55	III .32	V .30	IV .25
3	I.P.	III .55	I .32	II .32	IV .30
	C.E.P.	III .66	IV .42	I .25	
4	I.P.	II .56	I .44	III .39	IV .34
	C.E.P.	I .55	III .36		
5	I.P.	III .60	V .54	I .30	
	C.E.P.	I .61	IV .25		
6	I.P.	II .55	III .44	I .35	IV .35
	C.E.P.	III .71	I .49	IV .30	

tion. They alternate for primacy, and, when they do not appear in first place, they are, in most cases, in second. Factor I appears three times for the twelve groups, and only once is it in first place. We can conclude that factors II and IV are mnemonic factors and that of these two Factor II is more general since it is closely related to Function A which represents a cluster where other forms of memory are present (the memory of an oral text, digits, and associated words). Factor IV, consequently, might be more a specific mnemonic form of recognition. Finding it associated with Function A is not surprising, since one of the tests in Cluster A employs some of the words that are used in the recognition test concerning Function D. From the gerontological point of view, there is a remarkable constancy regarding factors II and IV.

Function E

Constancy despite age and education appears strong for Function E, which concerns precision in coordinating motions (Table 11). This function, explored by the number and duration of errors in the test of turning, is undoubtedly general. It seems to be the equivalent on the psychomotor plane of the logical intelligence test on the intellectual plane. In fact, in my experience with job selection, I have seldom found a subject who got a very good result in another psychomotor test when he had not achieved a fairly significant level in the test of turning. Moreover, in all the studies done for selection in occupations requiring manual dexterity, the test of turning is always extremely valid.

Not only does Function E almost always involve Factor I, but also the saturation of this factor reaches values seldom found in factorial analysis. In the only group where Factor I does not have primacy, it appears in second place, and the difference of saturation is negligible. It is Factor III which appears most often in second place. The other factors are very rarely represented. In relation to aging, once again there is remarkable constancy in this function's constellation.

Function F

Function F involves several factors, but Factor III predominates, occupying first place six, and second place three, out of twelve times (Table 12).

Knowing that the only test figuring under Function F concerns learning psychomotor choice reactions, I understood why Factor III came second in Function E, for the test of turning, which involves Function E, is repeated three times for each subject, and it is the mean of these three trials which is the final result. It is obvious that, in the last analysis, the factor of psychomotor learning is important, and this holds true for all subjects. Thus, Factor III held an important place for Function E. For Function F, on the contrary, we shall find Factor I, involving coordinating motions, in first place three times and in second place four times, since learning here involves the coordination of psychomotor choice reactions to visual and audiovisual stimuli. Again we find the two mnemonic factors; this is not surprising, since learning enters here. Factor II, which is more general, figures three times in first place, and twice in second, for the twelve groups.

In relation to aging, the pattern of the constellation is constant enough, although this constancy is less clear than that of functions A and E. It is generally Factor III or Factor I which predominates at any age and level of education.

Function H

For Function H, Factor III always dominates (Table 13). It might be thought that, as the tests progress, improved precision of psychomotor choice reactions would persist as the saturating characteristic, though mastery of it is practically accomplished in the preparatory phase where, in the rotations of the axes, it was separated under the name of Function F.

Again, from a gerontological point of view, there is constancy in the constellation of Function H, but factorial analysis shows that this function ought to be interpreted in terms of improvement rather than attention, as is generally done. One might be equally tempted to interpret Factor III in terms of attention rather than improvement, for concentration plays an effective part in the test of turning as well as in the acquisition and automatization of psychomotor reactions to visual and audiovisual stimuli appearing in rapid rhythm. This interpretation, however, does not seem to hold true, for the complete absence of Factor III for Function A, which concerns intellectual tests, could not be explained if it did.

I would like to insist that the constellation's (of Function H) constancy in aging has all the more significance, since it proved to be independent of education. (I shall speak of the four exceptions below.) This statement is important in considering the phenomenon demonstrated by previous research: the difference between the two levels of education is significant throughout aging for results from the same tests taken by subjects belonging to the same samples.

I would like to draw attention to another interesting phenomenon. In very few cases—only four—did the power of saturation by a factor regularly separate the two samples of unequal educational level. The first case concerns the factor of coordinating motions (Factor I) in speed (Function B). It is the only factor showing some stability in the constellation for Function B. For the less educated (I.P.) the speed function is more strongly saturated in the factor of coordinating motions than it is for the more educated (C.E.P.) for whom saturation in Factor I is nonexistent before forty; beyond that age, saturation by Factor I increases for both samples. One might be tempted to think that work speed will mean different ways of organizing work and that for the more educated subjects motor coordination is not important. From a gerontological point of view, the constant separation between the two samples until forty is to be noticed.

The second case is related to factors II and IV in Function D. Factor IV, the more specific of the mnemonic forms, is utilized in the auditory images recognition test and saturates this function to a much

TABLE 13
FUNCTION H

Age group	*Educational level*	*Factor saturations*			
1	I.P.	III .57	V .27		
	C.E.P.	III .50	II .28	I .25	
2	I.P.	I .41	V .41	III .39	II .30
	C.E.P.	I .50	III .39	V .30	
3	I.P.	III .59	IV .43	I .23	
	C.E.P.	II .44	III .36	I .30	IV .27
4	I.P.	I .48	II .40	III .27	
	C.E.P.	I .56	III .31	IV .30	
5	I.P.	III .61	I .37	IV .33	V .30
	C.E.P.	III .69	IV .35	I .33	
6	I.P.	III .45	II .45	IV .40	I .29
	C.E.P.	III .69	IV .35	I .33	

greater extent for the less educated subjects. This phenomenon becomes still more interesting when, on examining Factor II, one observes the reverse situation—the saturations are higher for the more educated subjects. It has already been seen that Factor II is a more general mnemonic factor since it involves Cluster A. One might think that more educated subjects call forth a general memorization mechanism even when a very particular form of memory is concerned, whereas less educated subjects remain, in their memorization, dependent on the particular form and are limited because they do not try other associative supports. From a gerontological point of view, the constancy of separation to forty years of age is to be pointed out, but the fact that at this age the phenomenon vanishes, even reverses slightly, for Factor II, as well as for Factor IV, is interesting.

The third case is the most accentuated. It involves Factor III, which is interpreted in terms of improvement, in Function E (coordinating motions). The saturation in the improvement factor is far higher in the more educated sample. Moreover—and this is important for gerontology—this separation is constant and very distinct for all age groups.

Comparing the saturations of Function E by Factor I, which is a psychomotor factor, and by Factor III, which concerns improvement, I can conclude that education induces no difference in saturation when an organic phenomenon, such as an aptitude to general motor coordination, is in question. Education does make a noticeable difference, however, when the point is improving this coordination by learning from the errors in a course of successive experiences. This, moreover, is true for all age groups.

SUMMARY AND CONCLUSIONS

In accordance with the initial hypothesis, I may conclude the following.

The constellations of the psychological and psychomotor functions studied here remain constant despite aging, since the axial rotations performed on a pilot group and automatically carried to eleven other groups reveal in the latter groups patterns of constellations similar to those observed in the pilot group. Evidently this constancy persists with some latitude of fluctuation. (This latitude ought to be admitted with even more tolerance since the rotations were carried out automatically.) An exception must be made, however, for the cluster of speed tests (Function B). No constancy of constellation appears for any factor in this function except Factor I, which saturates the function more for the less educated subjects.

The difference in saturation between the education samples remains distinctly constant in all age groups. This difference can be explained by saying that the performance in speed initiates different forms of work organization and that with less educated subjects the factor of psychomotor organization must have primacy over all other forms of organization.

The same phenomenon of regular separation of saturation despite aging appears in two other cases. The two mnemonic factors, II and IV, saturate Function D in reverse for both education samples. The more general factor (II) has greater saturation in the less educated subjects, whereas the more specific mnemonic factor (recognition of auditory images, Factor IV) saturates Function D less in the less educated sample. After the age of forty, the separation vanishes, and the phenomenon even reverses slightly. I think we can interpret this in light of the fact that more education trains subjects to use higher, more general techniques of memorization even when a very specialized form of memory is in question, whereas the less educated subjects remain concerned with the specific form and do not try other associative supports for memorization. The most distinct separation is manifested for the improvement factor (Factor III) in coordinating motions (Function E). This function is more saturated by the improvement factor at the higher education level.

Besides, if the identity of saturations for the two samples by Factor I is taken into consideration, the psychomotricity factor and these two phenomena are brought close, one can say that when purely organic aptitudes are in question, education causes no difference of saturation whatever the age group; in contrast, for drawing consequences from errors, education modifies the saturation power of the involved factor and modifies it in the same way for each age group.

In the twenty-six other cases, the constancy of the constellation is independent of education. This phenomenon is worthy of emphasis, as our other research has shown how much education influences the decline of psychological functions. This leads me to say that, whatever the level of these functions or aptitudes, the constellations of the functions remain similar.

How can one interpret the fact that, in this whole set of regularities and constancies, the sole speed function (B) is alien to the laws? All the studies in gerontology, particularly those of A.T. Welford (1951; 1958) and J.E. Birren (1955; 1959), have proven that speed is much altered by aging. To my mind, the rational explanation would be that maintaining speed—whether perceptive or psychomotor—throughout life depends on diverse factors whose influences can completely modify the normal organic ones. Occupation, athletics, driving a car, family environment, or, on the contrary, yielding to the slowness of old age by assimilating an environment of old people—all greatly modify the speed mechanism and its possible decline with age. These influences, moreover, specifically touch the individual and the speed function among the other psychological, psychomotor, and motor functions. The observed laws of decline are either caused by organic factors which provoke aging in the individual or by ecological factors which cause the senescence of the individual. These laws are altered by everybody's personal way of life. This is why speed does not inevitably decline with other functions. Besides, under such influences, the assumed links between speed and the other functions may deteriorate at any given age, and new links will be established. This could explain why one finds no constancy in the speed constellation although its decline has been demonstrated by all gerontologists.

REFERENCES

Birren, J.E. Age changes in speed of simple responses and perception and their significance for complex behavior. In *Old age in the modern world.* Edinburgh: E. & S. Livingstone, 1955. Pp. 235-247.

Birren, J.E. Sensation, perception and modification of behavior in relation to the process of aging. In J.E. Birren, H.A. Imus, & W.F. Windle (Eds.), *The process of aging in the various systems.* Springfield, Ill.: Charles C Thomas, 1959. Pp. 143-165.

Thurstone, L.L. *Multiple factor analysis.* Chicago: The University of Chicago Press, 1947.

Thurstone, L.L. Problèmes actuels et méthodes nouvelles en analyse factorielle. In *L'analyse factorielle et ses applications.* Paris: Centre National de la Recherche Scientifique, 1955. Pp. 31-41.

Welford, A.T. *Skill and age.* London: Oxford University Press, 1951.

Welford, A.T. *Ageing and human skill.* London: Oxford University Press, 1958.

CHAPTER 3

Information Transmission and Age

STEPHEN GRIEW

The theme of this paper is the aging individual's changing ability to receive and transmit information and the implications of this change for the maintenance of complex skills. The paper will consist of an attempt to put into perspective a section of the experimental work undertaken since 1955 by the Bristol University Unit for Research on Employment of Older Workers. Since the work of the unit formally ended in 1960 and since most of its experimental work has been concerned with information transmission, it seems appropriate at this time to attempt to summarize this part of its efforts and try to draw them together within a single framework.

BACKGROUND AND STUDIES

The history of research in aging and skill has been profoundly influenced in Great Britain by the ideas of Craik (1947; 1948), as the first report (Welford, 1951) of the Nuffield Unit for Research into Problems of Ageing at Cambridge University demonstrates. The basis of Craik's approach was that the exponent of skills may be regarded as a link in a communication network, receiving, processing, and transmitting information from devices designed to present data to him (displays) to others designed to receive data from him (controls). In acting this way, the operator is conceived rather like a self-regulating servomechanism, maintaining by his own intervention a state of equilibrium in the system he controls and of which he is a part.

Although it has been customary to fragment research on human performance into studies of sensory efficiency on one hand and motor performance on the other, the true significance of what takes place between the reception of signals at the sense organs and the initiation of responses by muscle groups has probably been properly appreciated only recently. Craik's early work led to a great deal of research into central limitations on performance. The introduction of concepts of cybernetics into psychology (Wiener, 1948) and the statistical procedures of modern communications theory (Shannon & Weaver, 1949) have done much to place the early analogical thinking on an empirical, quantitative basis. Numerous studies serve to reinforce the view of the human operator as a single channel of communication (for discussions see Broadbent, 1958; Welford, 1952; Welford, 1959c) of limited capacity (see especially Crossman, 1953; Fitts, 1954; Hick, 1952; Hyman, 1953; Quastler, 1955).

It has long been known that aging is associated with a marked slowing of responses and an increase in what is frequently termed "caution," and it was not unreasonable that early work on the effects of aging on skilled performance was concerned with whether this slowing down was caused mainly by peripheral or central factors. The literature on this topic has been reviewed by Birren (1955; 1956) and Welford (1958; 1959b), and it is apparent that the central mechanisms which classify, process, and decide about incoming signals are among those on which aging has its greatest effects. One of the hypotheses set up to account for this slowing, originally made by Crossman and Szafran (1956), is that the rate at which information can be transmitted from display to control declines with age. Direct experimental tests of this hypothesis were not attempted until recently. A study by Goldfarb (1941), however, of multiple-choice reaction time lends itself to information analysis. His data, when plotted as a function of log choice—the conventional measure of information conveyed by a signal (Bricker, 1955)—give more-or-less linear relations at all ages studied. These curves, however, are roughly parallel at different ages, and so the hypothesis that information transmission becomes slower with age is not well supported. This finding is corroborated by a card-sorting experiment by Crossman and Szafran (1956), which was undertaken to test the hypothesis directly. Despite the fact that both these experiments took intervals of time which included muscular movements as dependent variables and thus were not strictly measures of central efficiency, they must still be regarded as important objections to the generalization that the rate of information transmission declines with age.

Later studies did much to reaffirm the usefulness of the hypothesis. One of the first of these, conducted and reported by A.T. Welford (1958), essentially repeated an experiment of Fitts (1954) which investigated the information capacity of the motor system in controlling amplitude of movement. It was found that the rate of information transmission decreased very markedly with age. Recent experiments by Suci, Davidoff, and Surwillo (1960) and Griew (1958d) employing more formal choice reaction time tasks and excluding movement time in the measures of response latency used as dependent variables report linear relationships between reaction time and log choice at all ages studied and add that the slopes of the regression lines increase with age. These studies may be taken as direct support of the hypothesis that aging is accompanied by a decrease in the rate of transmission of information.

It is clear from this discussion that the concept of a reduced capacity for dealing with information is very useful in providing a framework for research into aging and skilled performance. At the same time, it is also clear that in very similar tasks a decrease with age may or may not be found. In order to elucidate the issues raised by this approach, it is necessary to know something about the effect of other variables which might influence the rate at which information can be transmitted by subjects of different ages. In addition to providing information which might be valuable in demonstrating the limits within which this approach is useful, a knowledge of these effects might also help clarify other issues concerned with the relation of age to different aspects of task complexity. This knowledge seems to be needed in view of the inescapable inference from research on aging and skilled performance that complex tasks might militate more severely against the old than the young (Clay, 1957; Kay, 1951; Welford, 1958). The research reported in this paper represents an attempt to clarify some of these issues.

The studies of information transmission outlined here were concerned with the relations of the speed and accuracy of the central processes, age, and a number of independent variables which were thought likely to be important aspects of task complexity. The grounds on which a decision to study any particular aspect of task complexity was made included the purely a priori, findings of previous experiments in related fields, and observation of the performance of older people. Although the conceptual framework of information theory was employed in all these studies, the quantitative analysis of information transmission was attempted in only a few. In most cases it was thought sufficient for the present to relate the speed and accuracy with which decisions are made to changes in task complexity.

A direct test was made of the hypothesis that rate of information transmission decreases with age, and other aspects of task complexity were studied, including the effects of stimulus-response incompatibility, of varying response complexity, of interrupting signals and enforced short-term storage of information in continuous controlling tasks, and of unbalanced signal frequencies.

CONDITIONS OF OPTIMAL CODING

The first experiment attempted to derive relationships between reaction time and log choice in a task which involved moving a stylus from a central position to one of a number of targets which bore a direct relationship with a signal light appearing in a semicircular array of signals. The apparatus used in this experiment has been described in detail by Griew (1959a). Sixteen subjects in two age groups (twenty to thirty and forty-six to sixty) took part in this experiment; all subjects were matched for intelligence, education, and occupation. Signal choice was varied at four levels (1/1, 1/2, 1/4, 1/8), and subjects attempted the four conditions in balanced orders. Suitable practice was given before they performed for experimental purposes. The regression equations which were calculated from the mean reaction time data (each mean was derived from 128 individual reaction times) were

R.T.=0.073 $\log^2$ n + 0.288 (younger subjects)
R.T.=0.094 $\log^2$ n + 0.307 (older subjects), where
n=the number of alternative signals which might be presented and
R.T.=mean reaction time (seconds).

From the constants of these equations (Bricker, 1955), rates of information transmission of 13.70 and 10.60 bits/second were calculated for younger and older subjects respectively.

These data provide support for the hypothesis that rate of information transmission decreases with age. The result is in line with that reported by Suci et al. (1960), but is in conflict with those of Crossman and Szafran (1956) and Goldfarb (1941).

CONDITIONS OF SUBOPTIMAL CODING

When the relation between stimulus and response is indirect, or incompatible (Fitts & Seeger, 1953), response latency appears to increase (Crossman, 1956; Fitts & Seeger, 1953; Morin & Grant, 1955). It has been suggested by Taylor (1960) that this increase might be caused by the complication of the stimulus coding involved. Crossman (1956), employing a multiple-choice reaction time task involving stimulus-response incompatibility, has shown consistently lower rates of information transmission than are found in tasks involving stimulus-response compatibility. An increase in complexity of this nature might be expected to affect the performance of older subjects more than that of younger and might be characterized by a greater proportional decrease in rate of information transmission.

In order to test this suggestion, this first experiment was repeated, but in this case the subject's task was to move the stylus to the target directly opposite that indicated by the signal light. In all other ways this experiment was identical with the first. The regression equations derived from the results of this study were

R.T.=0.127 $\log^2$ n + 0.296 (younger subjects)
R.T.=0.171 $\log^2$ n + 0.301 (older subjects).

The relation between mean reaction time and log choice remains linear, the slope constant increases in both cases, and the indication is that rate of information transmission has decreased in both groups (Griew, 1958d). These data suggest that a greater proportional decrease in information transmission may have occurred in older than in younger subjects. Calculation of rates of information transmission from the constants in the equations derived from this experiment, however, are 7.90 and 5.80 bits/second for younger and older subjects, respectively. Close examination of these rates of transmission in relation to those derived from the results of the first experiment suggest that the proportional decrease with age caused by the introduction of an incompatible stimulus-response relation is very small. If the rates in the optimally coded task are expressed as a fraction of the rates in the second task, figures of the order of 1.80 may be calculated for both younger and older subjects; the effect of increased complexity of task in the second experiment appears to be proportionate as a function of age. In both cases the important consideration appears to be how the information is handled by the central processes once it has been decoded, not the complexity of decoding. Although no firm conclusions may be drawn from so limited a study, the data suggest that stimulus-response incompatibility as such may not be an important obstacle to the efficiency with which older subjects process and transmit information.

CONDITIONS OF VARYING RESPONSE COMPLEXITY

Another variable which may have to be employed in defining the complexity of a task concerns the level of complexity of the response which has to be made at the appearance of a signal. Although Woodworth (1938) claims that, as the motor complexity of responses increases, their latencies rise, evidence presented by Brown and Slater-Hammel (1949) and Searle and Taylor (1948) fails to support this view. The question remains, however, whether a differential effect exists according to age in the relation between response complexity and response latency. If such an effect is found, it would be interesting to see whether it is associated with a reduced rate of information transmission or an increased response latency which is the same at all levels of signal choice.

The third experiment concerned this issue. It has been reported in full by Griew (1959a). The apparatus employed was the same as that used in the preceding experiments with the single modification that the motor complexity of the responses could vary slightly by demanding, in one set of conditions, a response which included not only moving the stylus to the target disc, but also, on arrival, thrusting the point of the stylus into a small hole in the middle of the disc. This increased the manipulative complexity of the response. Twenty-four younger and twenty-four older subjects took part, half of each group responding to signals presented at intervals of six seconds, half to signals presented continuously (each signal occurred as the response to the preceding signal was concluded). Each subject responded at both levels of complexity. Experimental conditions were attempted in balanced orders, and a compatible stimulus-response relation was used.

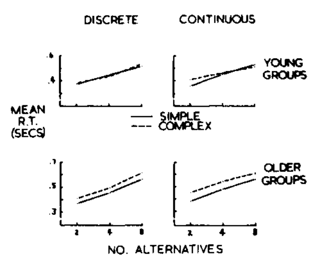

FIG. 1. Reaction time as a function of age, choice, and response complexity. (Griew, 1959a, p. 86. Reprinted with permission.)

The mean reaction times derived from this experiment are plotted in Fig. 1. They demonstrate a clear increase in reaction time of the older subjects when more complex responses are involved. This difference is not observable in the younger subjects' performance. The response latencies in this case, as in all cases reported in this series of experiments, included *only* the time elapsing between the appearance of the signals and the moment at which the response began. It is interesting that the time spent in actually moving the stylus to the target disc varied only slightly under the differing situations.

The data presented in Fig. 1 suggest that there is no decrease in the rate at which information is transmitted by older subjects when the response becomes more complex, but rather that increasing response complexity is accompanied by a constant addition to response latency which is the same at all choice levels. Therefore, despite the fact that in the strict communications-theory sense of the term rate of gain of information is unaffected by increasing response complexity, the speed of the older subjects' central decision-making processes is clearly reduced under these circumstances.

The interpretation of this finding most favored by the writer is that the manipulative part of the response, which at the more complex level follows the initial movement to the target, probably cannot be prepared by older subjects while the initial movement is being guided and monitored. This may be because of their visual and kinesthetic inability to process the information presented about the course of the initial movement at the same time that they are making decisions about what has to be done when the movement has been completed. If this is so, the preparation of the detailed, manipulative part of the response might occur before the response begins, during the latent period. Younger subjects, on the other hand, may be able to process this extra information while making decisions about the end part of responses, and so their response latencies would not be affected. Such an interpretation brings us back once more to the notion that older subjects' efficiency is generally reduced when coping with incoming information—in this case information derived from a feedback system on which successful monitoring of movement is probably based. This interpretation is consistent with, and might be thought to clarify, Welford's conclusion (1958) that ". . . there seems to be an added source of slowness due to difficulty in making decisions while executing movements, and this may be the cause of an inability to integrate series of actions into 'flowing' rhythmic wholes" (p. 107).

To elucidate further, Murrell and Entwisle (1960) have conducted a series of tests involving very high-speed chronocyclographic recordings of the patterns of response movements of varying complexity. These studies are not yet completed, but it seems clear that the patterns of movement are determined in some measure by the complexity of the responses of which they are a part. Plotting acceleration against time, a less regular pattern is observable in older subjects, especially in more complex responses.

CONTINUOUS TASKS

Until now our discussion has been of tasks in which series of discretely presented signals have been involved. Crossman (1960) has demonstrated that the quantitative methods of communication theory may be valuably applied to the analysis of continuous controlling tasks of the tracking variety. Tracking performance has been shown to deteriorate with age, and Welford (1958) has argued that this deterioration is caused by older subjects' compensating for their slower reaction time to signals derived from the track by reducing their accuracy in reproducing swings of the track, thus decreasing choice. This accounts for an increased amplitude error, which is particularly characteristic of tracking performances of older subjects.

Two studies involving continuous tracking performance have been included in the program. In both experiments the same basic apparatus was used. It was originally built by A.E. Earle and used by Welford (1958) and Crossman (1960). Its modifications for the present experiment have been described in Griew (1958a).

Short-Term Storage of Information

The experiment on short-term storage was designed to test the hypothesis that information loss would be relatively greater in older than in younger subjects in situations where data have to be stored for short periods of time prior to use. Six younger and six older subjects were presented with a pursuit tracking task in which a substantial preview of the course was given, but in which the course was obscured for a brief interval just prior to the time when matching took place. In this way, subjects were forced to use data a short time after they had been presented. The results of this experiment demonstrate a substantial increase in amplitude error by older and younger subjects when storage is required. The increase is relatively larger in the case of older subjects (Griew, 1958a). This finding is not entirely unexpected and is in line with other demonstrations that short-term retention deteriorates with age (Kirchner, 1958).

Two other points which deserve mention arise from the results. First, an analysis of the rates of information transmission from display to control in this experiment showed that older subjects transmit information more slowly than younger at all tracking speeds and degrees of obscurity. As obscurity increased, rate of information transmission decreased, and this decrease was more marked in older than in younger subjects. Enforced storage appeared, in fact, to result in a reduced rate of information transmission which was relatively greater in older subjects. Second, an analysis of tracking error clearly suggests that within the limits of duration—up to one second in this case—the main determinant of amplitude errors when storage is required was the amount of information to be stored irrespective of the duration of storage.

Effects of Interrupting Signals

The second experiment in this group concerned interfering signals to which rapid response has to be made during tracking performance. Ten younger and ten older subjects tracked with their left hands, keeping their right hands above a response key which had to be pressed whenever an auditory signal appeared. Again, double tasks of this sort may be regarded as more complex than either of the component tasks taken singly and merit consideration in any study of task complexity.

The results showed that tracking performance was worse and reaction time to the interrupting auditory signals was higher while tracking was taking place, but to the same extent in both age groups (Griew, 1958b; Griew, 1959b). The results suggest, rather surprisingly, that the efficiency of the central processes handling information is no more impaired in older than in younger subjects when two tasks are undertaken simultaneously. Such a conclusion is, perhaps, consistent with the idea of the human operator as a single channel of communication. Signals from the two tasks are treated as a single series of signals, and the efficiency with which they are handled depends on the capacity of the channel. An over-all decline with age in this efficiency might be expected to result in a corresponding decline in the speed and accuracy of response to both types of signals, but the decline of the older group is not relatively greater than that of the younger. It is only fair to add, however, that none of the subjects in this experiment was over fifty and that the results might have differed with subjects in their sixties and seventies.

Unbalanced Signal Frequency

Crossman (1953) and Hyman (1953) have shown that loss of information caused by frequency unbalance is reflected in reduced reaction times, and Hyman has shown that responses to frequent signals are faster than those to infrequent. In information-theory terms, the more probable signals convey less information than the less probable ones and hence occupy the central processes for a shorter time. This will not occur, however, until the subject has had some opportunity to learn the frequencies, which, it has been shown, he does fairly quickly (Hake & Hyman, 1953; Skinner, 1942).

Starting from a hypothesis based, perhaps, on an a priori assessment of the situation, subjects appear to modify their expectations about the occurrence of signals on the basis of experience with the series to which they are submitted. However, their expectations of receiving a certain signal at any point may not be closely related to a mathematically determined probability of this signal's occurrence, although their expectations will come closer to what actually occurs as their learning progresses. This topic and the closely related topic of the effect of sequential dependencies on behavior have recently been submitted to extensive examination (Collier & Verplanck, 1958; McGill, 1954; Senders & Sowards, 1952; Verplanck, 1955; Weiss, Coleman, & Green, 1955) and provide an intriguing field for further experimentation.

Although there seems to be no reason to expect age differences in handling frequency unbalance once it has been recognized, the process of achieving an accurate assessment of the probable occurrence of possible signals is one which might be expected to show variations with age. Assuming that the subject is left to formulate his own hypothesis about the frequency of signals at the outset and that learning will take the form of modifying his initial hypothesis on the basis of experience during the experiment, it might be predicted that older subjects will modify their initial hypotheses less readily. Kay (1951) found that errors made early in learning tended to persist among older subjects, and Korchin and Basowitz (1956) and O'Doherty, reported by Welford (1958), found that perceptual flexibility, as measured by the ability to revise interpretations of drawings which gradually changed, decreased with age. These studies point to the rigidity which is frequently discussed in relation to aging and which might be expected to influence the recognition of probabilities.

The prediction that older subjects would learn the nature of frequency unbalance more slowly than younger subjects was tested by taking readings of reaction times to different signals having unbalanced frequencies of occurrence. In view of the reduced amount of information conveyed by the more frequent signals and the increased amount conveyed by the less frequent ones, reaction times to the former should become shorter once the nature of unbalance was recognized, whereas those to the latter should lengthen. Two signals were employed, the first (A) occurring three times and the second (B) occurring nine times in every series of twelve. The signals in each series were in random order in those proportions, and ten series were presented without a break. Before dealing with the signals, all subjects responded to a series of twelve signals randomly drawn so that A and B each occurred six times. This series directly preceded the longer, unbalanced series. It was given to assist subjects in forming a hypothesis which was inadequate for the main task. The point at which the inadequate hypothesis was relinquished was that at which reaction time to Signal A differed significantly from reaction time to Signal B.

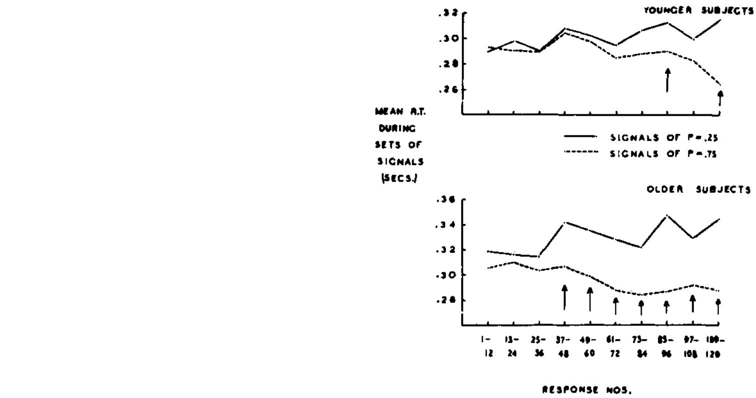

FIG. 2. The modification of reaction time during learning the statistical structure of series of signals. (Arrows indicate sets of signals in which differences between mean R.T.'s to signals of P=.75 and P=.25 are significant at the 5 per-cent level.) (Griew, 1962, p. 767.)

The results of the performances of ten younger and ten older subjects matched for intelligence, education, and occupation are shown in Fig. 2. They fail to support the hypothesis. They suggest, in fact, that the inadequate hypothesis was relinquished earlier by the older subjects. Certainly the type of inflexibility reported by Korchin and Basowitz (1956) in their perceptual study is not evident in the present results.

The implications of this finding are not yet fully understood. A number of explanations are possible, not the least important of which is that this finding may be an artifact of quicker and more efficient learning by younger subjects of the inadequate initial hypothesis. Some of these possible explanations are being explored in Bristol by G.S. Tune and this writer. A fuller account of this experiment and the work to which it is hoped it will lead is given elsewhere.

DISCUSSION AND CONCLUSIONS

These studies form part of a program which is to be continued. In the opinion of the writer, no realistic attempt to present these findings in a common theoretical framework is possible until further studies have been undertaken and the results of other current research are available. Tentative conclusions may be drawn, however, and suggestions made which might assist in framing appropriate hypotheses for further empirical testing.

With the exception of the last experiment, in all the experiments reported here the slopes of comparable curves relating reaction time to log choice are steeper and the amplitude errors in tracking performance greater in the older subjects' results. These results suggest very clearly that the basic rate of information transmission of older subjects is slower than that of younger ones. This supports the argument that aging is accompanied by a reduced capacity for transmitting information from display to control. Why should this be so? Why are there sometimes unexpected effects on the rates of information transmission when task complexity is introduced?

Crossman and Szafran (1956) suggest that random neural activity in the central nervous system increases with age so that older subjects require more time to accumulate data and distinguish them from noise. Gregory (1959) has already demonstrated the usefulness of this hypothesis in accounting for sensory decrements with age, and Welford (1958; 1959a) has also discussed it. If one accepts the idea that random noise may be evenly distributed through the tissue involved in a central activity and that the number of nerve cells involved in decision-making is proportional to the logarithm of the alternative decisions which might be made, it is easy to see how the extra time taken by older subjects in decision-making may also be related to the logarithm of the choice involved. The random activity of each extra ensemble of neural elements involved will contribute proportionally, and the measured rate of information transmission will decrease with age. This seems, in the light of present knowledge, the most profitable way of looking at possible behavioral and neurophysiological bases of what is otherwise a convenient, mathematically oriented description. Information theory, as the present writer understands it, was never meant to replace traditional methods of explanation in psychology (Quastler, 1955). As a statistical technique, it is valuable; as a system of concepts which assist in establishing a framework in which experimental work may progress, it is probably even more valuable. To imagine, however, that a description of behavior in terms of information transmission may pass as sufficient explanation of behavior is surely erroneous. What is required of the experimental psychologist interested in aging and performance is an explanation of the fact that the rate of information transmission appears to decline with age.

The second and, from some points of view, more interesting result of these experiments has been to demonstrate that the introduction of task complexity does not inevitably widen the gulf between the rates of information transmission of older and younger subjects. When stimuli are suboptimally coded, for example, we find that rates of information transmission are reduced to the same extent in both age groups. This suggests that the total capacity of the system may remain constant despite the added task complexity and that the decoding operation—which reappears at a speed proportional to the logarithm of the choice involved—is linked in some way to the process of handling information once it is decoded. The writer has suggested (Griew, 1958d) that it might be useful to view this simply as a way in which the amount of information conveyed by an event may vary with its means of presentation.

The findings in short-term storage require more elucidation than it has been possible to give them until now. The results of this study suggest that the interdependence of this and other forms of limitation may be considerable, especially in view of the subsidiary finding that information loss in this area is determined mainly by the amount of information to be stored.

Finally two comments may be hazarded about the general program of future research in this field. First, it seems fairly clear that there will be no sudden breakthrough in this area. The problems which remain are numerous, and the temptation to overindulge in theorizing should be resisted. The most suitable research at present involves long-term programs to obtain more information about the parameters of information transmission and a continual search for models. Looking to neurophysiology for these models seems, at present, premature, since, as someone recently described it, looking for something in the brain is like looking for a needle in a haystack thirty yards away.

The second program which might be extended is combined laboratory and field studies to test in the field predictions made from laboratory studies. A good example of this work is that of Belbin (1953). Early studies along these lines in Bristol have involved investigation of the accident behavior of workers of different ages in jobs of differing complexity (Griew, 1958c), the age structure of jobs of differing complexity (Murrell & Griew, 1958; Murrell, Griew, & Tucker, 1957) and the identification of behavioral elements of jobs of differing age structure (Griew & Tucker, 1958; Murrell & Tucker, 1960). K.F.H. Murrell and D.G. Entwisle are now conducting work in which the elements of specific machine operations in relation to age are being studied in an experimental setting and in which timing of the responses which form work cycles is being examined. Further work in this area seems to be desirable and should not only clarify certain basic problems concerning the adaptability of older subjects to their increasing limitations, but should also improve the quality of industrial field research in aging by serving as a valuable check on laboratory findings.

REFERENCES

Belbin, R.M. Difficulties of older people in industry. *Occup. Psychol.,* 1953, **27,** 177-190.

Birren, J.E. Age changes in speed of simple responses and perception and their significance for complex behaviour. In *Old age in the modern world.* Edinburgh: E. & S. Livingstone, 1955. Pp. 235-247.

Birren, J.E. The significance of age changes in speed of perception and psychomotor skills. In J.E. Anderson (Ed.), *Psychological aspects of aging.* Washington, D.C.: American Psychological Association, 1956. Pp. 97-104.

Bricker, P.D. Information measurement and reaction time. In H. Quastler (Ed.), *Information theory in psychology.* Glencoe, Ill.: The Free Press, 1955. Pp. 350-359.

Broadbent, D.E. *Perception and communication.* London: Pergamon Press, 1958.

Brown, J.S., & Slater-Hammel, H.T. Discrete movements in the horizontal plane as a function of their length and direction. *J. exp. Psychol.,* 1949, **39,** 84-95.

Clay, Hilary M. The relationship between time, accuracy and age on similar tasks of varying complexity. *Gerontologia,* 1957, **1,** 41-49.

Collier, G., & Verplanck, W.S. Non-independence of successive responses at the visual threshold as a function of interpolated stimuli. *J. exp. Psychol.,* 1958, **55,** 429-437.

Craik, K.J.W. Theory of the human operator in control systems: I. The operator as an engineering system. *Brit. J. Psychol.,* 1947, **38,** 56-61.

Craik, K.J.W. Theory of the human operator in control systems: II. Man as an element in a control system. *Brit. J. Psychol.,* 1948, **38,** 142-148.

Crossman, E.R.F.W. Entropy and choice time: The effect of frequency unbalance on choice response. *Quart. J. exp. Psychol.,* 1953, **5,** 41-51.

Crossman, E.R.F.W. The information capacity of the human operator in symbolic and non-symbolic control processes. In *Information theory and the human operator.* Ministry of Supply Publication, 1956, WR/D 2/56. (Ministry of Supply, London)

Crossman, E.R.F.W. The information capacity of the human motor system in pursuit tracking. *Quart. J. exp. Psychol.,* 1960, **12,** 1-16.

Crossman, E.R.F.W., & Szafran, J. Changes with age in the speed of information intake and discrimination. *Experientia Supplementum,* 1956, **4,** 128-135.

Fitts, P.M. The information capacity of the human motor system in controlling the amplitude of movement. *J. exp. Psychol.,* 1954, **47,** 381-391.

Fitts, P.M., & Seeger, C.M. S-R compatibility: Spatial characteristics of stimulus and response codes. *J. exp. Psychol.,* 1953, **46,** 199-210.

Goldfarb, W. An investigation of reaction time in older adults. *Teach. Coll. Contr. Educ.,* 1941, No. 831. (Columbia University, New York)

Gregory, R.L. Increase in "neurological noise" as a factor in ageing. In *Proceedings of the 4th congress, international association of gerontology, Merano, Italy.* Vol. 1. Florence: Tipographica Tito Mattioli [1959]. Pp. 314-324.

Griew, S. Age changes and information loss in performance of a pursuit tracking task involving interrupted preview. *J. exp. Psychol.,* 1958, **55,** 486-489. (a)

Griew, S. A note on the effect of interrupting auditory signals on the performance of younger and older subjects. *Gerontologia,* 1958, **2,** 136-139. (b)

Griew, S. A study of accidents in relation to occupation and age. *Ergonomics,* 1958, **2,** 17-23. (c)

Griew, S. Information gain in tasks involving different stimulus-response relationships. *Nature,* 1958, **182,** 1819. (d)

Griew, S. Complexity of response and time of initiating responses in relation to age. *Amer. J. Psychol.,* 1959, **72,** 83-88. (a)

Griew, S. Set to respond and the effect of interrupting signals upon tracking performance. *J. exp. Psychol.,* 1959, **57,** 333-337. (b)

Griew, S. The learning of statistical structure: A preliminary study in relation to age. In C. Tibbitts & Wilma Donahue (Eds.), *Social and psychological aspects of aging.* New York: Columbia University Press, 1962. Pp. 763-769.

Griew, S., & Tucker, W.A. The identification of job activities associated with age differences in the engineering industry. *J. appl. Psychol.,* 1958, **42,** 278-282.

Hake, H.W., & Hyman, R. Perception of the statistical structure of a random series of binary symbols. *J. exp. Psychol.,* 1953, **45,** 64-74.

Hick, W.E. On the rate of gain of information. *Quart. J. exp. Psychol.,* 1952, **4,** 11-26.

Hyman, R. Stimulus information as a determinant of reaction time. *J. exp. Psychol.,* 1953, **45,** 188-196.

Kay, H. Learning of a serial task by different age groups. *Quart. J. exp. Psychol.,* 1951, **3,** 166-183.

Kay, H. The effects of position in a display upon problem solving. *Quart. J. exp. Psychol.,* 1954, **6,** 155-169.

Kirchner, W.R. Age differences in short-term retention for rapidly changing information. *J. exp. Psychol.,* 1958, **55,** 352-358.

Korchin, S.J., & Basowitz, H. The judgment of ambiguous stimuli as an index of cognitive functioning in aging. *J. Pers.,* 1956, **25,** 81-95.

McGill, W.J. Multivariate information transmission. *Psychometrika,* 1954, **19,** 97-116.

Morin, R.E., & Grant, D.A. Learning and performance on a key-pressing task as a function of the degree of spatial stimulus-response correspondence. *J. exp. Psychol.,* 1955, **49,** 39-47.

Murrell, K.F.H., & Entwisle, D.G. Age differences in movement pattern. *Nature,* 1960, **185,** 948-949.

Murrell, K.F.H., & Griew, S. Age structure in the engineering industry: A study of regional effects. *Occup. Psychol.,* 1958, **32,** 86-88.

Murrell, K.F.H., Griew, S., & Tucker, W.A. Age structure in the engineering industry: A preliminary study. *Occup. Psychol.,* 1957, **31,** 150-168.

Murrell, K.F.H., & Tucker, W.A. A pilot job study of age related causes of difficulty in light engineering. *Ergonomics,* 1960, **3,** 74-79.

Quastler, H. (Ed.) *Information theory in psychology.* Glencoe, Ill.: The Free Press, 1955.

Searle, L.V., & Taylor, F.V. Studies of tracking behavior: I. Rate and time characteristics of simple corrective movements. *J. exp. Psychol.,* 1948, **38,** 615-631.

Senders, V.L., & Sowards, A. Analysis of response sequences in the setting of a psychophysical experiment. *Amer. J. Psychol.,* 1952, **65,** 358-374.

Shannon, C.E., & Weaver, W. *The mathematical theory of communication.* Urbana: University of Illinois Press, 1949.

Skinner, B.F. The processes involved in the repeated guessing of alternatives. *J. exp. Psychol.,* 1942, **30,** 495-503.

Suci, G.J., Davidoff, M.D., & Surwillo, W.W. Reaction time as a function of stimulus information and age. *J. exp. Psychol.,* 1960, **60,** 242-244.

Taylor, F.V. Human engineering. In S. Koch (Ed.), *Psychology: A study of science.* Vol. 5. New York: McGraw-Hill, 1960.

Verplanck, W.S. Non-independence of successive responses in coin guessing. In Response mechanisms at the visual threshold: A methodological study. (O.N.R., U.S. Navy Contract NSori-07639, Project NR140-015, Final Report.) Washington, D.C.: Office of Naval Research, 1955.

Weiss, B., Coleman, P.D., & Green, R.F. A stochastic model for time ordered dependencies in continuous scale repetitive judgements. *J. exp. Psychol.,* 1955, **50,** 237-244.

Welford, A.T. *Skill and age.* London: Oxford University Press, 1951.

Welford, A.T. The psychological refractory period and the timing of high speed performance—a review and a theory. *Brit. J. Psychol.,* 1952, **43,** 2-19.

Welford, A.T. *Ageing and human skill.* London: Oxford University Press, 1958.

Welford, A.T. Channel capacity and slowness in sensorimotor performance. In *Proceedings of the 4th congress, international association of gerontology, Merano, Italy.* Vol. 1. Florence: Tipographia Tito Mattioli [1959]. Pp. 334-337. (a)

Welford, A.T. Evidence of a single-channel decision mechanism limiting performance in a serial reaction task. *Quart. J. exp. Psychol.,* 1959, **11,** 193-210. (b)

Welford, A.T. Psychomotor performance. In J.E. Birren (Ed.), *Handbook of aging and the individual: Psychological and biological aspects.* Chicago: The University of Chicago Press, 1959. Pp. 562-613. (c)

Wiener, N. *Cybernetics.* New York: John Wiley & Sons, 1948.

Woodworth, R.S. *Experimental psychology.* New York: Henry Holt, 1938.

CHAPTER 4

Experimental-Clinical Method and the Cognitive Disorders of the Senium

JAMES INGLIS

Much effort has been devoted to the study of cognitive disturbances in elderly psychiatric patients (Dörken, 1954; Eysenck, 1946; Granick, 1950; Grewel, 1953; Inglis, 1958; Jones & Kaplan, 1956). Many, if not all, of these studies have been based on the prior selection of psychiatric groups, usually in terms of some such diagnosis as senile dementia. This study will examine and illustrate the difficulties and dangers inherent in this kind of research and will propose an alternative method for use in this field. This method is one which has been recommended mainly by Shapiro (1951) and Payne (1953) and employed by them in the study of overinclusive thought disorder (Payne, Matussek, & George, 1959) and delusional thinking (Shapiro & Ravenette, 1959).

Some of the difficulties and dangers involved in basing the investigation of abnormal behavior on psychiatric diagnosis are, in a sense, practical ones, for example, the dependability with which these nosological categories can be determined (Ash, 1949; Foulds, 1955; Mehlman, 1952; Schmidt & Fonda, 1956). For the purposes of the present discussion it seems more important to look at what may be called the difficulties in principle in using diagnosis as a basis for research.[1] These difficulties have been ably dscussed by Payne (1958), who has pointed out that diagnosis in psychiatry is almost entirely a matter of label. Few investigators, however, are interested in the label for its own sake. It is only useful insofar as it carries certain fairly specific implications, commonly four in number.

1. Descriptive implications: the parts of the labeling system that give a short picture of the presenting abnormalities, symptoms, or signs to which the psychiatrist accords importance.
2. Prognostic implications: the references to the natural history, likely course, and outcome of the disorder.
3. Etiological implications: the indications of the likely cause or precipitants of the disturbance.
4. Therapeutic implications: the indications inherent in the label as to what may be done about the disorder.

When the psychologist comes to investigate behavioral disorders and build a study on psychiatric labels, it is usually one or all of these implications that he has in mind, not the label itself. Still the dangers of fallacious inference in this process are great and deserve detailed consideration.

DESCRIPTIVE IMPLICATIONS

The relations which can exist among the label, its descriptive implications, and the results of any psychological investigation of performance variables may be considered first.

The criterion groups (which may be labeled "organic," "functional," "demented," "depressed," or the like) are usually chosen because the individuals comprising them show certain supposedly char-

[1] This paper was prepared for the International Research Seminar on Social and Psychological Aspects of Aging with the assistance of a summer research associateship from the Faculty of Arts and Science, Queen's University, Kingston, Ontario, in the summer of 1960.

acteristic behavioral abnormalities. An attempt to secure performance variables which will also be characteristic of such groups, however, must be built on the knowledge that a psychiatric label can correlate with the abnormalities which draw the attention of the psychiatrist and the selected performance measures even if there is no correlation between the abnormalities and the measures. This may be simply illustrated geometrically, since the size of the correlation between variables is equivalent to the cosine of the angle between the vectors represent-

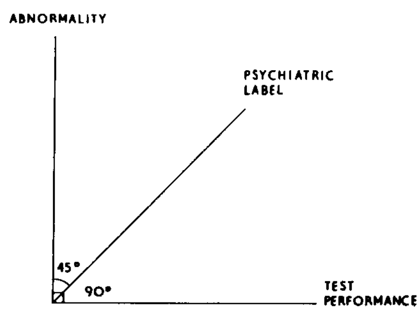

FIG. 1. Geometrical illustration of the size of the correlation between variables. (Cosine 45° = 0.7; cosine 90° = 0.)

ing them. It can be seen from Fig. 1 that, unless the correlation of each of two variables with a third is greater than .70, these two variables need not correlate with each other. Probably the reliability of psychiatric diagnosis seldom exceeds .70, thus it cannot correlate to a greater degree than that with any other variable, and psychological measures validated against diagnosis need never necessarily relate to any descriptive implications the label may suggest.

It is feared that the apparent success of some attempts to relate such labels, their descriptive implications, and performance variables is spurious and frequently the result of "criterion contamination" of some kind.

Direct criterion contamination results, of course, when the performance under investigation is used as one of the criteria for sorting the groups against whose behavior the relevance of the performance variables is being evaluated. This contamination can be seen in the study of Ames, Learned, Métraux, & Walker (1954) on Rorschach responses in old age. These investigators sought to discover what effect chronological age might have on performance on this test by examining decade groups of elderly people from sixty to one hundred years of age. Thus grouped, their test protocols did not show marked differences among the age groups. The authors then sorted the groups in terms of their test results and discovered that this method produced more significant differences among the group. (It would indeed have been surprising if they had failed to find significant differences then.)

More often, however, contamination enters such studies more subtly, as indirect contamination. Suppose a test is to determine whether the presence of Characteristic X (memory disorder) has any relation to the existence of Condition Y (organic brain lesions). To study this problem, it would first be necessary to secure at least two groups, one (Group Y+) with, one (Group Y–) without, Condition Y. Even if direct contamination were excluded, should the tester establishing the groups use his own judgment on the presence of X as a criterion for putting a person into Group Y+ and the absence of X for putting another into group Y–, and, if his judgment were good, it would then follow that any objective measure of X subsequently given to these individuals would inevitably show that Characteristic X was more frequent in the members of Group Y+ than in the members of Group Y–. It can be seen, however, that the original question about the association of Characteristic X with State Y remains unanswered and can be satisfactorily answered only when groups Y+ and Y– are initially sorted without any reference to X.

One study by Shapiro, Post, Löfving, and Inglis (1956) was specifically concerned with the possible effects of such indirect contamination. This study was initially intended to examine the efficiency of certain popular clinical tests to discriminate among functional, doubtful, and organic groups of elderly psychiatric patients. When the psychiatrist first formed the groups on the bases of examination, histories, and clinical judgment, analysis of variance revealed that no fewer than twenty-four of the twenty-eight subtests used discriminated among the groups at a 5 per-cent or higher level of significance.

The psychiatrist who classified the patients in this study had no knowledge of the results of the psychological tests, so that direct contamination could not have taken place; nevertheless, he could not fail to have formed impressions of general cognitive efficiency and memory functioning from the patients' histories and his clinical examination. These impressions might influence his criteria for sorting the patients. The purpose of the test items, however, was to objectify such impressions so that their diagnostic value could be empirically determined. If these impressions formed part of the criteria for classification, any agreement between the psychiatrist's sorting and the test results would mean that his impressions of cognitive status could be confirmed by objective tests. Indirect contamination might, therefore, have taken place, since the aim was to investigate the nature of the relation of cognitive and memory functions to illness, not merely to measure a relation already assumed to exist.

In order to eliminate the possibility of such contamination, it was necessary, therefore, for the psychiatrist to reclassify the same patients into the functional, doubtful, and organic categories, this time using only the most objective possible criteria which were entirely unrelated to cognitive or memory function. To achieve this, the psychiatrist provided a check list of signs (avoiding as far as possible any which might be related to cognitive function) that he considered useful in deciding whether a patient could be classified organic. He provided eight signs, four from the histories and four from the examination of the patients, and then reclassified according to these signs alone. The presence or absence of these signs was determined by the psychologist independently of the patients' case histories.

Three main questions could be answered by the second analysis.

1. Was there any other than a chance relation between the psychiatrist's first and second groupings?

2. If the two groupings were not completely independent, would it be possible to discover whether any significant change had taken place in the classification?

3. What effect had any changes in the grouping had on the discriminating power of the tests, and were such effects consistent with the hypothesis of indirect contamination?

Seventy-five of the 102 subjects remained in the same category on the first and second analyses. The results are shown in Table 1.

The relation of the two groupings was tested in the manner described by Garrett (1948) for a χ^2 test of independence in contingency tables. The χ^2 value was 76.45, which, with four degrees of freedom, is significant beyond the 1 per-cent level. These results answered the first question stated above, confirming the reliability (which was about 75 per cent) of the psychiatrist's diagnosis in these three groups after one year.

Since it had been shown that the two sets of data were related, it was necessary to determine whether any systematic change had taken place in the grouping on the second occasion compared with

TABLE 1
CHANGES IN DIAGNOSIS AFTER REDUCTION
OF THE INFLUENCE OF INDIRECT CONTAMINATION

Those diagnosed on second occasion as	*Those diagnosed on first occasion as*			
	Functional	Doubtful	Organic	Total
Functional	47	14	6	67
Doubtful	5	10	2	17
Organic	–	–	18	18
Total	52	24	26	102

the first. Unsystematic variation alone would have been expected to cause approximately as many individuals to be displaced in one direction as in another—the number of diagnoses changed, for example, from doubtful to functional should have been the same as the number changed from doubtful to organic. An alternative hypothesis was formulated which predicted that the flow of change would be significantly greater in the direction of functional diagnosis away from the doubtful and the organic groups. This change seemed caused by the fact that if the patient had, on the first occasion, presented enough objective evidence of brain lesions (such as abnormal neurological findings strongly indicative of pathology), he was placed in the organic group. Any impression of apparent preservation of cognitive efficiency did not seem to influence the diagnosis toward doubtful or functional. The fact that an individual showed few or none of the objective signs, although his mental functioning seemed impaired, did appear to influence the diagnosis, more likely making it doubtful or organic. It follows that reclassification when impressions of cognitive and memory functions were excluded would change the flow mainly in one direction, away from organic toward doubtful and functional and away from doubtful toward functional. This hypothesis was tested in the manner described by McNemar (1949) for a test of change in correlated proportions. This technique gave a critical ratio of 2.46, which is significant beyond the 1 per-cent level on a one-tailed test of significance (the direction of change having been predicted). This result permitted confident rejection of the null hypothesis and confirmed the alternative notion that the influence of the clinician's impression of cognitive and memory function had biased the first classification in favor of organic diagnosis. This result was also consistent with the hypothesis that the first phase of the study had produced a classification involving some contamination of the data.

Variance of the group results on each of the subtests was again analyzed to see what effect the changes in classification had on the discriminating efficiency of the tests. It was shown that now only eleven of the twenty-eight subtests discriminated at the 5 per-cent or higher level and that the general levels of significance were much lower. It is worth while to emphasize that one test which successfully discriminated between the groups on both occasions was a version of the Bender-Gestalt drawing test (Bender, 1946).

This study thus showed that spuriously positive relations between psychiatric labels and performance variables may be caused by inadequate control over the factors contributing to selection of criterion groups. Having recognized this difficulty, however, another possible difficulty must be remembered. Suppose that for the purpose of defining groups Y+ and Y– Characteristic X had been one of the most important criteria. To deny the person sorting the groups his judgment on this variable might deprive him of crucial information and weaken the criterion groups eventually chosen. How, then, can we determine the relation between the aspects of disturbed behavior which psychiatric labels apparently describe and objective estimates of performance? One answer is, of course, that the investigation of such relations may be determined directly.

In this way Inglis (1957) chose to examine, as directly as possible, one descriptive aspect of behavior commonly held important in senile cognitive impairment. The initial problem chosen for examination was to discover what, in objective psychological terms, could be shown to characterize patients said to be suffering from memory disorder. Here, it should be emphasized, the behavioral pursuit of the characteristic disorder was not mediated by any diagnostic label, but was undertaken directly in terms of the symptomatic disturbance.

Two major findings emerged from this study. First, patients said to be suffering from memory disorder had a marked disability in the acquisition phase of learning paired associates. Although this finding may hardly seem surprising, the approach used permitted at least the operational analysis of descriptive clinical impressions and also provided a method for examining memory deficit in an objective, quantifiable way relatively independent of the subject's past experience. Incidentally, these results illustrate the force of Hull's (1917) early insistence that neither the common nor clinical use of the term "memory" differentiates specifically enough between the acquisition and retention phases in the learning process, phases which may properly be held relatively distinct.

The second finding was that elderly patients with memory disorders showed a larger mean discrepancy between the verbal and performance scales (VS > PS) of the Wechsler-Bellevue Scale (Wechsler, 1944) and that this difference, at least in the memory-disorder group, seemed to be related to the amount of difficulty experienced in the acquisition of new knowledge. The connection between learning and some aspects of intelligence in these subjects seemed to be related to Cattell's (1943) and Margaret Davies Eysenck's (1945) use of "fluid" and "crystallized" ability.

This investigation showed that certain descriptive elements commonly held important in some of the psychiatric disorders of the elderly could be related to objectively defined performance variables, which, in turn, may also be relevant to both etiological and therapeutic implications. Thus, the relative usefulness of the prognostic implications of diagnostic categories and their relation to performance variables was demonstrated.

PROGNOSTIC IMPLICATIONS

Often enough the psychologist is concerned not merely with those contemporaneous descriptive elements which may or may not be implied by the use of a psychiatric label; frequently he is concerned with some prognostic indicator of the likely course of behavioral changes, such as deterioration, in the disordered.

It can be argued that the attempt to relate performance variables to psychiatric labels cannot ensure the existence of such a relation. Payne (1958) has argued this point. He supposes that the psychiatrist who originally labeled the criterion groups had been able to provide a fairly accurate prognosis for these groups and that each group member was labeled in terms of the presence or absence of ten symptoms and/or signs. It is possible that only four of these symptoms might be relevant to prognosis. The label would then have a significant, but imperfect, correlation with prognosis. Even a performance variable with a proven relation to the descriptive implications of the label might be related to a different set of four of these ten symptoms; thus, although the test would also have an imperfect, but perhaps significant, correlation with the label, it need not be related to any of the elements which are related to prognosis.

As has been noted above, the Bender-Gestalt Test has been shown to discriminate between functional and organic elderly patients (Inglis, Shapiro, & Post, 1956) even when the most stringent measures have been taken to rule out the possibility of any criterion contamination. Furthermore, Shapiro, Field, and Post (1957) have been able to show that a more objective measure derived from the same test also differentiated the criterion groups at a high level of significance. Another investigation was undertaken by Inglis, Colwell, and Post (1960) to study the prognostic power of such test results. In this study, fifty-nine elderly psychiatric patients whose results on this test were available were individually followed up approximately two years after they had been tested. The follow-up data were collected by psychiatric social workers and evaluated by the psychiatrist and psychologist. Information was collected about each patient's day-to-day activities; changes in symptomatology, cognitive status, and personality; hospitalization record; and the like. It emerged, upon analysis, that there was little or no relation between the test score and the estimates made of the patients' conditions during the follow-up period, even though it was confirmed that the original psychiatric labels did have some predictive power (Norris & Post, 1954).

This investigation demonstrated what Payne (1958) had contended: even a test which has been validated and cross-validated in terms of its classification power does not necessarily have the prognostic power of the classification system against which it was initially standardized. It seems likely that failure in this case is caused by the indirect (label-mediated) way in which the relation between the functions involved in test performance and behavioral disturbance was determined.

It has to be suggested again that a more profitable approach to determining psychological variables which carry some valid implications for psychiatric diagnosis may be made through the direct study of the principal descriptive characteristics of psychiatric disturbances. Inglis has made an attempt to use this method in a second analysis (1959c) of some data originally collected by Walton (1958), who had been concerned with assessing the predictive utility of a learning test for psychiatric disorders of the senium simply in terms of changes in diagnosis over a two-year period. However, of the forty-eight cases described by Walton, enough data were provided on nineteen to permit a further, perhaps more valid, direct prognostic evaluation in terms of the outcome of illness. Two outcomes could be discerned: favorable (for example, recovery and/or discharge) and unfavorable (for example, death). When the patients were also classified in terms of their test scores (scores of thirty-one or more trials indicated poor learning and were called "high," scores of below thirty-one, "low"), a fourfold table relating outcome to test score could be constructed (Table 2).

TABLE 2
PREDICTION OF OUTCOME OF ILLNESS FROM LEARNING TEST SCORES

Test score	*Outcome*	
	Favorable	Unfavorable
Low	10	3
High	0	6

A value of 9.47 was obtained for a χ^2 measure of association between these categories (Garrett, 1948) which is significant beyond the 1 per-cent level.

It is of interest to compare this direct prognostic (or, as Zubin [1952] might insist, at least, "hysterognostic") estimate provided by the test with the predictive efficiency of the original diagnoses. Thus, outcome in these cases could also be related to initial diagnosis in terms of another fourfold table, as shown in Table 3.

TABLE 3
PREDICTION OF OUTCOME OF ILLNESS FROM INITIAL DIAGNOSIS

Initial diagnosis	*Outcome*	
	Favorable	Unfavorable
Functional	4	4
Organic	6	5

This association yielded a nonsignificant χ^2 value of .025, showing that in some instances, at least, a direct objective estimate of a crucial element in abnormality may be a more satisfactory prediction than a label-mediated prognosis. In the case of prognosis, as in the case of description, therefore, available data support the contention that a direct attack on the implications of a given diagnostic label may be as profitable in the case of cognitive disturbances of the elderly as Payne (1958) has argued it may be in the psychological approach to general behavioral disorder.

ETIOLOGICAL IMPLICATIONS

It is possible to show that etiological implications may be related to psychiatric labels and psychiatric labels related to performance variables without the postulated etiology and observed performances being related themselves.

So little is certain about the etiology of the disorders indicated by psychiatric labels that it might be imagined this kind of mistaken inference would be rare. One common danger, however, in the case of the cognitive disorders of the aged is that using diagnostic labels as criteria may tie the investigator to psychiatric hypotheses which, in this area, are often organic in content and despairing in nature. Too often such implicit hypotheses as those lying behind the term "senile dementia" suggest causes at once inaccessible and irreversible. If these causes are accepted too readily, society may feel absolved from any responsibility other than custody.

A study by Bartlet and Shapiro (1956) illustrates the different activities which may be stimulated or suppressed merely by different ways of talking about a disorder. They cite the case of a boy of about average intelligence who was apparently unable to read. This child was said to be suffering from congenital word blindness, which, as Payne (1957) has pointed out, is a tenable hypothesis insofar as it accounted for most of the facts, but a sterile one insofar as it suggested few ways of controlling and discovering new facts about the disorder. Bartlet and Shapiro defined the child's difficulties as a defect of specific learning mechanisms and, with this new definition, were eventually able to effect some improvement in his condition.

In the case of cognitive and other behavioral abnormalities of the aged, analogous arguments may be put forward. What the psychologist must aim to produce are hypotheses which allow the usual scientific processes of description, prediction, and control. As Shapiro (1957) has argued, unless and until we can point to failure after long and stubborn attempts to erect and evaluate such hypotheses, we, as psychologists, have no right to fall back on psychiatric notions which are often simply hypotheses of despair.

A principal virtue of psychological hypotheses is that their interest is, or should be, focused directly on regularities or irregularities in the observed behavior. These hypotheses may be couched in language which involves neurophysiological elements, but can also be expressed in terms which do not involve any reference to such processes. Whatever the choice of language, however, interest remains directed at behavior as such and is not diverted to the vicissitudes of the machine—or, for that matter, the ghost—as is all too frequently the case with many psychiatric hypotheses.

Another attempt has been made (Inglis, 1958) to comprehend some data gathered in the psychological investigations of cognitive deficit of elderly psychiatric patients in the framework provided by Hebb's (1949) neuropsychological theory. It is possible to demonstrate experimentally (Inglis, 1959a) that Hebb's hypothesis can be used to relate impairment shown on learning tasks by some elderly psychiatric patients to particular defects in general intellectual ability, especially disturbances of conceptual usage.

It is also possible, and sometimes more convenient, to express relations between behavioral observations in language that is not committed to any neurophysiological frame of reference. Broadbent (1958) has suggested that some terms used to describe processes in information transmission may be used in a neutral fashion. An attempt has been made to conceive of learning disorder in elderly persons in these terms by Inglis (1960) in the suggestion that the failure in learning that is evinced by some elderly patients may be caused by a breakdown of the short-term storage system which Broadbent (1956) has used to account for the ability of normal subjects to respond sequentially to information delivered simultaneously through two channels. The results of a similar experiment with elderly patients are in accord with this hypothesis.

The direct study of abnormal behavior, then, can lead not only to greater clarity of description and more valid prediction, but might also formulate more fruitful, less stereotyped descriptive and explanatory hypotheses.

THERAPEUTIC IMPLICATIONS

The same possibilities of false inference exist in using psychiatric labels to mediate connections between control elements and performance variables. If these elements may be tackled directly, however, there are at least two functions which the psychologist may have in relation to them. First, the psychologist's function can be only evaluative, since he commonly lacks the qualifications which would permit him to play an executive role in treatment. Even if this argument is accepted, distinctive functions remain for him to fulfill directly in relation to evaluation processes.

The principal function here brings us back to the primary task of description. Most attempts which have been made to assess the effects of treatment on any kind of psychiatric disorders have been bedeviled by the almost complete lack of satisfactory means to measure changes in behavior. Attempts to carry out such assessment have commonly relied on changes in diagnosis or admittedly unsatisfactory rating scales. It cannot, however, too often be repeated that, unless we can estimate with a known degree of precision what is wrong with a person's behavior or how wrong it is, we cannot make a valid estimate of improvement or deterioration.

Even the best studies which have tried to assess the effects of various treatments (oxygen intake, hormone and vitamin administration, and so on) on cognitive disturbances of the elderly (Inglis, 1958; Post, 1959) have produced inconclusive results, either because no systematic, objective evaluation of the relevant cognitive functions had been made or because such assessment had been made by inappropriate techniques. An unpublished study by Inglis, Kendrick, and Post on the psychological effects of vitamin treatment for elderly psychiatric patients with memory disorders has attempted to circumvent some of these problems by using tests (Inglis, 1959b) which have been validated at least for the groups on which they were used.

The psychologist who is concerned with cognitive and other disorders of behavior in the elderly must attempt to assess directly the relevant aspects of such disorders through precise description, not indirectly through the mediating agency of psychiatric labels. One need not concede, however, that the psychologist should be concerned only with evaluating treatment devised by others. If the psychologist can describe behavior precisely enough, make hypotheses convincingly enough, and, as a consequence, provide controls efficient enough, the mechanics of the control procedures could, if necessary, be turned over to people with different qualifications, who would certainly be willing to apply them.

DISCUSSION

It has been advanced that the principal implications of psychiatric labeling procedures may—indeed, must—be explored directly by the psychologist and not, as is commonly the case, indirectly through the investigation of performance characteristics of pre-selected diagnostic groups. This recommendation may be expanded to include the suggestion that the psychologist should abstain altogether from using such loaded words as "diagnosis," "prognosis," "etiology," and "treatment."

What is the behavioral scientist interested in when he is faced with the problems of disordered behavior? Broadly, these are the questions he usually would like to answer.

1. Of what does this abnormality precisely consist? This question demands that investigation try first to describe the disorder as closely as possible.
2. How can we conceive of it in relation to other observations? To satisfy ourselves as scientists, we should be able to construct a working model which will comprehend our description of the abnormal phenomena and other apparently related observations.
3. How useful is our model? The way of talking about such observations must not only fit them together as neatly as possible, but, ideally, should also be manipulable in that it can produce further testable expectations. Since expectations, to be testable, must usually be related to change and since we are concerned primarily with abnormalities and their distressing consequences, we do our best to arrange for changes in the direction of amelioration.

To discuss what the psychologist does in terms of observation, hypothesis-making, and hypothesis-testing is simply to suggest that the psychologist whose concern is abnormal behavior should try to do in his area what other behavioral scientists do in theirs. The approach outlined here has proved, and will prove, fruitful in investigating general disorders of behavior and in understanding particular cognitive disorders of the elderly.

REFERENCES

Ames, Louise B., Learned, Janet, Métraux, Ruth W., & Walker, R.N. *Rorschach responses in old age.* New York: Hoeber, 1954.

Ash, P. The reliability of psychiatric diagnosis. *J. abnorm. soc. Psychol.,* 1949, **44,** 272-276.

Bartlet, Deone, & Shapiro, M.B. Investigation and treatment of a reading disability in a dull child with severe psychiatric disturbances. *Brit. J. educ. Psychol.,* 1956, **26,** 180-190.

Bender, Lauretta. *Instructions for the use of the visual-motor Gestalt test.* New York: American Orthopsychiatric Association, 1946.

Broadbent, D.E. Successive responses to simultaneous stimuli. *Quart. J. exp. Psychol.,* 1956, **8,** 145-152.

Broadbent, D.E. *Perception and communication.* London: Pergamon Press, 1958.

Cattell, R.B. The measurement of adult intelligence. *Psychol. Bull.,* 1943, **40,** 153-193.

Dörken, H. Psychometric differences between senile dementia and normal senescent decline. *Canad. J. Psychol.,* 1954, **8,** 187-194.

Eysenck, Margaret D. An exploratory study of mental organization in senility. *J. neurol. neurosurg. Psychiat.,* 1945, **8,** 15-22.

Eysenck, Margaret D. The psychological aspects of aging and senility. *J. ment. Sci.,* 1946, **92,** 171-181.

Foulds, G.A. The reliability of psychiatric, and the validity of psychological, diagnosis. *J. ment. Sci.,* 1955, **101,** 851-862.

Garrett, H.E. *Statistics in psychology and education.* (3rd ed.) New York: Longmans Green, 1948.

Granick, S. Studies in the psychology of senility: A survey. *J. Geront.,* 1950, **5,** 44-58.

Grewel, F. Testing psychology of dementias. *Folia Psychiat. Neerl.,* 1953, **56,** 305-339.

Hebb, D.O. *The organization of behavior: A neuropsychological theory.* New York: John Wiley & Sons, 1949.

Hull, C.L. The formation and retention of associations among the insane. *Amer. J. Psychol.,* 1917, **28,** 419-435.

Inglis, J. An experimental study of learning and "memory function" in elderly psychiatric patients. *J. ment. Sci.,* 1957, **103,** 796-803.

Inglis, J. Psychological investigations of cognitive deficit in elderly psychiatric patients. *Psychol. Bull.,* 1958, **55,** 197-214.

Inglis, J. A paired-associate learning test for use with elderly psychiatric patients. *J. ment. Sci.,* 1959, **105,** 440-443. (a)

Inglis, J. Learning, retention and conceptual usage in elderly patients with memory disorder. *J. abnorm. soc. Psychol.,* 1959, **59,** 210-215. (b)

Inglis, J. On the prognostic value of the modified word learning test in psychiatric patients over 65. *J. ment. Sci.,* 1959, **105,** 1100-1101. (c)

Inglis, J. Dichotic stimulation and memory disorder. *Nature,* 1960, **186,** 181-182.

Inglis, J., Colwell, Catherine, & Post, F. An evaluation of the predictive power of a test known to differentiate between elderly "functional" and "organic" psychiatric patients. *J. ment. Sci.,* 1960, **106,** 1486-1492.

Inglis, J., Shapiro, M.B., & Post, F. Memory function in psychiatric patients over sixty: The role of memory in tests discriminating between "functional" and "organic" groups. *J. ment. Sci.,* 1956, **102,** 589-598.

Jones, H.E., & Kaplan, O.J. Psychological aspects of mental disorders in later life. In O.J. Kaplan (Ed.), *Mental disorders in later life.* (2nd ed.) Stanford: Stanford University Press, 1956. Pp. 98-156.

McNemar, Q. *Psychological statistics.* London: Chapman Hall, 1949.

Mehlman, B. The reliability of psychiatric diagnosis. *J. abnorm. soc. Psychol.,* 1952, **47,** 577-578.

Norris, Vera, & Post, F. Treatment of elderly psychiatric patients: Use of a diagnostic classification. *Brit. med. J.,* 1954, **1,** 675-679.

Payne, R.W. The role of the clinical psychologist at the institute of psychiatry. *Rev. Psychol. appl.,* 1953, **3,** 150-160.

Payne, R.W. Experimental method in clinical psychological practice. *J. ment. Sci.,* 1957, **103,** 189-196.

Payne, R.W. Diagnostic and personality testing in clinical psychology. *Amer. J. Psychiat.,* 1958, **115,** 25-29.

Payne, R.W., Matussek, P., & George, E.I. An experimental study of schizophrenic thought disorder. *J. ment. Sci.,* 1959, **105,** 627-652.

Post, F. Early treatment of persistent senile confusion. *Geront. clin.,* 1959, **1,** 114-121.

Schmidt, H.O., & Fonda, C.P. Reliability of psychiatric diagnosis: A new look. *J. abnorm. soc. Psychol.,* 1956, **52,** 262-267.

Shapiro, M.B. An experimental approach to diagnostic psychological testing. *J. ment. Sci.,* 1951, **97,** 748-764.

Shapiro, M.B. Experimental method in the psychological description of the individual psychiatric patient. *Int. J. soc. Psychiat.,* 1957, **3,** 89-102.

Shapiro, M.B., Field, J., & Post, F. An enquiry into the determinants of a differentiation between elderly "organic" and "non-organic" psychiatric patients on the Bender Gestalt tests. *J. ment. Sci.,* 1957, **103,** 364-374.

Shapiro, M.B., Post, F., Löfving, Barbro, & Inglis, J. Memory function in psychiatric patients over 60: Some methodological and diagnostic implications. *J. ment. Sci.,* 1956, **102,** 233-246.

Shapiro, M.B., & Ravenette, A.T. A preliminary experiment on paranoid delusions. *J. ment. Sci.,* 1959, **105,** 295-312.

Walton, D. The diagnostic and predictive accuracy of the modified word learning test in psychiatric patients over 65. *J. ment. Sci.,* 1958, **104,** 1119-1122.

Wechsler, D. *The measurement of adult intelligence.* (3rd ed.) Baltimore: Williams and Wilkins, 1944.

Zubin, J. Discussion of contributions dealing with diagnosis and prognosis of mental disorder. In P.H. Hoch & J. Zubin (Eds.), *Relation of psychological tests to psychiatry.* New York: Grune and Stratton, 1952.

CHAPTER 5

Age Differences in Conceptual Abilities

DENNIS B. BROMLEY

The term "conceptual thought" refers to the processes of abstraction and generalization, especially if they involve symbolism. Humphrey (1951) has defined concept formation as follows: "The activity whereby an organism comes to effect a constant modification towards an invariable feature or set of features occurring in a variable context" (p. 256). It is not yet clear whether conceptual ability is a relatively distinct process like memory span or verbal fluency or simply an aspect of high-grade intelligence, since the process of forming concepts in both everyday life and the laboratory appears to involve the intellect as a whole.

Methods of assessing conceptual thought take various forms, but in general they require the subject to apply some principle or set of principles which will enable him to either sort or order a number of otherwise diverse items or account for an existing arrangement. He may be required to order or sort blocks or cards according to shape, color, or number; he may be asked to continue a series of terms such as "apple, bun, cake, . . ." or to find the odd member in a group of otherwise similar items. One common method is to ask the subject to state the meaning (give the abstract and general principle) of a proverb. At the University of Liverpool, Hearnshaw (1956) devised a novel form of testing which stresses the element of temporal integration in the formation of concepts by presenting the stimulus material over time and by introducing abstract principles of organization which involve temporal progression.

Considerable interest has been shown in the effects of mental disease and brain injury on conceptual thought processes (Goldstein & Scheerer, 1941; Halstead, 1947; Rapaport, Gill, & Schafer, 1944), but relatively few investigations have been made on the normal effects of aging. It is not intended to review these investigations here, but rather to outline some recent findings arising from some work, which is still incomplete, at the University of Liverpool.

METHODS AND RESULTS

This study is designed to give data on age differences in conceptual abilities compared with age differences in general intellectual abilities. The underlying assumption is that, because conceptual thought processes appear to be easily, often seriously, impaired in mental disease and brain injury, one can expect the normal processes of aging to have deleterious effects on them, too. These effects should reveal themselves in two sorts of age difference: (1) quantitative differences which should show significant, perhaps substantial, systematic decrements with age in conceptual test scores, and (2) qualitative differences which should show systematic alterations with age in the kinds of response made.

Observed age differences on conceptual tests can be compared with observed age differences on the various subtests of the Wechsler-Bellevue Scale (Wechsler, 1944) in order to see whether abstraction and generalization are processes which decline relatively quickly or slowly with age. (Wechsler speaks of "hold" and "don't hold" abilities, Cattell [1943] of "crystallized" and "fluid" abilities in connection with this differential decline.)

The author has published several studies in the *Journal of*

Gerontology (Bromley, 1956; Bromley, 1957), but not all of them are concerned with conceptual thought processes. They are based on a cross-sectional design using parametric methods of statistical inference. For various reasons a change was recently made to nonparametric methods, and the results and matching procedures have been reworked without departing from the basic cross-section design.

From a pool of 256 volunteer subjects, eighty men and eighty women were selected to secure comparability of Wechsler-Bellevue I.Q. (intelligence quotient), Wechsler-Bellevue vocabulary, and social background rating at all age levels. Sex differences in these variables and in chronological age were eliminated. This group of 160 subjects constitutes the middle (main) sample with an age range of seventeen to seventy-eight (median=48) and an I.Q. range of 110 to 132 (median=122). According to Wechsler (1944), intelligence quotients of this order are characteristic of the top 25 per cent of the population. In addition, a group of forty-eight superior subjects, mostly men, were selected for the upper sample with an age range of twenty-three to seventy-seven (median=51) and an I.Q. range of 128 to 145 (median=133). Finally, a group of forty-eight average subjects, mostly older women, were selected for the lower sample with an age range of seventeen to eighty-two (median=63) and an I.Q. range of 88 to 112 (median=103).

The use of three samples makes it possible to cross-validate observations, because reliable age differences should be observable in all three samples. It must be pointed out, however, that the subjects in the upper and lower samples are not so well matched as the subjects in the middle sample. Nevertheless, when inferences are being drawn, it should prove possible to make some allowance for this lack of comparability, especially since our interest lies in relative rather than absolute age differences and not, for the moment at least, in sex or ability differences in normal intellectual decline with age.

Many nonparametric statistics can be used to establish matched groups and examine age differences in intellectual abilities, but it is also possible to use graphs to illustrate some points which might otherwise receive less attention. The relation between scores on the Wechsler-Bellevue subtests and chronological age can be summarized in terms of Spearman's rank order correlation (r_s). Table 1 shows the r_s of each subtest with age and ranks of these correlations within samples. If the r_s can be regarded as an indication of the rate at which an ability is declining with age—and the graphs suggest that this is so—then, provided we can demonstrate a measure of agreement among the three samples, we have not only cross-validated our observations, but we have also made it possible to get a more exact estimate of the differential decline with age in the Wechsler-Bellevue subtests. The Kendall coefficient of concordance (W) expresses the degree of association between k ranked variables; in this case, $k = 3$ and $W = 0.89$. It is clear that there is considerable agreement among the three samples in the way in which the subtest scores are associated with age.

Several features of Table 1 call for comment. In the middle sample, the difference in correlation between the least and most declining subtests is very large (+ 0.11 and –0.71). The least declining performance subtest, object assembly, declines more than the most declining verbal subtest, arithmetic. This confirms Wechsler's opinion that performance tests seem to be more sensitive than verbal tests to the deleterious effects of aging. The similarities subtest, which is generally considered to involve conceptual thought, can be regarded as a declining verbal subtest, especially since it is untimed. Vocabulary, of course, has been experimentally held constant in the middle sample and is not strongly associated with age in either of the other two samples. Vocabulary is a base line of sorts in the examination of the differential effects of age in other subtests; that is, other scores change with age relative to vocabulary. The separation of verbal and performance subtests into hold and don't hold categories does not exactly coincide with that of Wechsler, but this does not concern us at the moment.

The graphs which illustrate the age relationships need a few words of explanation. They are intended to show the general trend of age differences in a sample when the test scores have been transformed to ranks. The graphs have been constructed by plotting the mean chronological age of a subgroup against the mean rank of that subgroup on a given variable. For instance, taking the middle sample with $N = 160$, we can select the twenty youngest subjects as the first subgroup and find their mean chronological age and rank on the Wechsler-Bellevue vocabulary, enabling us to plot the first point. We then take the twenty next youngest subjects, find their mean chronological age and rank for vocabulary, and plot the second point, and so on until we have plotted the mean Wechsler-Bellevue vocabulary ranks for eight age groups of twenty subjects each. If adjacent points are connected by straight lines, a general age trend will be shown. The size of the subgroups will determine the upper and lower limits of discrimination, and these limits are stated. As usual, a slope from upper left to lower right indicates a decreasing score with increasing age. In summary, the graphs show the mean rank of successive age groups on a test variable; the left ordinate shows the scale of ranks.

The first line in figs. 1, 2, and 3 and the fifteenth line in figs. 4, 5, and 6 show the relations between chronological age and Wechsler-Bellevue vocabulary and I.Q. respectively. For the middle sample (figs. 2 and 5), there is no consistent age trend, and the trend lines fluctuate about the midpoint (80.5) of the scale of ranks; the subgroups are matched in very narrow limits as far as raw scores on the matching variables—vocabulary, I.Q., and social background rating

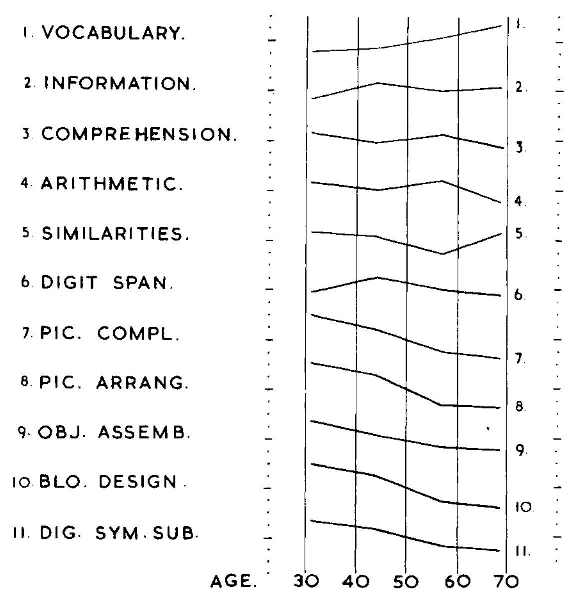

FIG. 1. Upper sample. (Applies to figs. 1-6.) See text for explanation of age differences in terms of ranks. In figs. 1, 3, 4, and 6, where $N = 48$, each interval on the vertical scale equals six ranks, the dash marks the median rank, and the limits of each graph lie eighteen ranks above and below the median. In figs. 2 and 5, where $N = 160$, each interval on the vertical scale equals ten ranks, the dash marks the median rank, and the limits of each graph lie seventy ranks above and below the median.

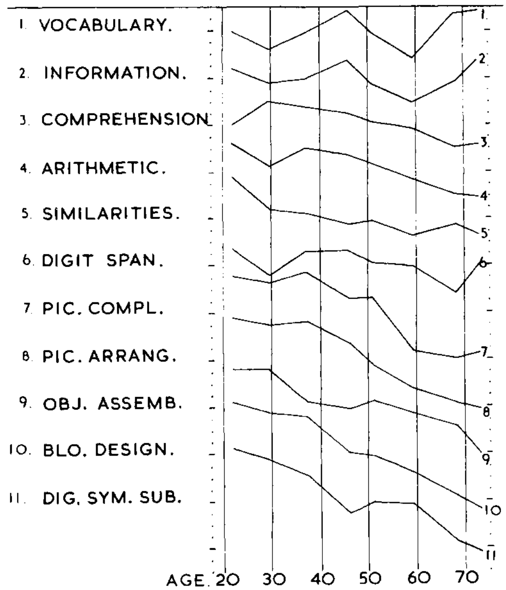

Fig. 2. Middle sample.

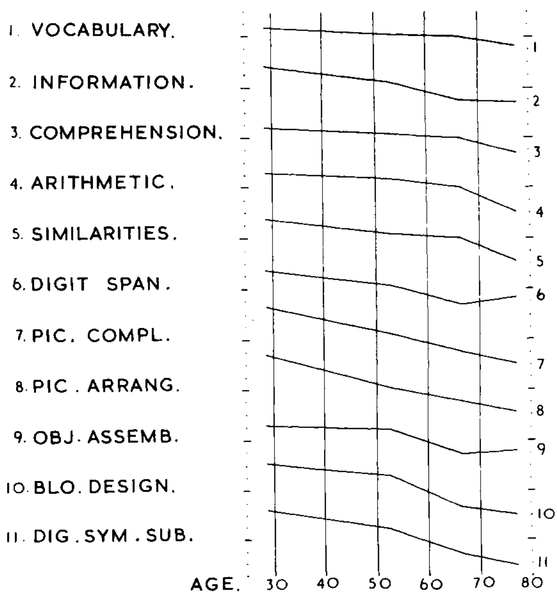

Fig. 3. Lower sample.

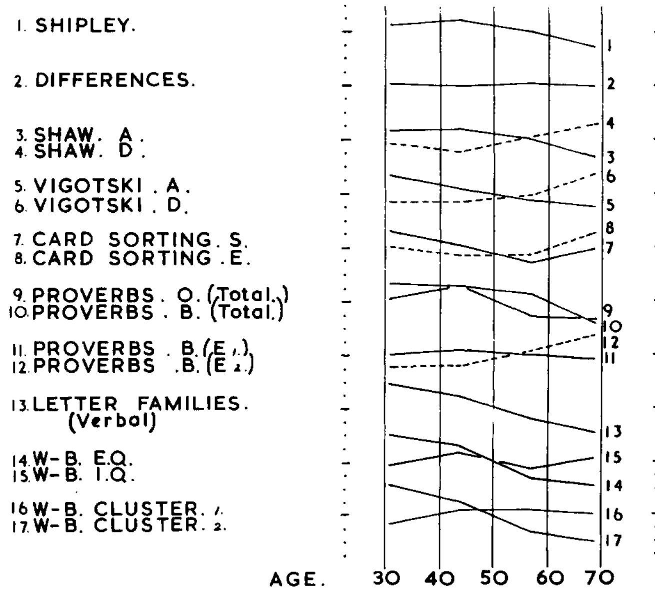

FIG. 4. Upper sample.

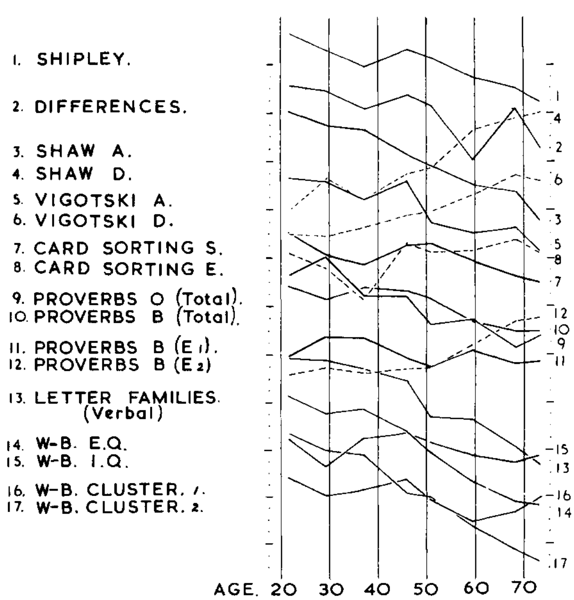

FIG. 5. Middle sample.

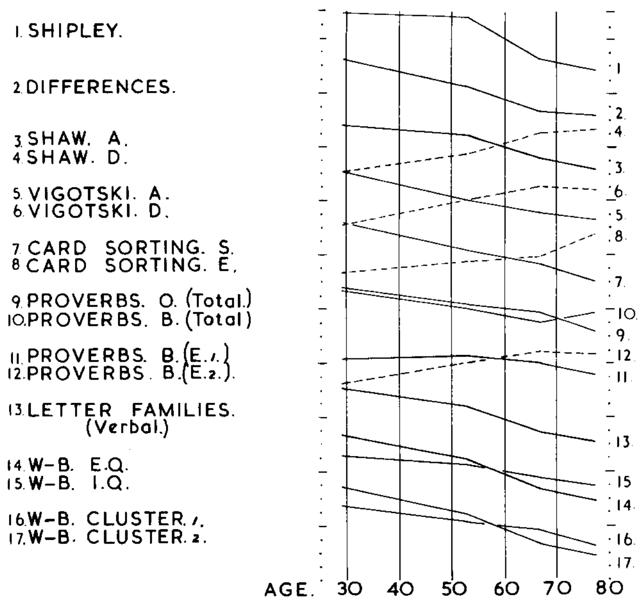

FIG. 6. Lower sample.

(not shown)—are concerned. Tables of equivalent raw scores have been omitted for reasons of economy. In the upper sample (figs. 1 and 4), there are slight increments with age in vocabulary, which can be attributed to inadequate matching, although Wechsler-Bellevue I.Q. shows no change with age. In the lower sample (figs. 3 and 6), there are very slight decrements with age in vocabulary and I.Q. By contrast, the fourteenth line on figs. 4, 5, and 6 shows age differences in Wechsler-Bellevue efficiency quotient (E.Q.) for the three samples. It is obvious that, as would be expected, age decrements in average intellectual efficiency are consistent and substantial.

It will be easier to judge the normal effects of aging on conceptual abilities if we first establish a frame of reference by studying the normal effects of aging on the abilities measured by the eleven subtests of the Wechsler-Bellevue Scale. Lines 1 to 11 on figs. 1, 2, and 3 show, for each sample, the normal effects of aging on vocabulary, information, comprehension, digit span, similarities, arithmetic, digit symbol substitution, block design, object assembly, picture arrangement, and picture completion. The figures illustrate and confirm the age differences already catalogued in Table 1. But in addition, it is possible to see that the age profiles are more similar between certain