4 The Seattle Longitudinal Study: A 21-Year Exploration of Psychometric Intelligence in Adulthood

K. WARNER SCHAIE

Introduction

If scientists had all the resources they could wish for, they would probably study a problem area by collecting large amounts of data on a great many individuals selected in as representative a manner as possible. Barring such utopian conditions, some scientists collect large amounts of data on a few carefully selected individuals. They can then proceed to write case histories, which may or may not be generalizable. Alternatively, many of us restrict our ambitions to a few carefully selected variables and then try to collect data bases sufficiently large enough to permit relatively rigorous statistical analyses and attempt generalizations to larger populations. The resultant danger here, of course, lies in the possibility that one knows a lot about a restricted variable set, which may or may not have practical importance.

I have probably erred in the latter direction, by restricting my efforts to the exploration of one definition of intelligence (the psychometric one) by means of a very small number of variables, the five major dimensions emerging from L. L. Thurstone's (1938) factor-analytic mapping of the Primary Mental Abilities (PMAs). Taking this narrow approach, however, has had the advantage of permitting the systematic exploration of experimental artifacts and the mounting of collateral studies leading to some degree of causal analysis which might get us eventually beyond the stage of mere description.

K. WARNER SCHAIE. Department of Individual and Family Studies and Department of Psychology, The Pennsylvania State University, University Park, Pennsylvania.

In this chapter, I attempt to survey the results of efforts that have preoccupied me for the past quarter century. Many of the individual pieces of this work have been reported in the journal literature, and a concise account of the natural history of the Seattle Longitudinal Study and its findings through 1970 has previously been published (Schaie, 1979). This chapter refers to many of these materials and brings matters up to date by including the 21-year follow-up data from the fourth (1977) cycle. It also reviews a number of contextual studies of a methodological and substantive nature that have been previously reported as convention papers and that either are not easily accessible or make little sense out of context.

There has been much recent discussion regarding the validity and utility of the sequential methods that were developed in the process of trying to account for the findings of our empirical studies (Baltes, 1968; Schaie, 1965, 1970, 1973b, 1975a, 1977). Each of these discussions (cf. Adam, 1978; Botwinick & Arenberg, 1976; Buss, 1979/1980) raises legitimate questions regarding (1) the interpretation of sources of developmental change and differences and (2) the estimation of the relative or absolute importance to be assigned to the various components. None of these critiques, however, offers constructive alternatives or even seriously impugns our recommendations for developmental data collection. Given explicitly stated assumptions, we continue to believe that the sequential methods offer much (cf. Baltes & Nesselroade, 1979; Schaie & Hertzog, 1982). In this chapter, their application is shown as clearly as possible, duly heeding the legitimate admonitions of our critics.

Controversy has also arisen regarding the substance of the study (cf. Baltes & Schaie, 1976; Horn & Donaldson, 1976; Schaie & Baltes, 1977). Again, some legitimate criticisms have been raised, particularly regarding the magnitude of changes in age in the general population as estimated from longitudinal studies of highly selected panels. These criticisms are addressed in this chapter by appropriate comparisons with our control samples. I have no stake in fitting one particular theoretical model or another to the data, nor do I desperately seek to reconstrue the data of others to fit my preferred outcome. I can take that position because I have consistently believed that the final arbiter of scientific disputes must be the collection of *appropriate* empirical data, rather than opinions stated in the heat of acrimonious debate.

This chapter begins with an outline of some of the programmatic objectives of the Seattle study, those that seemed clear at the beginning and others that emerged as we went along. Next, I describe the variables and review the emergent design of the study. Findings reviewed are restricted to the material on the PMAs; the personality data from the study are of almost equal interest, but would detract from the clear focus of the topic covered here. I hope that the systematic application of our control data will serve as a response to many of the reservations raised regarding the internal and external validity of findings from long-term studies. I also hope that our conclusions will be relevant to the thoughtful discussion of a number of social policy questions.

As is the case in most longitudinal studies, colleagues and students made many contributions to the collection, analysis, and interpretation of data from the study. Much credit for the many aspects of the work that went well goes to these contributors; the responsibility for what went awry is, of course, mine.[1]

Why Should One Study Intelligence in Adulthood?

Applied psychology virtually began with the investigation of intellectual competence, whether its purpose was to determine the orderly removal of mentally retarded children from the public school classroom (Binet & Simon, 1905) or to study the distribution of individual differences in the interest of demonstrating their Darwinian characteristics (Galton, 1869). What kind of complex mental function did the early investigators seek, one that we are still pursuing today? Binet's definition remains a classic guide: "To judge well, to comprehend well, to reason well, these are the essentials of intelligence. A person may be a moron or an imbecile if he lacks judgment; but with judgment he could not be either" (Binet & Simon, 1905, p. 196).

Early empirical work on intelligence investigated how complex mental functions were acquired early in life (Brooks & Weintraub, 1976). But interest was awakened quickly by theoretical writers, such as G. Stanley Hall (1922), H. L. Hollingsworth (1927), and Sydney Pressey (Pressey, Janney, & Kuhlen, 1939), who were concerned in following the complexities of intellectual development beyond childhood. Questions raised concerned the age of attaining peak performance level, the maintenance or transformation of intellectual structures, and the decremental changes thought to occur from late midlife into old age.

[1]The following colleagues and students (in alphabetical order) participated in the various data collections and analyses and/or contributed to the resultant scholarly products: Margaret Baltes, Paul Baltes, Tom Barrett, Gisela Bertulis, Barbara Buech, Michael Gilewski, Kathy Gribbin, Christopher Hertzog, Judy Higgins, Eric Labouvie, Gisela Labouvie-Vief, Karen Laughlin, Ann Nardi, John Nesselroade, Iris Parham, Robert Peterson, Alan Posthumer, Margaret Quayhagen, Pat Sand, Coloma Harrison Schaie, Michael Singer, Vicki Stone, Charles Strother, Nathaniel Wagner, Sherry Willis, and Elizabeth Zelinski.

Empirical work relevant to these questions soon began to appear. For example, Terman (1916), in his original standardization of the Binet tests for American use, assumed that intellectual development reached a peak at age 16 and then remained level through adulthood. Large-scale studies with the Army Alpha Intelligence Test (Yerkes, 1921) suggested that the peak level of functioning for young adults might already be reached, on the average, by age 13. Other early empirical studies, however, questioned these inferences. Perhaps one of the most influential studies, that of Jones and Conrad (1933), obtained cross-sectional data on most of the inhabitants of a New England community who were between the ages of 10 and 60 years. Interestingly enough, age differences found in this study were substantial on some of the subtests of the Army Alpha, but not on others. Likewise, Wechsler's standardization studies, leading to the development of the Wechsler–Bellevue scales, found that growth of intelligence does not cease in adolescence. Of even greater interest was the finding that peak ages differed for various aspects of intellectual functioning and that decrements at older ages were not uniform across the different subtests used to define intelligence (Wechsler, 1939).

The interest in intelligence testing reached a peak after World War II with the widespread introduction into clinical practice of the Wechsler Adult Intelligence Scale (WAIS) and its derivatives (Matarazzo, 1972), the almost universal introduction of intelligence and/or aptitude testing in the public schools, and the development of widely accepted classification batteries such as the Differential Aptitude Test (DAT) and the General Aptitude Test Battery (GATB; cf. Cronbach, 1970). But soon disenchantment set in, with widespread criticism of the misapplication of intelligence tests in education (e.g., Kamin, 1974). Clinicians learned that profile analyses of intelligence tests were less useful than was previously thought and that the information gained on intellectual status seemed to contribute little to the programming of therapeutic intervention.

In spite of these criticisms, the fact remains that omnibus measures of intelligence have been rather useful in predicting a person's competence in dealing with the standard educational systems of our country. They have also been useful in predicting success in vocational pursuits whenever job requirements depend upon educationally based knowledge and skills. And specific measures of abilities, although somewhat more controversial, have nevertheless had some utility in predicting competence in those specific situations where special abilities could be expected to be of importance. A reasonable argument could be made for the proposition that motivational and other personality variables are of greater potency in predicting adjustment and competence in midlife than is intelligence, but the empirical evidence is less than convincing. When dealing with the elderly, however, it becomes readily apparent that assessment of intellectual competence again reaches paramount importance. Questions such as who shall be retired for cause (in the absence of mandatory retirement at an early age), whether there is sufficient remaining competence for independent living, or whether persons can continue to conserve and dispose of their property clearly involve the assessment of intellectual functions.

If we agree that the preceding issues are important to our society, it then becomes necessary to study in detail the factual issues involved in the development of intelligence beyond young adulthood. We must begin to differentiate intraindividual changes (IACs) of a decremental nature from interindividual differences which result in the obsolescent behavior of older cohorts when compared with their younger peers. In this context, it is necessary to know at what age developmental peaks occur and to assess generational differences as well as within-generation age changes. In addition, we must give careful attention to the question of why some individuals show intellectual decrement in early adulthood while others maintain or even increase their level of functioning well into old age.

The programmatic inquiry reported in this chapter has tried to address these questions more or less systematically. In particular, it has asked the following broad questions:

1. Does intelligence change uniformly or in different ability patterns?
2. At what age is there a reliably detectable age decrement in ability, and what is its magnitude?
3. What are the patterns of generational differences, and what is their magnitude?
4. What accounts for individual differences in IAC in intellectual function across adulthood?

The following section discusses more detailed objectives and gives a brief history of how the final design of the study emerged.

History and Objectives of the Study

The origins of the Seattle Longitudinal Study may be traced back to work done by me as an undergraduate at the University of California at Berkeley as part of directed studies under the supervision of Professor Read D. Tuddenham. After he introduced me to the basic concepts of factor analysis and to the writings of L. L. Thurstone, I inferred that, although the work of Wechsler on adult intelligence might be of great concern to clinicians, the Wechsler–Bellevue and its derivatives, because of their

factorial complexity, were less than desirable for the exploration of developmental issues. I also learned that the more explicitly defined PMAs had not been explored beyond adolescence and concluded that this was a possibly fruitful topic for systematic pursuit. In an initial study, I explored whether the factorial independence of the five abilities measured in the most advanced form of the PMA test (Thurstone & Thurstone, 1949) was retained in adulthood and then proceeded to ask whether adults functioned at the same level as did adolescents and, more specifically, if there were ability-related differentials in adult PMA performance. I also questioned whether differences in pattern would be maintained if the PMA test were administered under nonspeeded conditions (Schaie, Rosenthal, & Perlman, 1953).

With my appetite having been whetted by some provocative results in this early pilot study, I continued to explore a variety of corollaries of intelligence in adulthood during my graduate work at the University of Washington (Schaie, Baltes, & Strother, 1964; Schaie & Strother, 1968a, 1968d; Strother, Schaie, & Horst, 1957). As part of this work, it also became necessary to develop a new factored test of behavioral rigidity (Schaie, 1955, 1960; Schaie & Parham, 1975). This work culminated in a doctoral dissertation designed to replicate the earlier work on differential ability patterns across a wider portion of the adult life span as well as to test the effect of rigidity–flexibility on maintenance or decline of intelligence (Schaie, 1958a, 1958b, 1958c, 1959a, 1959b). This dissertation, of course, became the base for the subsequent longitudinal and sequential studies.

The search for a suitable population frame for the base study was guided by the consideration that what was needed was a subject pool with known demographic characteristics, which had been established for reasons other than research on cognitive behavior. That is, if possible, the initial selection of volunteer subjects for the study should not be designed so as to maximize selection in terms of the subjects' interest in, concern with, or performance level on the dependent variables. When plans for the study matured, my mentor, Charles Strother, was, by coincidence, president of the board of the Group Health Cooperative of Puget Sound, one of the first broadly based health maintenance organizations. An arrangement was worked out with the managers of the health plan that permitted me to recruit research subjects who had been selected by a random draw from the age/sex stratification of plan members above the age of 21 years. The appeal to participate was made by the plan's managers as part of a membership satisfaction survey, the administration and analysis of which was my *quid pro quo* for gaining access to this population.

Results of the 1956 base study did not support a causal model involving differential patterns of intellectual performance across age for flexible and rigid individuals. The study did demonstrate a relationship between flexibility-rigidity and intelligence at all ages, but more important, provided a sound demonstration of differential patterns of intelligence across age, and by virtue of its design, serendipitously provided the basis for the following sequential studies.

Perhaps the final stimulation leading to the conversion of a one-time cross-sectional study into a series of longitudinal studies was my reading of the reports of longitudinal studies of individuals reaching middle adulthood, such as the papers by Bayley and Oden (1955); Jarvik, Kallmann, and Falek (1962); and Owens (1953, 1959). (See Chapters 2 and 3, this volume, for descriptions of the last two of these studies.) Taken together, these studies suggested maintenance of most intellectual abilities at least into middle age, and of some abilities beyond this point, findings that contrasted with the results of the earlier cross-sectional literature and my own dissertation data. What seemed to be called for, I was soon convinced, was the follow-up of a broad cross-sectional panel, such as the one I had examined, by means of a short-term longitudinal inquiry. Intensive discussions of such a project with Charles Strother were followed by a grant application to the National Institutes of Health (NIH), which was funded in time to collect the first set of follow-up data in the summer of 1963.

In addition to tracking down and retesting as many of the persons studied in 1956 as possible, we decided to draw a new random sample from the original population frame in order to provide controls for the examination of retest effects and to begin to address the possibility that sociocultural change affects intellectual performance, heeding the thoughtful admonitions previously voiced by Raymond Kuhlen (1940, 1963). The new sample extended over the original age range (22–70 years) plus an additional 7-year interval to match the range now reached by the original sample.

Whereas the second cross-sectional study provided essential replication of the earlier findings, the short-term longitudinal study disclosed substantially different information about peak levels and rate of decline. Publication of results was therefore delayed until a theoretical model could be built that accounted for the discrepancy between the longitudinal and cross-sectional data (Schaie, 1965, 1967). These analyses suggested that group mean comparisons ought to be conducted both for repeatedly measured samples and for successive independent samples drawn from the same cohorts. Results were reported that called attention to the large observed cohort differences and that questioned the [illegible]

significance of intellectual decrement in community-dwelling persons (Nesselroade, Schaie, & Baltes, 1972; Schaie, 1970; Schaie & Strother, 1968b, 1968c). Availability of the longitudinal data also permitted a first pass at addressing the problems of experimental mortality (Baltes, Schaie, & Nardi, 1971) and regression effects in longitudinal studies (Baltes, Nesselroade, Schaie, & Labouvie, 1972).

It soon became clear that the conclusions based on a single 7-year interval required further replication, particularly because two occasions of measurement permit examination of cross-sectional, but not of longitudinal, sequences (cf. Baltes, Reese, & Nesselroade, 1977); the latter require a minimum of three occasions of measurement. It is the latter, however, that explicitly permit contrasting age and cohort effects. A third data collection was therefore conducted in 1970, with the retesting of as many persons as possible from the first two occasions, and the drawing of a third random sample from the residual members of the base population frame (Schaie, 1979; Schaie, Labouvie, & Buech, 1973; Schaie & Labouvie-Vief, 1974; Schaie & Parham, 1977).

Although results of the third data collection seemed rather definitive, a number of questions remained. Discrepancies between the repeated-measurement and independent-sampling studies argued for a replication of our 14-year longitudinal sequences, and it seemed of interest to take another look at our original sample. Consequently, a fourth data collection was conducted in 1977, again retesting the previous samples and adding a new random sample (this time from an expanded population frame). Continuous funding also made it possible to address collateral questions. These included an examination of the aging of tests (Gribbin & Schaie, 1977), an analysis of the effects of monetary incentives upon subject selection and characteristics (Gribbin & Schaie, 1976), and the beginning of the causal analysis of health and environmental factors upon change or maintenance of adult intelligence (Gribbin, Schaie, & Parham, 1980; Hertzog, Schaie, & Gribbin, 1978b).

A longitudinal study soon develops its own social network. None of the studies reported here could have occurred without the cooperation of many devoted graduate students and colleagues or without the enthusiastic cooperation of members and staff of our population source, the Group Health Cooperative of Puget Sound. Our study may be a good model for showing how long-range developmental studies can be conducted through meaningful collaboration with organizations that must maintain long-term panel membership for socially significant reasons. Over the past few years, results from this study have greatly affected my interpretative writing on adult intelligence addressed to a variety of target audiences

& Parr, 1981; Schaie & Willis, 1978, 1981). The remainder of the chapter will provide the reader with a basis for judging whether the assertions I have made in the interpretative writing are indeed justified.

Description of the Measurement Variables

Although the Wechsler scales have been most widely used with adults for purposes of clinical diagnosis (cf. Matarazzo, 1972; Schaie & Schaie, 1977) and have also received substantial attention in developmentally oriented studies (for reviews, see Botwinick, 1977; Schaie, 1980), they do not have a clear-cut factorial structure. The latter is necessary, however, if the objective of one's inquiry is to delineate the differential life course of human abilities. At the outset of my investigation, it therefore seemed reasonable to consider the factored tests provided by the work of the Thurstones (1941, 1949), even though this work had previously not extended beyond the life stage of adolescence. In addition, we required certain control measures related to cognitive style, which led to the development of the Test of Behavioral Rigidity (TBR; Schaie, 1955, 1960; Schaie & Parham, 1975). Other materials used in this study included regularly collected demographic data, indicators of health behavior (Hertzog, Schaie, & Gribbin, 1978b; Parham, Gribbin, Hertzog, & Schaie, 1975), and, since 1974, contextual data collected by means of the Life Complexity Inventory (LCI; Gribbin, Schaie, & Parham, 1980; Schaie & Gribbin, 1975b).

The Primary Mental Abilities

The PMA test battery was derived from a series of factor-analytic studies of some 56 mental tests, which resulted in the definition of relatively independent mental abilities (L. L. Thurstone, 1938). The test form used consistently in our studies was the 1948 PMA 11–17 version.[2] This version, which at the time was the most difficult form of the test, consists of five subtests designed to cover the abilities listed in this section. The descriptions given are slightly modified from those provided by the test manual (Thurstone & Thurstone, 1949).

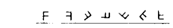
[2]Illustrations in the following sections are from *SRA Primary Mental Abilities*, Ages 11–17, Form AM. Copyright 1948 by L. L. Thurstone and Thelma Gwinn Thurstone. Reprinted by permission of the publisher, Science Research Associates, Inc.

1. Verbal Meaning (*V*). This is a test of the ability to understand ideas expressed in words. It measures the range of a person's passive vocabulary used in activities where information is obtained by reading or listening to words. The task requires verbal recognition by means of a multiple-choice format. In the following example, the subject must select that alternative which is the best analogue of the capitalized stimulus word:

BIG A. ILL B. LARGE C. DOWN D. SOUR

The test contains 50 items in increasing order of difficulty, with a time limit of 4 minutes.

2. Space (*S*). This is a measure of the ability to think about objects in two or three dimensions. It may be described as the ability to imagine how an object or figure would look when it is rotated, to visualize objects in two or three dimensions, and to see the relations of an arrangement of objects in space. It is probably important in skills such as deducing one's physical orientation from a map or visualizing what objects would look like when assembled from pieces. The current technical term for this ability is often given as "spatial orientation." Space is measured by 20 test items, with a time limit of 5 minutes. In the example given here, every lettered figure that is the same as the stimulus figure, even though it is rotated, is to be marked. Figures that are mirror images of the stimulus figure are not to be marked.



3. Reasoning (*R*). This ability, which in current ability-factor taxonomies is often specifically identified as "inductive reasoning," involves the solution of logical problems—to foresee and plan. The Thurstones (1949) proposed that persons with good reasoning ability could solve problems, foresee consequences, analyze a situation on the basis of past experience, and make and carry out plans according to recognized facts. Reasoning is measured by items such as the following:

a b x c d x e f x g h x h i j k x y

The letters in the row form a series based on a rule. The problem is to discover the rule and mark the letter that should come next in the series. In this case, the rule is that the normal alphabetic progression is interrupted with an *x* after every second letter. The solution would therefore be the letter *i*. There are 30 test items, with a time limit of 6 minutes.

4. Number (*N*). This is the ability to work with figures and to handle simple quantitative problems rapidly and accurately. It is measured by asking subjects to check simple addition problems, with items of the following kind:

17		
84	R	W
29		
140		

The sum for each column of figures is given. However, some of the solutions given are right (R) and others are wrong (W). The test contains 60 items with a time limit of 6 minutes.

5. Word Fluency (*W*). This ability is concerned with verbal recall involved in writing and talking easily. It differs from verbal meaning in that it focuses on the speed and ease with which words are used, rather than the degree of understanding of verbal concepts. The measurement task requires the subject to write as many words as possible beginning with the letter *s* during a 5-minute period.

Composite Indexes

In addition to the five ability-factor scores, we consistently reported data on two derived linear composites. Both of these were originally suggested by the Thurstones (1949). The first is an index of Intellectual Ability (*IA*), or a composite measure likely to approximate a conventional deviation IQ, obtained by summing subtest scores weighted approximately inversely to the standard deviation of each test:

$$IA = V + S + 2R + 2N + W$$

The second is an index of Educational Aptitude (*EA*), suggested by T. G. Thurstone (1958) as the best predictor, from the test battery, of performance in educational settings:

$$EA = 2V + R$$

Scaling of PMA Scores

No adult norms for the PMA test were available at the initiation of these studies. We therefore generally proceeded to obtain comparability across variables and age groups by expressing scores in *T*-score form, with a mean of 50 and a standard deviation of 10, using as the reference group all records at first test at the time of the particular analysis. Results reported for the total data base (four cycles) were scaled using all 2810 subjects at first test as the reference group.

The Test of Behavioral Rigidity

The TBR was developed as part of an inquiry concerned with determining the dimensions of the trait of rigidity (Schaie, 1955). Three factors were identified: Motor-Cognitive Rigidity (*MCR*), Personality-Perceptual Rigidity (*PPR*), and Psychomotor Speed (*PS*). These factors are measured by combinations of eight scores obtained from the three subtests described in the following paragraphs.

1. The Capitals Test. This test was adapted from Bernstein's (1924) study of quickness and intelligence and represents the Spearmanian, or "functional," approach to the study of perseveration or rigidity. Subjects spend 2½ minutes copying a printed paragraph, which contains some words starting with capital letters, others spelled entirely in capitals, and some starting with lower case letters and with the remainder in capitals. Subjects must copy the paragraph in writing, not printing. In the second half of the test, subjects must recopy the paragraph in writing, substituting capitals for lower case letters and lower case letters for capitals. The Psychomotor Speed score is the number of words correctly copied in the first series (*Cap*). The Motor-Cognitive Rigidity score is the ratio (rounded to integers) of the number of correctly copied words in the second series to that in the first series (*Cap-R*).

2. The Opposites Test. This was a newly constructed test, following the work of Scheier and Ferguson (1952). Subjects are given 2 minutes each to work on three lists of words (at a third-grade level of difficulty), the first of which requires providing the antonym, and the second the synonym, of the stimulus word. The third list contains selected stimulus words from the previous lists which must be responded to by an antonym if the stimulus word is printed in lower case letters, but by a synonym if printed in capitals. The Psychomotor Speed score is the sum of correct responses in the first two lists (*Opp*). There are two Motor-Cognitive Rigidity scores. List 3 is examined for responses that are incorrect, responses started incorrectly, or erasures. The first score (*Opp-R1*) is obtained by the formula

$$100 - \frac{\text{Series 3 errors}}{\text{Series 3 total}} \times 100$$

The second score (*Opp-R2*) involves the formula

$$\frac{\text{Series 3 correct}}{\tfrac{1}{2}\,(\text{Series 1 correct} + \text{Series 2 correct})} \times 100$$

3. The Questionnaire. This 75-item true–false questionnaire contains 22 rigidity–flexibility items (*R* scale) and 44 masking social responsibility items from the California Psychological Inventory (Gough, 1957; Gough, McCloskey, & Meehl, 1952; Schaie, 1959b). It also contains 9 items (*P* scale) obtained from the Guttman scaling of a 17-item perseveration scale first used by Lankes (1915). These items were selected to be suitable for adults of all ages.

Factor Scores

The eight raw scores from the TBR subtests are first transformed into standard score form and then converted, scaled to factor scores by multiplication with the appropriate factor weights determined in the original study:

$$MCR = .25\ Cap\text{-}R + .35\ Opp\text{-}R1 + .40\ Opp\text{-}R2$$
$$PPR = .50\ R\ \text{scale} + .50\ P\ \text{scale}$$
$$PS = .60\ Cap + .40\ Opp$$

For the purposes of the 1977 study, the resultant scaled scores (also see Schaie & Parham, 1975) were converted to *T* scores with a mean of 50 and a standard deviation of 10, based on the 2810 records of subjects at first test.

Demographic Information

Demographic information that was routinely collected in this stúdy includes social status variables (years of education, income, and occupational level), marital status, family size, and measures of mobility (frequency in change of living quarters, number of job changes, and number of different occupations during the preceding 5 years).

Health Behavior Variables

Since all of our subjects received their health care from the plan that constituted the population frame, it became possible to gain access to health history charts. These were systematically abstracted using the *International Classification of Diseases* (ICDA; USPHS, 1968). Each visit to the outpatient clinic or each day in the hospital was coded by diagnosis. Annual frequency counts were constructed by illness incidents (single visits) and illness episodes (continuous series of visits for a specific diagnostic code). Physician ratings were obtained on the relative severity (impact on future health and well-being) of diagnostic entities along a normally distributed 11-point scale, permitting the construction of severity-weighted indexes (Schaie, 1973a).

Life Complexity Inventory

Beginning in 1964, we expanded the contextual information available on our subjects by routinely administering a questionnaire (originally administered as a structured interview) surveying the person's microenvironment (cf. Schaie & Gribbin, 1975a, 1975b). The major topics include individual work circumstances (with homemaking defined as a job), friends and social interactions, daily activities, travel experiences, physical environment, and educational pursuits (including individualized programs such as reading and writing). A cluster analysis permits scoring of individuals on the factors of Social Status, Subjective Dissatisfaction with Life Status, Homemaker Characteristics, Disengagement, Semiengagement, Family Dissolution, Noisy Environment, and Maintenance of Acculturation.

Description of the Data Base

The data base for the Seattle Longitudinal Study consists of the results of four major testing cycles (1956, 1963, 1970, 1977). In addition, there were three pilot studies concerned with the characteristics of the PMA test and the TBR in work with adults (1952, 1953, 1954). And finally, there were two collateral studies concerned with the consequences of shifting to an expanded sampling frame (1974) and of dealing with the aging of our test battery (1975).

Age and Cohort Frequencies

All of our subjects (with the exception of those involved in the pilot studies) were members of the Group Health Cooperative of Puget Sound. Our original 1956 population frame consisted of approximately 18,000 potential subjects. These were stratified by age and sex, and 25 men and 25 women were randomly selected for each year of birth from 1880 to 1939. After removing individuals who were not in the area, 2818 persons were actually contacted, of whom 910 agreed to participate. Testing then proceeded in small groups of 10 to 30 persons, until 25 men and 25 women had been tested in each 5-year birth interval over the age range of 22 to 70 years (cf. Schaie, 1958c, 1959a).

For the 1963 cycle, in addition to the longitudinal follow-up, approximately 3000 names were again drawn randomly from the 1956 population frame, after deleting names of all individuals tested in 1956. Of these, 996 persons ranging in age from 22 to 77 years were successfully tested. A similar procedure was followed in 1970: retesting survivors of the 1956 and 1963 panels, and establishing a new randomly selected panel (aged 22 to 84 years), consisting of 705 individuals. Our population frame having been virtually exhausted, we determined, by means of a collateral study, (Gribbin, Schaie, & Stone, 1976) that it would be feasible to shift to a sampling-with-replacement basis. For the 1977 cycle, we therefore sampled approximately 3000 persons from what had now become a 210,000-member health plan. Of these, 609 new subjects were tested.

Because of our 7-year intervals, all data have been reorganized in 7-year age and cohort groupings. Tables 4.1 and 4.2 show that we now have, for purposes of analysis, ten different data sets. These are as follows:

1. A cross-sectional sequence consisting of four independent data sets: Aa ($n = 500$)—seven cohorts tested in 1956 (mean ages: 25 to 67; mean birth years: 1889 to 1931); Bb ($n = 996$)—eight cohorts tested in 1963 (mean ages: 25 to 74; mean birth years: 1889 to 1938); Cc ($n = 705$)—nine cohorts tested in 1970 (mean ages: 25 to 81; mean birth years: 1889 to 1945); and Dd ($n = 609$)—nine cohorts tested in 1977 (mean ages: 25 to 81; mean birth years: 1896 to 1952) (see Table 4.1).
2. Longitudinal sequences involving six data sets include three 7-year, two 14-year, and one 21-year follow-ups: Ab ($n = 303$)—seven cohorts followed from 1956 to 1963; Bc ($n = 420$)—eight cohorts followed from 1963 to 1970; Cd ($n = 340$)—nine cohorts followed from 1970 to 1977; Ac ($n = 162$)—seven cohorts followed from 1956 to 1970; Bd ($n = 337$)—eight cohorts followed from 1963 to 1977; and Ad ($n = 130$)—seven cohorts followed from 1956 to 1977 (see Table 4.2).[3]

Successively longer studies, of course, involve subsets of those examined earlier. Our total data base consequently consists of 4504 test records

[3]In data set Ac, 81 subjects missed the 1970 testing. Similarly, in data set Ad, 2 subjects missed the 1970 testing, and 8 subjects missed both the 1963 and the 1970 data collections.

TABLE 4.1. Distribution of Subjects at First Test in the Main Study, by Cohort, Sex, and Test Occasion

	Mean year of birth (cohort)									
	1889	1896	1903	1910	1917	1924	1931	1938	1945	1952
1956 Sample Aa										
Mean age	(67)	(60)	(53)	(46)	(39)	(32)	(25)	—	—	—
M	38	35	35	35	36	33	38	—	—	—
F	38	37	35	30	35	37	38	—	—	—
T	76	72	70	65	71	70	76	—	—	—
1963 Sample Bb										
Mean age	(74)	(67)	(60)	(53)	(46)	(39)	(32)	(25)	—	—
M	38	64	68	62	79	71	52	42	—	—
F	39	63	64	81	76	79	70	58	—	—
T	77	127	122	143	155	150	122	100	—	—
1970 Sample Cc										
Mean age	(81)	(74)	(67)	(60)	(53)	(46)	(39)	(32)	(25)	—
M	26	46	42	38	40	44	34	28	31	
F	24	42	49	42	49	43	50	37	40	—
T	50	88	91	80	89	87	84	65	71	—
1977 Sample Dd										
Mean age		(81)	(74)	(67)	(60)	(53)	(46)	(39)	(32)	(25)
M		27	37	35	35	40	32	37	29	28
F		31	33	38	37	37	37	36	33	27
T		58	70	73	72	77	69	73	62	55
Cohort totals										
M	102	172	172	170	180	188	156	107	60	28
F	101	173	181	191	197	196	195	131	73	27
T	203	345	353	361	377	384	351	238	133	55
Age totals										
Mean age	(25)	(32)	(39)	(46)	(53)	(60)	(67)	(74)	(81)	—
M	139	142	178	190	177	166	179	121	53	—
F	160	177	200	186	192	180	188	114	55	—
T	299	319	378	376	369	346	367	235	108	—

involving 120 subjects tested four times, 300 subjects tested three times, 734 subjects tested twice, and 1656 subjects tested one time only.

Demographic Characteristics

Our subject source provided a population frame that was reasonably close to the demographic pattern of the community from which it was drawn, although somewhat sparse at the lowest socioeconomic levels. I report here data on educational and occupational levels for the four successive cycles and discuss shifts caused by nonrandom subject attrition. Data on

TABLE 4.2. Distribution of Repeatedly Tested Subjects in the Main Study, by Cohort, Sex, and Test Occasion

	Mean year of birth (cohort)								
	1889	1896	1903	1910	1917	1924	1931	1938	1945
1963 Sample Ab									
Mean age	(74)	(67)	(60)	(53)	(46)	(39)	(32)	—	—
M	25	13	21	22	23	19	19	—	—
F	23	27	23	18	24	25	21	—	—
T	48	40	44	40	47	44	40	—	—
1970 Sample Ac									
Mean age	(81)	(74)	(67)	(60)	(53)	(46)	(39)	(32)	—
M	8	3	13	17	11	11	10	—	—
F	6	12	15	15	15	15	11	—	—
T	14	15	28	32	26	26	21	—	—
1970 Sample Bc									
M	8	19	19	29	36	36	23	9	—
F	6	24	22	45	37	43	38	26	—
T	14	43	41	74	73	79	61	35	—
1977 Sample Ad									
Mean age	(88)	(81)	(74)	(67)	(60)	(53)	(46)	(39)	(32)
M	3	2	10	16	9	8	10	—	—
F	2	7	14	15	12	11	9	—	—
T	5	9	24	31	21	19	19	—	—
1977 Sample Bd									
M	1	11	11	27	31	32	19	10	—
F	3	16	12	40	38	35	36	15	—
T	4	27	23	67	69	67	55	25	—
1977 Sample Cd									
M	4	13	18	21	24	28	17	14	10
F	4	17	16	25	29	26	28	22	24
T	8	30	34	46	53	54	45	36	34

income were also collected, but because of inflationary factors, they are not directly comparable across occasions.

Table 4.3 provides percentage figures for our ten data sets by educational level (grade school, high school, college, and graduate training), and Table 4.4 gives similar data for occupational level (unskilled = cleaning services, maintenance services, laborers, factory workers, fishermen; semiskilled = protective services, personal services, bartenders, custodians; skilled = mechanical–technical and clerical occupations; semiprofessional = managers, proprietors, professions requiring less than an MA degree; professional = requiring MA or more). Inspection of these tables shows that we, too, experience an upwardly skewed socioeconomic

TABLE 4.3. Educational Levels for Data Sets in the Main Study as Proportions of Each Sample

	First test	Second test	Third test	Fourth test
	Sample Aa	Sample Ab	Sample Ac	Sample Ad
0–8 years grade school	11.0	9.2	4.3	4.2
9–12 years high school	42.4	38.2	41.0	38.7
13–16 years college education	32.6	35.6	36.6	38.7
17 years plus graduate training	14.0	16.8	18.0	18.5
	Sample Bb	Sample Bc	Sample Bc	
0–8 years grade school	12.9	7.4	4.2	
9–12 years high school	46.1	43.8	42.3	
13–16 years college education	30.9	37.4	40.6	
17 years plus graduate training	10.0	11.4	12.9	
	Sample Cc	Sample Cd		
0–8 years grade school	10.1	4.4		
9–12 years high school	40.4	37.4		
13–16 years college education	35.5	40.6		
17 years plus graduate training	14.0	17.6		
	Sample Dd			
0–8 years grade school	9.7			
9–12 years high school	32.8			
13–16 years college education	38.0			
17 years plus graduate training	19.5			

TABLE 4.4. Occupational Level for Data Sets in the Main Study as Proportions of Each Sample

	First test	Second test	Third test	Fourth test
	Sample Aa	Sample Ab	Sample Ac	Sample Ad
Unskilled	4.5	4.0	2.5	3.3
Semiskilled	10.9	8.6	3.7	4.2
Skilled	47.2	45.5	48.1	47.5
Semiprofessional	32.2	36.0	40.1	38.3
Professional	5.3	5.9	5.6	6.7
	Sample Bb	Sample Bc	Sample Bd	
Unskilled	5.1	2.9	2.0	
Semiskilled	11.3	7.2	7.1	
Skilled	56.5	57.7	56.0	
Semiprofessional	23.4	29.0	31.7	
Professional	3.8	3.1	3.2	
	Sample Cc	Sample Cd		
Unskilled	.6	.9		
Semiskilled	5.0	5.0		
Skilled	48.7	44.1		
Semiprofessional	38.0	39.7		
Professional	7.7	10.3		
	Sample Dd			
Unskilled	6.6			
Semiskilled	8.0			
Skilled	30.6			
Semiprofessional	32.8			
Professional	22.0			

distribution upon completion of the acquisition of volunteer subjects. Some further complications arise because of an upward socioeconomic tendency due to nonrandom retest attrition and nonrandom outflow of members of the population frame over the successive random draws. Nevertheless, our sample structure does represent a reasonable approximation of the urban population structure, and shifts across samples, although worthy of further investigation, would not seem to interfere seriously with the comparison to be reported.

Age Differences in Ability Patterns

Our inquiry began by questioning whether factorially defined measures of different intellectual abilities would show differential age patterns. Before this question could be examined parametrically, it was first necessary to examine the applicability of the PMA test to an older population, with respect to both its level of difficulty and the continuing low correlation among the several abilities. Two pilot studies concerned with these questions are described in this section, and then cross-sectional data at first test are presented from the four testing cycles.

The Pilot Studies

Sixty-one subjects, gathered from the geriatric practice of my family physician and from the membership of the small first cohort of the San Francisco Senior Citizen Center, were given the PMA test under standard conditions. For purposes of analysis, they were arbitrarily divided into four approximately equal groups: ages 53 to 58, 59 to 64, 65 to 70, and 71 to 78 years. In the absence of available adult norms, and to permit comparison across the different ability measures, raw scores were converted into percentiles using norms for 17-year-old adolescents (Thurstone & Thurstone, 1949). The results of this study are shown in Figure 4.1. For the group in its 50s, stability is suggested for Verbal Meaning and Number (by the members' performance being slightly above the 50th percentile for the adolescent-norm group), but there is substantial lowering of scores for the other three tests. This differential pattern was observed for all groups, with some further lowering of scores into the 60s and apparent maintenance of the lower level for the group in its 70s (Schaie, Rosenthal, & Perlman, 1953).

On the off chance that this pattern might be caused by the differential effect of the slightly speeded instructions for older individuals, four of the tests were administered to 31 subjects without a time limit. Results shown in Figure 4.2 indicate that, if anything, differential performance levels were greater and in the same order as under the standard conditions of instruction.

The first pilot study also investigated the construct validity of the PMA 11–17 when used with older individuals. Intercorrelations between the five tests were computed and shown to be quite low, ranging from .07 for the correlation between Space and Number to .31 for that between Space and Reasoning. These correlations did not differ significantly from those

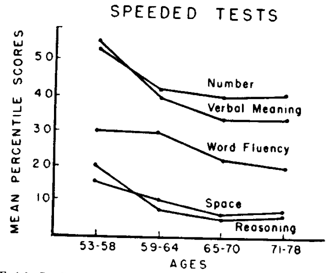


FIGURE 4.1. Performance of adult subjects on the *Primary Mental Abilities* test in percentile scores for an adolescent comparison group. (From "Differential Deterioration of Factorially 'Pure' Functions in Later Maturity" by K. W. Schaie, F. Rosenthal, and R. M. Perlman, *Journal of Gerontology*, 1953, *8*, 192. Copyright 1953 by the Gerontological Society. Reprinted by permission.)

obtained for an adolescent comparison group (Schaie, 1958d). Split-half reliabilities computed under the power-test condition were also quite satisfactory, all being above .92 after Spearman-Brown correction.

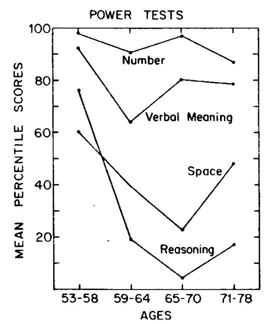
A second pilot study was conducted in 1954 as part of an investigation of the optimal limits of functioning of a small group of well-educated, community-dwelling older persons (more completely described in Schaie & Strother, 1968a). A campus and community appeal resulted in the selection of 25 men and 25 women, all college graduates with professional careers, ranging in age from 70 to 88 years (mean age 76.5 years). These subjects were all in fair to superior health and free of diagnosable psychiatric symptoms. The differential pattern of the first pilot study was replicated, with Number, Word Fluency, and Verbal Meaning substantially above values for Space and Reasoning. Also noteworthy was the finding that some of the octogenarians in the study still equaled or exceeded the adolescent mean on some of the verbal tests, even though it was most likely that this represented a decrement from a previous higher level suggested by their unusual population characteristics. Findings also suggested sex differences in favor of the males for the Space and Number tests and for the females for the three verbally oriented tests (Strother, Schaie & Horst, 1957).

Having satisfied ourselves that the test battery selected seemed appropriate for our questions, we next proceeded to design a parametric study for a representative sample across a broad spectrum of the adult age range in the context of investigating the relationship between intelligence and flexibility-rigidity (discussed later). This resulted in the first cross-sectional inquiry (Schaie, 1958c), the base of the main study.

The Cross-Sectional Studies

In this section, I review the findings of the first cross-sectional inquiry and its three successive replications. Having previously presented the first three of these studies in their historical sequence (Schaie, 1979), I here compare all four cross-sectional studies jointly, to see what can be learned from their simultaneous analysis.

FIGURE 4.2. The *Primary Mental Abilities* test administered as a power test to older adults. (From "Differential Deterioration of Factorially 'Pure' Functions in Later Maturity" by K. W. Schaie, F. Rosenthal, and R. M. Perlman, *Journal of Gerontology*, 1953, *8*, 194. Copyright 1953 by the Gerontological Society. Reprinted by permission.)



Differential Ability Patterns

Mean scores by age and sex for the five PMAs and the two composite measures of intellectual ability and educational aptitude are presented in Table 4.5. These values are graphed separately by sex for the 1956 and 1977 studies in Figure 4.3. The findings of the original pilot study were virtually replicated in our first cross-sectional inquiry. For the oldest groups, relative performance remains best for Word Fluency and Number; it is worst for the men for Reasoning, and for the women for Space. Age gradients appear to be steepest for Space and Reasoning, and flattest for Number. But note an interesting age/cohort-by-sex interaction. Young men are relatively superior on Space, Reasoning, and Word Fluency, but do less well on Verbal Meaning and Number. The earlier cohorts in advanced age, however, reverse this order for Reasoning and Number. Likewise, young women are relatively highest on Reasoning, Verbal Meaning, and Word Fluency, with lower performance on Space and Number. For them, Reasoning, Verbal Meaning, and Number reverse their positions.

Except for the age/cohort extremes, the 1956 study noted greater dispersion of the ability profile for women than for men. Another noteworthy finding was the differential attainment of peak performance levels by age. For example, age 25 is the peak age for Reasoning, but the peak for Word Fluency appears at age 46; for Number, women showed peak performance at age 53 (see Table 4.5).

By 1977, the pattern of ability at age 25 remained very similar to that found in the first study, conducted 21 years earlier, but the sex difference in profile dispersion was no longer found, and extension of the data base to more advanced ages resulted in a somewhat different ability pattern by the 80s. Examination of Figure 4.3 shows that the oldest male age/cohort does relatively best on Space and Reasoning, and worst on Verbal Meaning. The oldest women, by contrast, do best on Word Fluency, and worst on Space and Verbal Meaning.

Age-Difference Patterns across Time

It is commonplace to suggest that age-difference data are not directly relevant to testing propositions about ontogenetic change. Such data in the context of cross-sectional sequences, however, are quite relevant to testing the proposition that age-difference patterns remain invariant over time and, given certain assumptions, to evaluating the magnitude of cohort differences and time-of-measurement (period) effects. The issue of whether or not age-difference patterns remain invariant over time has been addressed previously, with the conclusion that there are indeed

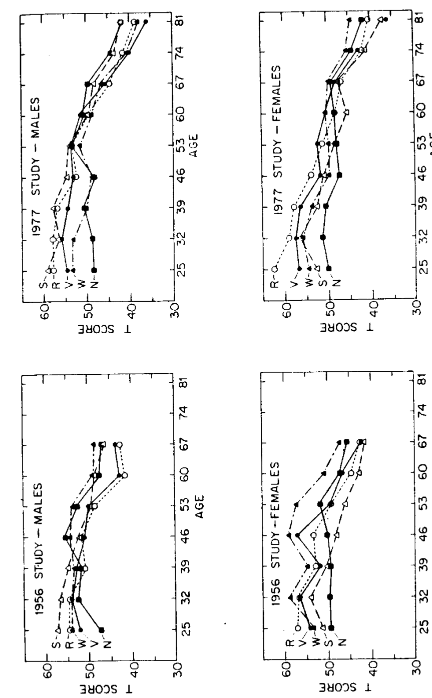


FIGURE 4.3. Mean scores for the five *Primary Mental Abilities* for the 1956 and 1977 cross-sectional studies, by sex.

TABLE 4.5. *T*-Score Means for the Cross-Sectional Data, by Age, Sex, and Study[a]

	1956			1963			1970			1977		
Age	M	F	T	M	F	T	M	F	T	M	F	T
Verbal Meaning												
25	52.2	54.1	53.1	53.0	54.3	53.8	53.3	55.1	54.3	54.6	56.9	55.7
32	54.0[b]	56.5	55.3[b]	53.8	55.1[b]	54.5	52.8	55.3	54.2	55.8[b]	57.4[b]	56.7[b]
39	52.7	51.9	52.3	55.3[b]	54.0	54.6[b]	54.7	54.3	54.4	54.4	56.3	55.3
46	51.0	57.0[b]	53.8	51.1	53.2	52.1	54.1	55.7[b]	54.9	53.9	51.9	52.8
53	49.8	49.4	49.6	47.6	49.6	48.8	55.8[b]	54.1	54.9[b]	54.2	52.2	53.3
60	42.8	46.7	44.8	45.4	49.0	47.3	54.5	51.1	52.7	51.3	50.5	50.9
67	43.6	42.4	43.0	41.7	44.3	43.0	44.6	46.8	45.8	45.6	48.0	46.9
74	—	—	—	40.0	40.1	40.0	39.0	41.9	40.4	40.0	42.8	41.3
81	—	—	—	—	—	—	37.5	38.9	38.1	36.0	36.2	36.1
Space												
25	57.2[b]	51.3	54.2	59.3[b]	56.5[b]	57.7[b]	6.2[b]	55.8[b]	58.1[b]	58.9[b]	52.9	55.9
32	56.6	53.9[b]	55.2[b]	56.9	52.8	54.6	60.2	55.6	57.6	56.5	56.3[b]	56.4[b]
39	54.7	50.1	52.4	56.7	50.3	53.4	57.5	51.0	53.6	57.7	52.8	55.3
46	52.7	48.0	50.4	54.3	48.9	51.6	56.0	52.0	54.0	54.5	51.0	52.6
53	49.9	45.9	47.9	51.1	47.2	48.9	53.4	49.1	51.0	53.9	48.3	51.2
60	48.3	42.7	45.4	49.4	45.4	47.3	52.2	47.3	49.6	49.7	45.6	47.6
67	46.3	41.6	43.9	45.3	41.8	43.6	47.0	41.3	44.0	48.2	47.4	47.8
74	—	—	—	43.2	40.1	41.6	43.0	40.0	41.6	43.7	41.0	42.4
81	—	—	—	—	—	—	42.9	37.8	40.4	42.0	37.2	39.4
Reasoning												
25	54.6[b]	57.1[b]	55.8[b]	58.6[b]	59.7[b]	59.2[b]	60.8	60.2[b]	60.5[b]	57.7[b]	62.3[b]	60.0[b]
32	54.5	56.8	55.8	54.9	58.0	56.7	58.2	59.2	58.8	57.7	59.0	58.4
39	50.8	52.9	[illegible]	54.9	54.1	54.5	55.3	54.5	54.8	56.8	57.8	57.3
46	51.5	53.3	52.3	49.6	52.0	50.8	53.5	54.4	53.9	52.5	53.9	53.3
53	48.5	49.2	48.9	46.7	47.5	47.2	51.0	52.0	51.6	53.3	51.2	52.3
60	41.4	44.6	43.1	44.1	46.5	45.4	51.6	49.1	50.2	49.7	48.3	49.0
67	42.8	42.6	42.7	40.9	41.8	41.3	42.5	43.5	43.0	44.7	46.8	45.8
74	—	—	—	42.0	38.7	40.3	39.8	40.5	40.1	41.4	41.7	41.5
81	—	—	—	—	—	—	39.1	39.1	39.1	38.6	40.3	39.5
Number												
25	47.2	49.6	48.4	50.0	50.5	50.3	51.7	50.1	50.8	48.5	50.0	49.2
32	52.7	49.8	51.2	54.5	52.1	53.2	57.2[b]	49.6	52.9	48.8	51.5[b]	50.2
39	52.0	49.4	50.7	55.8[b]	51.8	53.7[b]	53.3	50.8	51.8	50.7	50.7	50.7
46	55.3[b]	50.2	53.0[b]	52.3	52.6[b]	52.4	54.5	53.2	53.9	48.2	47.4	47.8
53	52.6	51.9[b]	52.2	50.6	48.4	49.3	54.2	53.5	53.8	53.5[b]	48.0	50.9[b]
60	47.4	47.1	47.2	49.0	48.2	48.6	55.4	53.7[b]	54.5[b]	50.8	48.4	49.5

TABLE 4.5. (*Continued*)

	1956			1963			1970			1977		
Age	M	F	T	M	F	T	M	F	T	M	F	T
Number (*continued*)												
67	46.8	45.5	46.2	46.5	43.9	45.2	48.2	46.8	47.4	49.7	49.1	49.4
74	—	—	—	46.1	41.2	43.6	44.1	43.8	44.0	44.3	44.3	44.3
81	—	—	—	—	—	—	43.5	38.0	40.9	41.9	41.7	41.8
Word Fluency												
25	53.9	53.7	53.8	51.1	53.1	52.2	52.5[b]	53.9[b]	53.3[b]	53.4[b]	54.5	53.9
32	53.9	58.9	56.6	49.3	54.8[b]	52.5[b]	47.8	52.8	50.7	53.2	56.0[b]	54.7[b]
39	53.4	54.9	54.1	52.4[b]	51.2	51.8	49.0	51.1	50.3	50.2	53.8	51.9
46	54.3[b]	59.0[b]	56.5[b]	49.5	51.9	50.7	50.7	53.6	52.1	48.9	49.9	49.4
53	53.7	57.3	55.5	45.9	48.9	47.5	52.1	53.3	52.8	51.6	49.9	50.8
60	48.9	50.9	49.9	47.0	50.9	49.0	50.4	50.2	50.3	48.9	50.4	49.7
67	48.6	47.2	47.9	44.0	45.0	44.5	42.4	45.3	44.0	46.5	48.5	47.5
74	—	—	—	44.8	44.2	44.5	39.9	43.0	41.4	40.4	45.7	42.9
81	—	—	—	—	—	—	41.2	43.5	42.3	38.0	44.5	41.5
Intellectual Ability												
25	52.9	53.7	53.3	55.0	55.6	55.3	56.9	55.7[b]	56.2[b]	54.9[b]	56.2	55.5
32	55.3[b]	55.8[b]	55.6[b]	55.1	55.6[b]	55.4[b]	57.1[b]	55.0	55.9	54.8	57.0[b]	56.0[b]
39	53.3	52.0	52.7	56.6[b]	53.0	54.7	54.9	52.8	53.6	54.6	55.0	54.8
46	54.3	54.1	54.2	51.8	52.4	52.1	55.0	54.9	54.9	51.3	50.5	50.9
53	51.4	51.2	51.3	48.2	47.9	48.0	54.2	53.4	53.7	54.3	49.6	52.1
60	44.7	45.5	45.1	46.3	47.4	46.9	54.1	51.0	52.4	50.2	48.2	49.2
67	44.4	42.5	43.5	42.3	41.5	41.9	43.9	43.5	43.7	46.4	47.6	47.0
74	—	—	—	41.8	38.2	32.9	39.1	39.9	39.4	40.0	41.3	40.6
81	—	—	—	—	—	—	38.7	36.2	37.5	37.0	37.5	37.3
Educational Aptitude												
25	52.8	55.1	53.9	54.5	56.0	55.4[b]	55.4[b]	56.8[b]	56.2[b]	55.5	58.6[b]	57.0
32	54.4[b]	57.0[b]	55.7[b]	54.3	56.1[b]	55.3	54.4	56.6	55.7	56.7[b]	58.3[b]	57.5[b]
39	52.4	52.3	52.4	55.5[b]	54.4	54.9	55.1	54.5	54.8	55.3	57.1	56.2
46	51.3	56.5	53.7	50.8	53.1	52.0	54.2	55.7	55.0	53.9	52.6	53.2
53	49.5	49.2	49.3	48.3	47.3	49.1	54.9	53.9	54.3	54.3	52.1	53.3
60	42.0	45.9	44.0	44.8	48.3	46.6	54.1	50.7	52.3	51.1	49.9	50.5
67	42.9	42.0	42.5	40.9	43.3	42.1	43.6	45.7	44.8	45.1	47.6	46.4
74	—	—	—	39.7	39.2	39.5	38.4	41.0	39.7	39.7	42.0	40.8
81	—	—	—	—	—	—	37.2	38.2	37.7	35.9	36.3	36.1

[a]For cell frequencies, refer to Table 4.1.
[b]Peak performance level.

statistically significant shifts in such patterns. This conclusion was based in part upon the finding of significant age-by-time interactions in time-sequential analyses and of cohort-by-time interactions in cross-sequential analyses (Schaie, Labouvie, & Buech, 1973; Schaie & Strother, 1968c; Stone, Schaie, & Gonda, 1979).

To examine shifts in age profiles as well as peak ages across all four cross-sectional studies, mean scores for Verbal Meaning (to represent a verbal, or "crystallized," measure) and Reasoning (to represent nonverbal, or "fluid," abilities) have been graphed in Figure 4.4. What seems most apparent is that, until the 70s, means observed at the same ages tend to fall at progressively higher levels for successive cohorts attaining a given age. Most noteworthy for Verbal Meaning (see Figure 4.4) is the apparent shift in substantial age differences to older levels. For example, the first appearance of a noteworthy age difference disadvantaging the older group occurred in 1956 and 1963 between those aged 46 and those aged 53; a similar gap for the 1970 and 1977 studies does not appear until we examine the difference between those aged 60 and those aged 67. This phenomenon is not quite as pronounced for Reasoning (see Figure 4.4), since age differences follow a more linear pattern. Nevertheless, it is interesting to note that the largest age difference in 1956 occurred between those aged 53 and those aged 60, but in 1977, between those aged 60 and those aged 67. It is suggested that these age-difference shifts may have considerable impact on the public perception of ability differences between age groups and may affect the decision process with respect to the age at which an attempt should or must be made to rejuvenate the work force (whether by voluntary or mandatory retirement or by discharge for cause).

Although, in the absence of independent information, it is not possible to unconfound cohort and period effects unambiguously, it is possible, from data such as ours, to estimate cohort differences over fixed time periods by comparing the performance of successive cohorts over the age ranges for which both have been observed. These cohort differences will, of course, be confounded with period effects, but if computed over the same period, they will be equally affected. In our case, it is possible to generate nine cohort differences for ten 7-year birth cohorts born from 1889 to 1952.[4] Table 4.6 provides mean differences in *T*-score points computed for all cohort combinations in our study. This table should be read as follows: A positive value indicates that the performance of the cohort identified in the column exceeds, on average, by the value given at equivalent ages, the performance of the cohort identified by the row. A

[4]Cohort comparisons are based on three age levels, or an age range of 14 years, except for the cohorts born in 1945 and 1952, for which only two and one comparisons, respectively, are available.

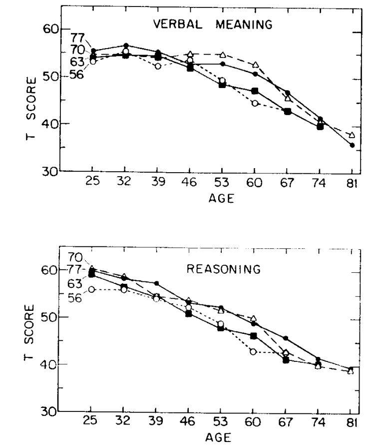


FIGURE 4.4. Comparison of mean scores for the abilities of Verbal Meaning and Reasoning for the four cross-sectional studies.

negative value, conversely, means that the performance of the row (earlier born) cohort exceeds that of the column (later born) cohort.

It is interesting to note that the composite index of Intellectual Ability will tend to obscure cohort differences because of differential cohort trends of the subtests; for this composite index, only the three earliest born cohorts differ significantly from later born cohorts. On the other hand, when the abilities are considered separately, it becomes clear from these data that there are systematic advances in cohort level for Space and Reasoning; a significant disadvantage with respect to later cohorts is apparent up to the cohort born in 1931! A similar pattern prevails for Verbal Meaning, but here only cohorts born in 1917 or earlier are at a significant disadvantage when compared with later born cohorts.

TABLE 4.6. Mean Advantage of Later Born Cohorts over Earlier Born Cohorts, in *T*-Score Points[a]

	Mean year of birth								
	1896	1903	1910	1917	1924	1931	1938	1945	1952
Verbal Meaning									
1889	−.28	1.77	2.93*	3.83*	4.98*	3.97*	4.21	5.70*	7.11*
1896		2.05*	3.21*	4.11*	5.26*	4.25*	4.49*	5.98*	7.39*
1903			1.16	2.06*	3.21*	2.20*	2.44*	3.93*	5.34*
1910				.90	2.05*	1.04	1.28	2.77*	4.18*
1917					1.15	.14	.38	1.87	3.28*
1924						−1.01	−.77	.72	2.13
1931							.24	1.73	3.14*
1938								1.49	2.90
1945									1.41
Space									
1889	−.44	.59	2.99*	3.37*	4.55*	3.98*	6.67*	6.30*	4.07*
1896		1.03	3.43*	3.81*	4.29*	4.42*	7.11*	6.74*	4.51*
1903			2.40*	2.78*	3.96*	3.39*	6.08*	5.71*	3.48*
1910				.38	1.56	.99	3.68*	3.31*	1.08
1917					1.18	.61	3.30*	2.93*	.70
1924						−.57	2.12*	1.75	−.78
1931							2.69*	2.32	.09
1938								−.37	−2.60
1945									−2.23
Reasoning									
1889	−.39	1.41*	3.39*	3.91*	6.08*	6.30*	8.95*	9.36*	8.87*
1896		1.80*	3.78*	4.30*	6.47*	6.69*	9.34*	9.75*	9.26*
1903			1.98*	2.50*	4.67*	4.89*	7.54*	7.95*	7.46*
1910				.52	2.69*	2.91*	5.56*	5.97*	5.48*
1917					2.17*	2.39*	5.04*	5.45*	4.96*
1924						.22	2.87*	3.28*	2.79
1931							2.65*	3.06*	2.57
1938								.41	−.08
1945									−.49
Number									
1889	.13	1.42	3.08*	2.73*	3.22*	1.23	1.39	1.33	−1.25
1896		1.29	2.95*	2.60*	3.09*	1.10	1.26	.20	−1.38
1903			1.66	1.31	1.80	−.19	−.03	−1.09	−2.67
1910				−.35	.14	−1.85	−1.69	−2.75*	−4.33*
1917					.49	−1.50	−1.34	−2.40*	−3.98*
1924						−1.99	−1.83	−2.89*	−4.47*

TABLE 4.6. (*Continued*)

	Mean year of birth								
	1896	1903	1910	1917	1924	1931	1938	1945	1952
Number (*continued*)									
1931							.16	−.90	−2.48
1938								−1.06	−2.64
1945									−1.58
Word Fluency									
1889	−2.44*	−2.39*	−3.45*	−3.84*	−4.80*	−7.57*	−8.20*	−5.65*	−4.28*
1896		.05	−1.01	−1.40	−2.36*	−5.13*	−5.76*	−3.21*	−1.74
1903			−1.06	−1.45	−2.41*	−5.18*	−5.81*	−3.26*	−1.79
1910				−.39	−1.35	−4.12*	−4.75*	−2.20	−.73
1917					−.96	−3.73*	−4.46*	−1.81	−.44
1924						−2.77	−3.40*	−.85	.52
1931							−.63	1.92	3.29
1938								2.55*	3.92*
1945									1.37
Intellectual Ability									
1889	−.76	.82	1.79	1.92*	2.92*	1.17	2.41*	2.89*	2.18
1896		1.58	2.55*	2.68*	3.68*	1.93*	3.17*	3.65*	2.94
1903			.97	1.10	2.10*	.35	1.59	2.07	1.36
1910				.13	1.13	−.62	.62	1.10	.39
1917					1.00	−.75	.49	.97	.26
1924						−1.75	−.51	−.03	−.74
1931							1.24	1.72	1.01
1938								.48	−.23
1945									−.71
Educational Aptitude									
1889	.57	2.70*	4.80*	5.64*	7.13*	7.38*	7.43*	8.97*	9.62*
1896		2.13*	4.23*	5.07*	6.56*	6.81*	6.86*	8.20*	9.05*
1903			2.10*	2.94*	4.43*	4.68*	4.73*	6.07*	6.92*
1910				.84	2.33*	2.58*	2.63*	3.97*	4.82*
1917					1.49	1.74	1.79	3.13*	3.98*
1924						.25	.30	1.64	2.49
1931							.05	1.39	2.24
1938								1.34	2.19
1945									.85

[a]Negative values indicate that the later born cohort is at a disadvantage compared to the earlier born cohort.

*$p < .01$.

Very different findings occur for Number and Word Fluency. The former shows positive cohort changes up to about the 1910 cohort. Then there is a plateau and a shift to successive lowering of performance level. As a consequence, the 1924 cohort is found to exceed both earlier and later born cohorts; both the youngest and oldest cohorts are now at a disadvantage compared to the middle cohorts. For Word Fluency, we find a successive lowering of cohort level until the 1938 cohort, but improvement for the last two cohorts. Earlier born cohorts consequently have an advantage over the later born ones, with the recent reversal noted previously.

Finally, on the issue of cohort differences, and possibly of considerable significance in terms of policy implications, are the findings for the composite index of Educational Aptitude. This index shows systematic positive cohort shifts, with a significant disadvantage to all cohorts born in 1917 or earlier. This would seem to be another convincing demonstration of the importance of taking generational differences into account in planning present and future adult education activities.

Estimates of Time-of-Measurement Effects

Just as we estimated cohort differences by matching across age and assuming equivalence of period effects across cohorts, so can we use these data to estimate time-of-measurement (period) effects by matching across age and assuming equivalence of cohort effects across periods. This computation has been done by considering the four sets of first-time tests totaled across the range of mean ages from 25 to 67 years (for which all sets are represented four times). The three period effects obtained are shown in Table 4.7 for the total sample, since no significant time-by-sex interactions were found. A significant negative time trend occurred from 1956 to 1963 only for Word Fluency. However, there was a positive trend for all variables to 1970. No further changes occur in the period to 1977, except for Number, which now shows a significant negative trend. For the two composite indexes, significant positive time trends are found only for the period from 1963 to 1970.

Several alternative explanations can be offered for these period effects. They may simply represent systematic testing effects, that is, small but systematic changes in test administration and scoring procedures, which, even with the best documentation, can readily slip into longitudinal studies. Although unlikely for large samples, it is nevertheless possible that these differences represent systematic sampling error, attributable to changes in the composition of the pool from which the successive samples were drawn. Another explanation would be a systematic cohort trend,

TABLE 4.7. Time-of-Measurement (Period) Effects for Three Periods, in *T*-Score Points

	Verbal Meaning			Space			Reasoning			Number		
	1963	1970	1977	1963	1970	1977	1963	1970	1977	1963	1970	1977
1956	.43	2.73	2.74*	.95	2.27*	2.27*	.57	2.87*	3.43*	.76	2.37*	−.04
1963		2.30*	2.31*		1.32	1.32		2.29	2.85*		1.61*	−.80
1970			.01			.00			.56			−2.41*

	Word Fluency			Intellectual Ability			Educational Aptitude		
	1963	1970	1977	1963	1970	1977	1963	1970	1977
1956	−3.66*	−2.99*	−2.39*	−.12	1.98*	1.31	.50	2.94*	3.11*
1963		.67	1.27		2.10*	1.43		2.43*	2.61*
1970			.60			−.66			.18

Note. n = 1956, 500; 1963, 919; 1970, 567; 1977, 481.
*$p < .01$.

although cohort differences should only minimally affect our period estimates since, for each estimate, five of the seven cohorts used were identical. Finally, these findings might represent true period effects caused by a systematic environmental impact such as the improvement of media, increased utilization of adult education opportunities, improved nutrition, and increased application of preventive health care principles.

These matters are not trivial because longitudinal data should be adjusted for period effects if generalizable age functions are to be adduced. In particular, this becomes an important problem when age functions are constructed from short-term longitudinal studies applying sequential data-gathering strategies. Data from cross-sectional sequences make it possible to consider certain adjustments to observed longitudinal data. If one assumes that there are no significant cohort differences, then it would be possible to adjust longitudinal change data by means of values such as were presented in Table 4.7. If cohort differences are presumed to exist, then more complicated corrections may be needed. In that case, one would compute age/time-specific time lags from the cross-sectional data in Table 4.5, subtract the appropriate cohort differences given in Table 4.6, and use the resultant age/cohort-specific estimates of period effect to correct age-change data. The first correction would be most appropriate in the case of testing effects or true period effects occurring across all age/cohort levels. The second correction would be appropriate for use in dealing with age/cohort-specific sampling fluctuations. Examples of such adjustments as applied to our longitudinal data are given later in this chapter.

Age Changes in Intellectual Abilities

In this section, I review the results of our longitudinal studies. As indicated in the discussion of the data base, these consist of three 7-year follow-ups, two 14-year follow-ups, and one 21-year follow-up. Again, I have not repeated the presentation of data and conclusions presented elsewhere (Hertzog, Schaie, & Gribbin, 1978a; Schaie, 1979; Schaie & Labouvie-Vief, 1974; Schaie & Parham, 1977; Schaie & Strother, 1968b; Stone & Schaie, 1979). Instead, I have tried to integrate the entire longitudinal data base in order to provide estimates of age change based on the largest available number of subjects for each age interval, to consider how such estimates are affected if one applies corrections for period and cohort differences (based on the estimates presented in the previous section), and to deal with the comparability of age changes obtained from the replications of the 7-year and 14-year studies.

Estimates of Age Changes Based on 7-Year Data

If one is interested in forecasting ontogenetic change within individuals and in generating normative data that would permit assessing whether a particular individual change is within the average range of individual differences in such change or is excessive and thus a possible clue to behavior pathology, it would seem best to obtain estimates averaged over as many cohorts and times of measurement as possible. I have therefore computed average IAC estimates for 7-year intervals from ages 25 to 88, based upon the 1601 test records for which measures were available for two points 7 years apart. Table 4.8 provides the resultant average IACs in *T*-score units, with positive values indicating gain from the age listed in the row to that listed in the column, and negative values indicating age decrement. The values in the diagonals of that table represent the observed within-group age changes. The off diagonals are the cumulated changes obtained by summing the appropriate successive within-group values. These estimates are needed in order to determine the ages at which decrement from some previous age reaches statistical significance. One can immediately see that statistically significant cumulative age decrement from any previous age was not observed for any of the variables prior to age 67. Several variables showed modest increment in young adulthood. Such increment above performance shown at age 25 remained significant for Verbal Meaning until age 60. It also led to the finding that cumulative age decrement, when taken from age 25, reached statistically significant magnitudes for Verbal Meaning, Reasoning, and Word Fluency only at age 74, and for Space as late as age 81.

To permit comparison of the longitudinal findings with the cross-sectional data reported earlier, I have computed estimated mean-level values for the most recent cohort, the one born in 1952. The average IACs were cumulated and added to the base values for the 1952 cohort that were empirically obtained when it was observed at age 25. These predicted values were computed for the total sample and separately by sex; they are given in Table 4.9. It is interesting to note that the resultant data suggest far later attainment of peak performance levels than was suggested by the cross-sectional studies. Peak performance ages for the total group occurred for Number at 32, for Reasoning at 39, and for Space and Word Fluency as well as the Index of Intellectual Ability at 46, but for Verbal Meaning and the Index of Educational Aptitude not until 53. There were also sex differences in peak-level ages, with Space peaking for men at 46, but for women at 53; Reasoning peaking for women already at 39, but for men not until 53; and Number peaking for men at 32, but for women at 46. Differences for the composite indexes indicated that men peaked on the

TABLE 4.8. Cumulative Age Changes from 7-Year Longitudinal Data, in *T*-Score Points

	Mean age								
	32	39	46	53	60	67	74	81	88
					Verbal Meaning				
25	1.60	2.98*	3.68*	4.02*	3.73*	1.75	−1.33	−4.95*	−14.01*
32		1.38	2.08*	2.42*	2.13*	.15	−2.93*	−6.55*	−15.61*
39			.70	1.04	.75	−1.23	−4.31*	−7.93*	−16.99*
46				.34	.05	−1.93	−5.01*	−8.63*	−17.69*
53					−.29	−2.27*	−5.35*	−8.97*	−18.03*
60						−1.98*	−5.06*	−8.68*	−17.74*
67							−3.08*	−6.70*	−15.76*
74								−3.52*	−12.58*
81									−9.06*
					Space				
25	1.31	1.45	1.97	1.88	1.58	−.14	−2.46	−4.92*	−8.76*
32		.14	.66	.57	.27	−1.45	−3.77*	−6.23*	−10.07*
39			.52	.43	.13	−1.59	−3.91*	−6.37*	−10.21*
46				−.09	−.39	−2.11*	−4.43*	−6.89*	−10.73*
53					−.30	−2.02*	−4.34*	−6.80*	−10.64*
60						−1.72	−4.04*	−6.50*	−10.34*
67							−2.32*	−4.78*	−8.62*
74								−2.46	−6.30*
81									−3.84
					Reasoning				
25	.65	1.04	1.07	.94	.77	−1.12	−3.80*	−5.89	−9.42*
32		.39	.42	.29	.12	−1.77	−4.45*	−6.54	−10.07*
39			.03	−.10	−.27	−2.16*	−4.84*	−6.93*	−10.46*
46				−.13	−.30	−2.19*	−4.87*	−6.96*	−10.49*
53					−.17	−2.06	−4.74*	−6.86*	−10.36*
60						−1.89*	−4.67*	−6.66*	−10.19*
67							−2.68*	−4.77*	−8.30*
74								−2.09	−5.62*
81									−3.53
					Number				
25	1.59	.97	1.15	.14	−.23	−2.73*	−5.37*	−9.56*	−16.44*
32		−.62	−.44	−1.45	−1.82	−4.32*	−6.96*	−11.15*	−18.03*
39			.18	−.83	−1.20	−3.70*	−6.34	−10.53*	−17.41*
46				−1.01	−1.38	−3.88*	−6.52*	−10.71*	−17.59*
53					−.37	−2.87*	−5.51*	−9.70*	−16.58*

TABLE 4.8. (*Continued*)

	Mean age								
	32	39	46	53	60	67	74	81	88
					Number (*continued*)				
60						−2.50*	−5.14*	−9.33*	−16.21*
67							−2.64*	−6.83*	−16.71*
74								−4.19*	−11.07*
81									−6.88*
					Word Fluency				
25	.69	.75	1.29	.49	−.34	−2.24	−4.67*	−8.06*	−10.40*
32		.06	.60	−.20	−1.03	−2.03	−5.36*	−8.75*	−11.09*
39			.54	−.26	−1.09	−2.99*	−5.42*	−8.81*	−11.15*
46				−.80	−1.63	−3.53*	−5.96*	−9.35*	−11.69*
53					−.83	−2.73*	−5.16*	−8.55*	−10.89*
60						−1.90	−4.33*	−7.72*	−10.06*
67							−2.43	−5.82*	−8.16
74								−3.39*	−5.73
81									−2.34
					Intellectual Ability				
25	1.92	2.75*	3.66*	3.38*	3.41*	.90	−2.17	−6.37*	−12.55*
32		.83	1.74	1.45	1.49	−1.02	−4.09*	−8.29*	−14.47*
39			.91	.63	.66	−1.85	−4.92*	−9.12*	−15.30*
46				−.28	−.25	−2.76*	−5.83*	−10.03*	−16.21*
53					.03	−2.48*	−5.55*	−9.75*	−15.93*
60						−2.51*	−5.58*	−9.78*	−15.96*
67							−3.07*	−7.27*	−13.46*
74								−4.20	−10.38*
81									−6.18
					Educational Aptitude				
25	1.49	2.29*	2.78*	2.87*	2.35*	.41	−2.72*	−5.98*	−14.33*
32		.80	1.29	1.38	.86	−1.08	−4.21*	−7.47*	−15.82*
39			.49	.58	.06	−1.88*	−5.01*	−8.27*	−16.62*
46				.09	−.43	−2.37*	−5.50*	−8.76*	−17.11*
53					−.52	−2.46*	−5.59*	−8.85*	−17.20*
60						−1.94	−5.07*	−8.33*	−16.68*
67							−3.13*	−6.39*	−14.74*
74								−3.26*	−11.61*
81									−8.35*

*$p < .01$.

TABLE 4.9. Predicted Mean Values, in T Scores, of Performance at Successive Ages for a Cohort Born in 1952 (from 7-Year Longitudinal Data)

	Verbal Meaning			Space			Reasoning			Number			Word Fluency			Intellectual Ability			Educational Aptitude		
Age	M	F	T	M	F	T	M	F	T	M	F	T	M	F	T	M	F	T	M	F	T
25	52.8	56.5	55.2	60.0	55.6	58.7	58.7	60.0	59.5	49.0	51.4	50.5	52.7	54.3	53.8	55.0	56.6	56.0	54.4	57.8	56.6
32	55.8	57.4	56.8	61.6	56.8	58.4	58.6	61.0	60.2	52.5[a]	51.9	52.1[a]	52.6	55.3	54.5	57.8	58.0	58.0	56.8	58.8	58.1
39	57.4	58.6	58.2	61.8	56.8	58.6	58.5	61.8[a]	60.6[a]	50.6	52.2	51.5	53.2	55.0	54.5	58.0	59.2	58.8	57.8	59.5	58.9
46	58.8	58.8	58.9	62.5[a]	57.2	59.1[a]	61.4	61.4	60.6	50.8	52.3[a]	51.7	53.4[a]	55.8[a]	55.1	58.8[a]	60.2	59.7[a]	59.0	59.5[a]	59.4
53	59.4[a]	58.9[a]	59.2[a]	62.3	57.3[a]	59.0	59.2[a]	61.0	60.5	50.1	51.1	50.7	52.5	55.1	54.3	58.6	59.8	59.4	59.4[a]	59.2	59.5[a]
60	58.8	58.8	59.0	61.7	57.2	58.7	58.8	61.3	60.3	49.1	51.2	50.3	51.9	54.1	53.4	58.2	60.3[a]	59.4	58.7	57.6	59.0
67	56.5	57.9	57.0	59.3	56.0	57.0	57.0	59.3	58.4	46.0	49.1	47.8	50.4	51.9	51.5	55.4	57.9	56.9	56.2	56.1	57.0
74	53.9	54.4	43.9	56.9	53.8	54.7	54.6	56.4	55.7	43.2	46.6	45.2	47.7	49.7	49.1	52.7	54.6	53.9	53.4	52.7	53.9
81	50.6	50.7	50.4	52.7	51.9	52.2	52.3	54.4	53.6	38.8	42.6	44.8	46.2	44.8	45.7	48.4	50.4	49.7	50.2	49.4	50.6
88	45.9	37.8	41.2	50.0	44.5	48.4	51.8	48.2	50.1	34.5	33.4	34.1	46.6	39.7	43.4	45.1	41.4	43.5	46.2	37.2	42.3

[a]Peak performance level.

summary score of Intellectual Ability at 46, but women at 60, while for Educational Aptitude, women peaked at 46, but men at 53.

Estimates of Age Changes Based on 14-Year Data

In addition to the longitudinal age-change estimates available from our replicated 7-year studies, it is also possible to obtain estimates that derive from the observation of the same individuals, albeit a smaller number of them, over 14 years. The data used for this analysis were obtained by combining 14-year retest observations for the samples followed from 1956 to 1970 and from 1963 to 1977, a total of 617 subjects. Table 4.10 gives average 14-year changes in T-score points. These data suggest significant 14-year gains in performance for Reasoning and Word Fluency to age 39 and for Verbal Meaning, Space, and the composite indexes to age 46. Significant 14-year loss is shown for Number by age 53, for Word Fluency by age 60, and for the remaining measures by age 67. Note again that absolute loss for the fluid abilities is less than for the crystallized and speeded measures.

Estimates of Age Changes Based on 21-Year Data

A final set of age-change data is provided from the 128 subjects who were observed over the entire 21-year duration of the study. This data set, of course, has been systematically attrited, and its subsets have small cell frequencies; the resultant estimates of age change must clearly be treated with much caution. They are reported here, however, because of the scarcity of longitudinal data for such an extended time span.

TABLE 4.10. Average 14-Year Longitudinal Age Changes, in T-Score Points

Age range	n	Verbal Meaning	Space	Reasoning	Number	Word Fluency	Intellectual Ability	Educational Aptitude
25–39	46	2.59*	.87	1.72*	1.09	2.26*	4.11*	.85
32–46	98	1.47*	.95	.17	−.65	−.39	1.04*	1.06*
39–53	109	.18	−.20	.01	−1.44*	−.04	−.31	−.16
46–60	122	.25	−.29	−.43	−1.81*	−1.38*	−.50	−.64
53–67	123	−2.36*	−2.52*	−1.76*	−2.13*	−2.68	−3.34*	−2.23*
60–74	61	−5.00*	−3.62*	−3.56*	−3.97*	−3.45*	−5.03*	−4.81*
67–81	49	−6.22*	−5.16*	−4.88*	−5.71*	−6.79*	−7.68*	−6.08*

*$p < .01$.

Table 4.11 shows significant gains over the 21-year span from 25 to 46 years for Verbal Meaning and the index of Educational Aptitude. Statistically significant age decrement over a 21-year interval is shown first for Word Fluency at age 60 and for Space, Number, and the index of Intellectual Ability at age 67; for Verbal Meaning, Reasoning, and the index of Educational Aptitude, however, such decrement is shown beginning at age 74.

Cumulative age decrement from the three data sources do not differ a great deal at most ages. The 14-year data generally show the least decrement, but in further discussions, I consider primarily the cumulated 7-year longitudinal data because of the larger sample size.

Adjustments for Cohort, Period, and Dropout Effects

The validity of the within-cohort estimates of ontogenetic age change in ability can, of course, be questioned by arguing that the age-change data are obviously specific to the cohorts from which they were gained, that the data are affected by idiosyncratic period effects, and that the unavoidable attrition (dropout) in longitudinal panels will largely lead to results generalizable only to the favorable subset remaining in this study. The first two confounds will affect primarily the estimated magnitudes of change, and the third will determine reported levels of functioning. I have already described, in the section on age differences, the approach used to estimate cohort and period effects. Some additional comments are in order with regard to dropout.

TABLE 4.11. Average 21-Year Longitudinal Age Changes, in *T*-Score Points

Age range	n	Verbal Meaning	Space	Reasoning	Number	Word Fluency	Intellectual Ability	Educational Aptitude
25–46	19	3.26*	3.10	1.26	1.00	−1.33	1.63	3.11*
32–53	19	.58	−.79	−.58	−.84	−3.05	−1.25	.33
39–60	21	−1.19	−1.38	−.57	−.219	−4.67*	−2.57	−1.00
46–67	31	−1.22	−3.84*	−2.08	−4.94*	−6.06*	−4.87*	−1.35
53–74	24	−4.42*	−3.13*	−4.42*	−4.42*	−7.30*	−6.63*	−4.66*
60–81	9	−7.11*	−1.89	−5.00*	−2.78	−10.00*	−6.67*	−6.99*
67–88	5	−9.80	−5.60	−6.20	−10.80*	−5.60	−10.60*	−9.60

*$p < .01$.

Dropout Effects

These effects were examined cross-sectionally by cohort after a single 7-year period (Baltes, Schaie, & Nardi, 1971) and by means of sequential analyses for two successive 7-year intervals (Schaie, Labouvie, & Barrett, 1973) and for three successive 7-year intervals (Gribbin & Schaie, 1977, 1979). What is at issue here is that, because of selective mortality and other factors (such as health and motivation), there has been selective attrition with respect to the dependent variables of interest. As a result, retest survivors are found to score higher at first test than individuals who drop out. This finding has been replicated and is consistent for all but the youngest cohorts. (See Figure 4.5 for an example of the dropout analysis reported for the 1970 data collection.) There are, however, a number of age-by-dropout interactions, and it was discovered more recently that selective dropout is particularly severe only upon the second test occasion. That is, once longitudinal participants are brought back for follow-up, it appears that further attrition then becomes reasonably random.

The findings on selective dropout suggest that age gradients, such as those shown in Figure 4.6, will have inflated base levels even when there is no age-by-dropout interaction. Most typically, they will lead to more favorable conclusions than are warranted regarding the magnitude of change as a function of base levels; that is, levels of functioning may be predicted that are higher than may be warranted. The first correction for longitudinal estimates, therefore, would seem to be the assignment of base levels to values obtained from the full, rather than the attrited, sample.

Correction for Period Effects

Since longitudinal estimates confound age and period effects, which may either attenuate or heighten age changes, it is desirable to correct estimates for known period effects. As shown in the preceding section, the least biased estimates of period effects will be the average time-lag difference between successive occasions across all available cohorts equating for age. To the extent that stable age estimates were obtained by averaging across several cohorts, this correction, however, will be excessive for some cohorts and too low for others, and a further adjustment is therefore needed.

Correction for Cohort Effects

Given the fact that time-lag estimates confound period and cohort effects, it is next necessary to subtract out the appropriate cohort differ-

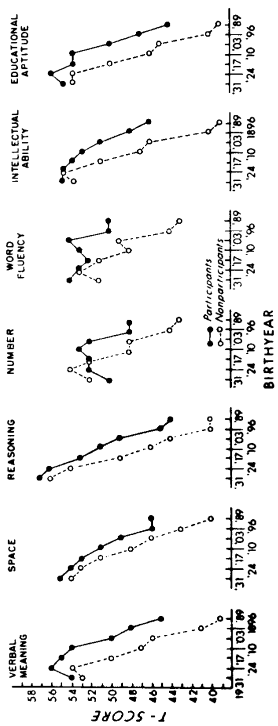


FIGURE 4.5. Cohort differences for retest participants and dropouts. (From "Selective Attrition Effects in a Fourteen Year Study of Adult Intelligence" by K. W. Schaie, G. V. Labouvie, and T. J. Barrett, *Journal of Gerontology*, 1973, 28, 331. Copyright 1973 by the Gerontological Society. Reprinted by permission.)

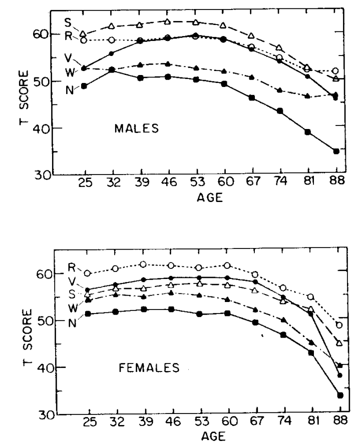


FIGURE 4.6. Longitudinal estimates of age changes for men and women for the *Primary Mental Abilities* from 7-year data.

ences, estimated across all available times of measurement. The final approach taken consequently involves longitudinal estimates obtained by averaging across all available age changes within individuals, adjusting for period effects weighted according to the size of subsamples involved for each period, and adding cohort adjustments weighted for the cohorts involved in each particular age change. In the following subsection, where we attempt to get a better understanding of the significance of age changes, data are reported both in their directly observed form and after correction for dropout, period, and cohort effects.

Estimates from Successive Independent Samples

As long as one's interest is primarily in age changes expressed as population parameters, it is possible to obtain estimates of age change by computing mean differences at successive ages within cohorts, where each measurement point is represented by a distinct random sample drawn from the same parent population. In this case, we assume, of course, that the population has remained stable, or that there has indeed been sampling with replacement, and further, that we have indeed succeeded in drawing comparable successive random samples. If these assumptions are justified (see Gribbin, Schaie, & Stone, 1976), then it is possible to compute age-change estimates that are controlled for the effects of testing and experimental mortality. Such estimates based upon successive independent samples have previously been reported for more limited data across a 7-year time interval (Schaie & Parham, 1977). Tables 4.12, 4.13 and 4.14 present estimates based upon the entire data set for within-cohort changes estimated over 7-, 14-, and 21-year intervals, respectively.

The 7-year estimates in Table 4.12 may be compared with the longitudinal panel data to be found in the diagonals of Table 4.8. They are generally quite comparable, except for small but statistically significant age decrements from age 46 to 53 for Reasoning, Word Fluency, and the composite indexes, decrements not seen in the repeated measurement data. Further, the gains into the 30s shown in the panel data fail to be significant in the independent-sample data except for the Number variable.

TABLE 4.12. Average 7-Year Age Changes Estimated from Independent Samples, in *T*-Score Points

Age range	n^a	Verbal Meaning	Space	Reasoning	Number	Word Fluency	Intellectual Ability	Educational Aptitude
25–32	247/249	1.40	−.51	−.54	2.25*	−.53	.81	1.02
32–39	257/307	.12	−1.68	−1.55	−.68	−1.90	−1.26	.69
39–46	305/311	−.50	−.38	−1.04	−.72	−1.31	−1.04	−.62
46–53	307/309	−1.28	−1.67	−2.00*	−1.75	−2.73*	−2.45*	−1.89*
53–60	302/274	−.80	−1.13	−1.02	−.90	−2.27*	−1.53	−.85
60–67	274/291	−3.08*	−2.34*	−2.86*	−2.76*	−4.39*	−3.95*	3.23*
67–74	294/235	−3.25*	−1.95*	−1.59	−2.34*	−2.54*	−3.01*	−3.14*
74–81	165/107	−3.07*	−1.64	−.91	−2.44	−1.04	−2.30*	−2.64*

[a]First number indicates frequency at first age; second number indicates frequency at second age.
*$p < .01$.

TABLE 4.13. Average 14-Year Age Changes Estimated from Independent Samples, in *T*-Score Points

Age range	n^a	Verbal Meaning	Space	Reasoning	Number	Word Fluency	Intellectual Ability	Educational Aptitude
25–39	176/157	1.44	−1.51	−1.48	1.92	−1.93	−.09	2.32*
32–46	192/156	−1.04	−1.56	−2.63*	−1.68	−3.72*	−2.60*	−1.46
39–53	221/166	−.63	−1.76	−1.20	.16	−1.18	−.78	.18
46–60	220/252	−1.16	−2.50*	−1.96	−.66	−3.58*	−2.34	−1.42
53–67	213/164	−2.88*	−2.54*	−3.62*	−2.36	−5.74*	−4.30*	−3.28*
60–74	194/158	−5.23*	−4.19*	−3.40*	−3.78*	−7.32*	−6.00*	−5.10*
67–81	203/108	−5.88*	−3.81*	−2.70*	−4.38*	−4.28*	−5.27*	−5.36*

[a]First number indicates frequency at first age; second number indicates frequency at second age.
*$p < .01$.

In a like manner, the 14-year estimates in Table 4.13 can be compared with the panel data in Table 4.10. Major discrepancies occur for Reasoning and Word Fluency, where the independent-sample data show a significant difference over the 32- to 46-year-old range, and for Space, where significant decrement is found by age 60. On the other hand, statistically significant decrement for number does not appear until age 74, much later than in the panel data.

Finally, comparison may be made between the 21-year data in Table 4.14 and the corresponding panel values in Table 4.11. Again, there is substantial correspondence, the major exceptions being, in the independent samples, an earlier appearance of decrement for Word Fluency and a later decrement for Number.

TABLE 4.14. Average 21-Year Age Changes Estimated from Independent Samples, in *T*-Score Points

Age range	n^a	Verbal Meaning	Space	Reasoning	Number	Word Fluency	Intellectual Ability	Educational Aptitude
25–46	76/79	−.29	−1.64	−2.53	−.64	−4.38*	−3.41	−.73
32–53	70/77	−2.01	−3.93	−3.49	−.31	−5.79*	−3.56	−2.47
39–60	71/72	−1.42	−4.81*	−2.86	−1.16	−4.47*	−3.52	−1.84
46–67	65/73	−6.91*	−2.76*	−6.56*	−3.59	−8.90*	−7.14*	−7.50*
53–74	70/70	−8.29*	−5.45*	−7.36*	−7.95*	−12.61*	−10.70*	−8.64*
60–81	72/58	−8.75*	−5.98*	−3.54*	−5.45*	−8.42*	−7.84*	−7.89*

[a]First number indicates frequency at first age; second number indicates frequency at second age.
*$p < .01$.

Individual Differences in Intraindividual Change

Until recently, most analyses of intellectual change in adulthood (including our own) have confirmed themselves to the comparison of mean-level changes. One of the major rationales and the exclusive advantage of the longitudinal study is the possibility of tracking individual patterns of change. If we are simply interested in the range of talent at given ages, we do not need longitudinal data because only interindividual differences are involved. What we are concerned with here are the interindividual differences in IAC, that is, the differences in scores between successive occasions.[5] There are a number of different approaches that can be taken to summarize the resultant findings. Two indexes will be reported on here: The first is the standard deviation (*SD*) of the difference scores for successive longitudinal observations; the second involves creating a ratio in standard deviation units, obtained by dividing the observed mean differences for successive ages within the same group by the standard deviation of the difference scores.

Range of Individual Variability

Inspection of Table 4.15 immediately calls attention to the fact that individual differences of change scores are considerably smaller than those of the base scores ($SD = 10$). Although there is a predominant pattern for such differences to be smallest in midlife, with a subsequent increase in variability, there are exceptions. Thus variability once again declines for all abilities except Verbal Meaning as the 80s are reached. Also, it is apparent that different abilities show differential variability patterns, with the result that the greatest regularity is found in the composite indexes, which minimize the apparent age-by-ability interaction in variability.

Magnitude of Average Contrasted to Individual Differences

One way in which the significance of average IAC can be assessed is by contrasting the magnitude of mean changes to the range of individual differences of such change. Cohen (1977), in his work on power analysis, has proposed that one might distinguish between small, moderate, and large effects, depending upon the amount of overlap, as expressed in

[5] For detailed discussions of the differential information to be gathered from longitudinal studies with respect to intraindividual and interindividual differences, see Baltes and Nesselroade (1979) or Schaie and Hertzog (1982).

TABLE 4.15. Standard Deviations of Longitudinal 7-Year Difference Scores, in *T*-Score Points

Age range	*n*	Verbal Meaning	Space	Reasoning	Number	Word Fluency	Intellectual Ability	Educational Aptitude
25–32	109	5.00	7.29	5.77	5.78	6.90	4.28	4.63
32–39	184	4.14	5.64	4.92	6.33	7.84	3.88	3.64
39–46	255	3.62	6.96	4.78	5.78	7.13	3.84	3.89
46–53	261	4.06	6.57	4.91	5.15	5.46	3.60	3.37
53–60	275	5.45	6.76	5.10	5.30	6.32	3.83	4.67
60–67	231	6.71	6.30	4.78	5.21	7.47	4.42	6.17
67–74	181	7.34	6.03	5.40	6.99	5.97	4.67	6.15
74–81	88	7.42	4.98	4.51	5.14	5.88	4.21	6.44

standard deviation units, between individuals in groups to be compared. In the case of repeated measurement studies such as the longitudinal investigation of age changes, the overlap in question refers to the proportion of individuals who would be identified as having shown reliable change from one occasion to the next. By Cohen's definition, a difference of .2 *SD* units reflects a small change (roughly 15% nonoverlap), a difference of .5 *SD* a moderate change (33% nonoverlap), and .8 *SD* a large change (47% nonoverlap).

Table 4.16, using these criteria, suggests small, positive changes for Verbal Meaning through age 46 and for Number to age 32. The earliest

TABLE 4.16. Average Individual 7-Year Change as Expressed in Standard Deviations of Individual Differences of IAC

Age range	*n*	Verbal Meaning	Space	Reasoning	Number	Word Fluency	Intellectual Ability	Educational Aptitude
25–32	109	+.32[a]	+.18	+.11	+.28[a]	+.10	+.45[b]	+.32[a]
32–39	184	+.33[a]	+.02	+.08	−.10	+.01	+.21[a]	+.22[a]
39–46	255	+.47[b]	+.07	+.01	+.03	+.08	+.24[a]	+.13
46–53	261	+.08	−.01	−.03	−.20[a]	−.15	−.08	+.03
53–60	275	−.05	−.04	−.03	−.07	−.13	+.01	−.11
60–67	231	−.30[a]	−.27[a]	−.40[a]	−.41[a]	−.25[a]	−.57[b]	−.31[a]
67–74	181	−.42[a]	−.38[a]	−.50[b]	−.38[a]	−.41[a]	−.66[b]	−.51[b]
74–81	88	−.47[b]	−.49[b]	−.46[b]	−.82[c]	−.58[b]	−1.00[c]	−.51[b]

[a] Small effect.
[b] Moderate effect.
[c] Large effect (see Cohen, 1977).

small decremental change occurs for Number by age 53, but it is not until age 67 that small or moderate changes are found for all abilities. Note that a large effect in terms of individual differences in IAC is detected for the index of Intellectual Ability by age 81; the only separate ability that shows such a sizable effect is Number.

Changes in Ability Structure with Age

What is labeled by some as "qualitative change with age" can, in the psychometric frame of reference, be most directly addressed by considering measurement models that can be fitted to the intercorrelations between abilities across age and cohort groups. Although a number of authors (e.g., Cohen, 1957) have addressed the question of factorial invariance of intelligence test batteries across different age groups, such work has been primarily cross-sectional in nature (but see Horn & McArdle, 1980). Until the seminal work by Joreskog and his associates (e.g., Joreskog, 1979; Joreskog & Sorbom, 1977) became available, there had also been conceptual and algorithmic obstacles to a careful analysis of this question. The powerful new methods developed by Joreskog and his associates were recently applied to part of our data base by Hertzog (1979), with his findings being substantially replicated by means of the LISREL IV and COFAMM algorithms.

Hertzog fitted both test-specific and occasion-specific models to our longitudinal sample tested in 1956, 1963, and 1970. He found reasonable fits for both approaches, using the entire sample. To study age-related changes in factor structure, he followed the occasion-specific model by merging the three-occasion data from the two panels first tested in 1956 and 1963. To obtain samples large enough for model fitting, he aggregated across sex and cohorts to obtain three subsamples: young adult (mean ages 30, 37, and 44), middle-aged (mean ages 42, 49, and 56), and old adult (mean ages 58, 65, and 72). Factor covariances remained high over the three occasions for all three samples, indicating consistency of individual differences across time. Group differences occurred primarily as a function of differences in factor variance, the youngest group having the least variance and the oldest the greatest. There were also differences in change in variability over time. Consistently with the between-group findings, within-group variance changes were in the direction of reduced variance from age 30 to 44, but increased variances were found from age 58 to 72. Hertzog's examination of the test-specific model showed greatest covariances in the older group, all above .5 when standardized, suggesting that the factor space had become more oblique as the sample aged. In addition, factor variability was greatest for Verbal Meaning, Reasoning, and Number, and least for Space.

The preceding analyses led me to conclude that the ability domain investigated in our studies does indeed retain its structural properties across the adult life span and that the conclusions based on our parametric findings cannot be questioned on the basis of possible changes in variable meaning over time. Nevertheless, the increase in factor variance with increasing age suggests that group norms for the older age levels may be less representative of individual change than is true at earlier ages.

Practical Significance of Age Changes and Cohort Differences

Scientists frequently become preoccupied with demonstrating the presence or absence of reliable differences and relationships. What is often ignored is the question of whether or not the obtained differences are substantial enough to warrant use of the data as the factual basis for implementing public policy decisions or in deciding practical matters. In this section, I provide an intuitive rationale on how to proceed in this matter, giving relevant estimates of age changes over 7-year intervals from 25 to 81 years and similar estimates of cohort differences for cohorts with average birth years from 1889 to 1952.

To be sure, one must first demonstrate that there are indeed statistically reliable differences within or between groups. Once this is done, however, we need some reasonable approach to determining effect size. One such approach, advocated by Cohen (1977), is to consider the amount of change or difference in standard deviation units, where .2 *SD* is considered a small effect, .5 *SD* moderate, and 1 *SD* large. The reader may wish to apply these criteria directly to the data presented in Tables 4.6, 4.7, 4.8, 4.10, and 4.11. It will be found that the differences reported there generally range from small to moderate.

Assessing the Practical Significance of Age Changes

The preceding approach is problematic because it assumes that a large difference on a variable having modest variability is equivalent to a much smaller change in a variable with large variability. In addition, the approach does not at all account for the fact that absolute performance at base age may be a psychologically more meaningful scaling base than taking one's departure from the overall population average. We think we have addressed these issues by the alternative approach of computing cumulative age changes as proportions of performance level at age 25. Obviously, our data permit similar computations using any other base ages within the range of our study. In the case of the repeated-measurement data, this approach leads to quite conservative estimates, actually favoring greater decrement than might be found in individuals monitored over their entire adult age span, because the favorably selected members of a panel will tend to have scores that regress toward the sample mean (cf. Baltes, Nesselroade, Schaie, & Labouvie, 1972).

Using this approach, it is possible to compute an index that represents average performance at an older age as a proportion of the base performance at a younger age, with 100 indicating the level at base. Table 4.17 provides a tabulation for this index for men, women, and all subjects combined, based on the 7-year data reported previously in the section on age changes in abilities. The reader may wish to apply these criteria directly to the data presented in Tables 4.6, 4.7, 4.8, 4.10, and 4.22. It will be found that the differences reported there generally range from small to moderate.

I have recently advocated that a reasonable approach to appraising the practical significance of cumulative age changes or cohort differences is to take recourse to the traditional psychometric assumption that one probable error (*PE*) about the mean defines the middle 50% (average) range of performance on mental abilities, assuming their normal distribution in the population (cf. Matarazzo, 1972, pp. 124–126). Given this premise, it follows that average cumulative decrement attains practical importance where such loss reduces the average performance of the older sample more than 1 *PE* below the mean of the younger comparison base, that is, a drop to the lower quartile of the base group. Table 4.17 indicates that a drop of such magnitude occurs for male panel members by age 74 for Number and by age 81 for Space, Reasoning, and the index of Intellectual Ability. For the female panel members, however, the criterion of a practically significant drop is reached for all parameters, except Space, by age 81.

As was previously indicated, our estimates may be inflated by favorable time-of-measurement effects, favorable cohort differences, and (for the panel members) favorable dropout effects. Table 4.18 therefore gives corrected values for all subjects across sex (to obtain more stable corrections from the resultant larger cell sizes). The corrections appear to affect primarily the variables of Reasoning, Number, and Word Fluency. As corrected, age decrement on Reasoning now attains practical significance by age 74, and decrement on Word Fluency as early as age 67. Number seems most heavily affected by these corrections. The adjusted scores suggest attainment of peak performance as late as age 60 and no drop of practical importance over the age range studied.

TABLE 4.17. Performance at Various Ages as a Proportion of Performance at Age 25

Age	Verbal Meaning	Space	Reasoning	Number	Word Fluency	Intellectual Ability	Educational Aptitude
				Males			
32	109	106	99	117	100	108	108
39	115	107	99	108	101	109	111
46	119	110	101	109	102	111	114
53	121	109	102	105	99	110	116
60	119	107	100	100	97	109	113
67	112	97	94	85	93	101	106
74	103	88	84	71[a]	85	93	97
81	93	72[a]	76[a]	49[a]	81	81[a]	87
−1 *PE* at age 25	81	77	83	72	83	85	83
				Females			
32	102	105	104	102	103	104	103
39	106	106	106	104	102	108	105
46	106	107	105	104	104	110	105
53	107	108	104	99	102	109	104
60	107	107	105	99	100	110	103
67	104	102	98	90	93	104	99
74	94	92	87	79	87	94	89[a]
81	84[a]	83	80[a]	61[a]	73[a]	83[a]	80[a]
−1 *PE* at age 25	89	71	83	76	85	87	89
				All subjects			
32	105	106	102	111	102	106	104
39	109	106	104	108	102	108	107
46	111	108	104	104	104	110	108
53	112	108	104	96	101	110	107
60	111	106	103	91	99	110	107
67	105	99	96	78	94	103	101
74	96	89	86	67[a]	87	94	92
81	85	79	78[a]	55[a]	77[a]	82[a]	82[a]
−1 *PE* at age 25	85	72	83	74	84	80	86

[a]Index is more than 1 *PE* below the mean of the 25-year-old base comparison group.

TABLE 4.18. Performance at Various Ages as a Proportion of Performance at Age 25, Corrected for Time Lag, Cohort Differences, and Dropout

Age	Verbal Meaning	Space	Reasoning	Number	Word Fluency	Intellectual Ability	Educational Aptitude
32	105	103	100	107	105	105	104
39	109	105	103	110	105	108	106
46	109	107	102	120	104	109	105
53	113	106	103	122	94	111	108
60	111	105	101	126	90	110	105
67	107	103	91	122	83[a]	104	100
74	97	90	81[a]	109	81[a]	92	91
81	87	79	73[a]	90	62[a]	80[a]	84[a]
−1 *PE* at age 25	85	72	82	73	84	86	86

[a]Index is more than 1 *PE* below the mean of the 25-year-old base comparison group.

Assessing the Practical Significance of Cohort Differences

The approach we have taken to estimating the practical significance of age changes can also be applied to the evaluation of the impact of cohort differences. We can take the estimates of cumulative cohort differences given in Table 4.6 and express them as proportions of the performance level of the youngest cohort (born in 1952). Cohort obsolescence indexes can then be computed for each cohort with average birth years from 1896 to 1945. Once again, it is assumed that the value of 1 *PE* below the mean (the lower quartile) of the younger cohort can serve as an indicator that the obsolescence of the earlier born (older) cohort assumes practical importance. Since cohort differences are strictly interindividual difference variables, these data are based on the cohort-differences estimated from the unattrited samples at first test (see Table 4.19).

On the basis of these data, it becomes obvious that obsolescence effects on intelligence-test performance are also quite ability-specific. Older cohorts even seem to have an advantage over the more recent ones on both Word Fluency and Numbers skills. On the other hand, substantial obsolescence effects are noted on Reasoning, with obvious implications for effectiveness in decision-making situations. More modest obsolescence effects are noted as well for Verbal Meaning and Space. For the composite indexes, this results in a balancing out for the global index of intelligence (further evidence as to the questionable value of such indexes in studies of aging), while the index of Educational Aptitude shows a substantial disadvantage for cohorts born around the turn of the century.

Factors Affecting Change in Intellectual Performance

Our attempt to provide an accurate description of age change in intellectual abilities over the adult life span is obviously only a first step in our understanding of that process. Throughout our endeavors, we attempted to collect collateral data that might help us to discover some explanatory principles. That is, we wanted to know whether there are predictable causal factors that will distinguish between individuals who show rapid or slow decline in advanced age or that at least will permit us to describe differential patterns of aging. In this section, I briefly describe the result of our investigation of health history factors, of environmental factors, and of the relationships of certain personality variables to performance on the PMA test.

Health and Change in Intelligence

Since our research participants all received their health care in a single system throughout the period of our studies, it was possible to gain access to fairly complete health histories. We soon discovered, however, that although physicians were very good at recording their diagnostic findings, very little work had been done on retrieving and quantifying health

TABLE 4.19. Performance of Various Cohorts as a Proportion of the Performance of the Cohort Born in 1952

Mean year of birth	Verbal Meaning	Space	Reasoning	Number	Word Fluency	Intellectual Ability	Educational Aptitude
1945	96	110	102	108	96	102	98
1938	92	112	100	113	89	101	94
1931	91	100	91	112	90	97	94
1924	94	103	90	122	98	102	93
1917	90	97	82	120	101	99	88
1910	88	95	80[a]	122	102	99	86
1903	85	84	73[a]	115	105	96	80[a]
1896	79[a]	79	67[a]	107	105	92	74[a]
1889	79[a]	81	68[a]	107	112	94	72[a]
−1 *PE* for 1952 cohort	85	75	81	70	83	85	85

[a]Index is more than 1 *PE* below the mean of the 1952 base cohort.

history contents in such a manner that they could be meaningfully related to behavioral data. For this purpose, what was needed was a method of characterizing health trauma by specific type of disease as well as by the likely impact of such disease upon the individual's future life experience (Schaie, 1973a). Although we did not solve this problem to our complete satisfaction, we approached a solution by charting each clinic or hospital contact of our participants by the appropriate code from the ICDA (USPHS, 1968). Individual incidents of disease were further linked into "disease episodes," which refers to the entire set of consecutive physician contacts for a particular health problem.

The problem of determining the impact of illness was addressed by charting the health records of 150 participants over a 14-year period. Although the ICDA lists 8000 possible classifications, only approximately 800 diagnoses were actually encountered. After overlapping categories were collapsed, it was possible to reduce the diagnostic terms to a total of 448 classifications. These were then *Q*-sorted by 12 physicians (6 internal medicine and 6 psychiatry residents) on an 11-point scale ranging from benign to extremely severe with respect to the impact of each disease entity upon the future health and well-being of a patient encountering such conditions (Parham, Gribbin, Hertzog, & Schaie, 1975). When cumulative incident and episode illness scores were correlated, to our initial surprise, only minor relationships were found. Low-level negative correlations occurred between cumulative health trauma (limited to the episode-weighted scores) and Verbal Meaning and Word Fluency.

Although some variance associated with verbal behavior decrement could be attributed to cumulative disease, it is perhaps not unreasonable to expect only low-level relationships when a gross, cumulative grab bag of diseases is considered jointly. A more fine-grained analysis requires attention to specific disease entities in relation to cognitive function. This line of inquiry was therefore pursued with respect to individuals with known cardiovascular disease (CVD). A number of interesting findings occurred upon detailed analysis of 155 panel members followed over a 14-year period. At first glance, it appears that CVD can be implicated in lowered function on all of the variables included in our study. Further analyses, however, reduce the plausibility of this conclusion. For example, controlling for cohort membership (CVD is simply more prevalent in the older cohorts!) wipes out the effect for Space and Word Fluency. And when socioeconomic status (SES) is taken into consideration, the effect of CVD upon decremental change in intellectual performance remains significant for Number and the composite index of Intellectual Ability (Hertzog, Schaie, & Gribbin, 1978). Although these data suggest that CVD does indeed contribute to intellectual decline, the amount of variance accounted for is relatively small, and moreover, effects may be indirect rather than causally specific. That is, CVD may lead to life-style changes that in turn more directly affect cognitive behavior.

Further studies of the effect of disease upon cognitive function conducted with our data base more recently have utilized the LISREL approach to testing the model fit for certain hypothesized relationships and as a by-product have estimated path coefficients indicative of the proportion of variance predicted (Stone, 1980). These analyses were conducted separately for the younger and the older half of our longitudinal samples. Disease categories investigated included circulatory disorders, digestive disorders, genitourinary disorders, infective and parasitic diseases, disease of the musculoskeletal system and connective tissues, neoplasms, diseases of the nervous system and sense organs, and diseases of the respiratory system. No relationships were found for the younger group. For the older group, circulatory disorders, neoplasms, and musculoskeletal disorders were found to be significant predictors of intellectual change over 7-year intervals. The causal direction was verified by an appropriate falsification study, in which change in intelligence was not found to predict significantly changes in health status on the disease categories cited. The proportions of variance accounted for were small, ranging from 1.6% for neoplasms to 4.4% for CVD. These values must be evaluated, however, in the context of the massive stability of intellectual ability. That is, about 85% of the variance is predicted by prior ability level, and consequently, a maximum total of 15% of the variance could be attributed to ability extraneous factors.

Environmental Factors and Changes in Intelligence

The effect of environmental factors upon the maintenance or decline of intelligence was investigated by considering a number of variables present in the day-to-day experience of adults that might be assumed to make a difference with respect to intellectual functioning. These variables were assessed by means of a specially constructed survey instrument, LCI (cf. Gribbin, Schaie, & Parham, 1980). Initial analyses of this questionnaire for 140 participants for whom 14-year intellectual ability data were available yielded eight item clusters representing (1) Subjective Dissatisfaction with Life Status, (2) Social Status, (3) Noisy Environment, (4) Family Dissolution, (5) Disengagement from interaction with the environment, (6) Semipassive Engagement with the environment, (7) Maintenance of Acculturation, and (8) Female Homemaker Characteristics.

Negative correlations were found between age and the cluster scores for Social Status, and positive correlations occurred between age and the Disengagement and Family Dissolution patterns. Considering the relationship of LCI cluster scores and intellectual ability, we found that all ability variables correlated positively with the Social Status and negatively with the Disengagement cluster. Further, Verbal Meaning, Word Fluency, and Educational Aptitude correlated positively with Maintenance of Acculturation; Word Fluency correlated positively with Noisy Environment; Space correlated negatively with Female Homemaker Characteristics; and Number and the index of Intellectual Ability correlated negatively with Family Dissolution. Correlations were also computed between 7-year changes in intellectual ability and LCI scores. The results of the latter analysis suggest that a personal environment characteristic of Disengagement and Family Dissolution is associated with cognitive decrement, while Dissatisfaction with Life Status appeared to be associated with maintenance or improvement of cognitive functions (Gribbin, Schaie, & Parham, 1980).

An alternative approach to the study of the relationship between personal environment and cognitive change consists of the investigation of differential change in ability over time for individuals with different life-styles. For this purpose, we examined cluster profiles for those persons who had been followed for the first 14 years of the study. Four major types emerged: Type 1 persons were mostly males of average social status and average level of acculturation, who lived with intact families in a relatively noise-free environment and who were quite engaged with life, but who voiced strong dissatisfaction with their life status. Type 2 persons had high social status, with which they were well satisfied; they had intact families, lived in noisy and accessible environments, and indicated above-average maintenance of acculturation. Type 3 persons were mostly women of average social status who were homemakers with intact family situations and average life-status satisfaction. These persons were low on maintenance of acculturation, but lived in accessible and noisy environments and reported activities reflecting passive engagement. Type 4 persons were almost all female, but, on average, older than the previous type. They had low social status, with which they were dissatisfied, and they were lowest on reported activities, whether active or passive. They lived in largely noise-free, but also inaccessible, environments and were highest on family dissolution. When a change in mental abilities is related to these life-style types, a pattern of relationship becomes evident. Table 4.20 lists average change scores for the PMAs over a 14-year period by life-style type. It is quite apparent that the first two engaged types generally show maintenance or gain, whereas the most disengaged type, the widowed homemakers, show clear evidence of decrement (cf. also Schaie & Gribbin, 1975b).

The LISREL approach has also been used to estimate effects accounted

TABLE 4.20. Cumulative Change in Mean Score on Cognitive Variables over a 14-Year Period, by Subject Type, in *T*-Score Points[a]

	Type 1	Type 2	Type 3	Type 4	All types
Verbal Meaning	+3.6	+1.4	−.2	−4.4	+.4
Space	+1.0	−1.1	+1.5	−.1	+.2
Reasoning	−.2	+1.1	−1.9	−3.1	−.7
Number	+1.0	+.8	−.9	−1.6	
Word Fluency	−3.5	−4.2	−6.2	−5.6	−4.8
Intellectual Ability	+.5	−.2	−1.9	−4.0	−1.1
Educational Aptitude	+2.8	+1.3	−.6	−4.3	+.1

[a]Positive values denote incremental change; negative values denote decremental change.

for in intellectual change by items surveyed in the LCI. Hertzog (1979) estimated the contribution of a latent SES variable (derived from the observed variables of years of education, family income, and occupational status) at initial testing to the initial level of intellectual ability. Regression coefficients under different model assumptions ranged from .50 to .60. Interestingly enough, SES predicted the initial level of ability, but not change in ability. With respect to the specific ability variables, SES was related to all but Space, with maximum correlation with Verbal Meaning. In a related study, Stone (1980) found significant path coefficients between initial ability levels and SES as well as an index of life-change events. However, falsification of the model showed these relationships to be reciprocal rather than causal.

In sum, it appears that there are substantial relationships among social status, life-styles, and the maintenance of intellectual ability. But these relationships seem to be interactive rather than causal. Thus early, favorable life experience may be implicated in attaining high levels of intellectual functioning in young adulthood; their maintenance into old age, however, may be related to an engaged life-style, but that life-style may also be a function of a high level of ability.

Personality Variables and Changes in Intelligence

Throughout our investigation, we collected data on our participants on measures of behavioral rigidity. In fact, our study began with the question whether there was an age-differentiated relationship between rigidity-flexibility and intelligence (Schaie, 1958a, 1958b). In this section, I describe the age-related patterns for the TBR (Schaie, 1960; Schaie & Parham,

1975) and discuss our findings on concurrent correlations between intelligence and rigidity-flexibility, as well as the data on the cross-lagged relationships based on longitudinal data.

Age Changes and Age Differences in Rigidity–Flexibility

Cross-sectional data for the rigidity-flexibility variables reported in Table 4.21 for each of the four studies show a nearly linear, negatively accelerating age-difference pattern. For these data, high values are scored in the flexible direction. Consequently, ages at which peak flexibility occurs appear to be 25 for both Motor–Cognitive and Personality–Perceptual Rigidity, and 32 for Psychomotor Speed. Sex differences on the whole point to men being more flexible than women, but to women at comparable ages demonstrating greater Psychomotor Speed than men. Time-of-measurement (period) trends are generally positive, except for a negative period effect for Psychomotor Speed from 1956 to 1963. As for the intellectual abilities, positive cohort trends are apparent.

Using the same method described earlier, we averaged across 7-year longitudinal data at all available ages to determine IACs. Table 4.22 provides the resultant cumulative age-change data from ages 25 to 88. Consistent with expectations, decremental changes appear in the 60s for Psychomotor Speed, becoming statistically significant by age 67. The rigidity-flexibility factor scores, however, differ dramatically from each other. Motor–Cognitive Rigidity does not increase to a statistically significant level until age 81, whereas Personality-Perceptual Rigidity shows an early trend in the rigid direction, with statistically significant cumulative change occurring by age 67.

For comparability with the intellectual ability data, we also computed rigidity-flexibility scores for a cohort born in 1952, estimated for mean ages from 25 to 88. Table 4.23 shows that the most flexible age (for our total sample) is 67 with respect to Motor–Cognitive Ridigity, but 32 for Personality–Perceptual Rigidity and 39 for Psychomotor Speed. Figure 4.7 graphically shows the virtually stable pattern for Motor–Cognitive Rigidity until the 70s, with obvious decline in the rigid direction occurring for Personality–Perceptual Rigidity from age 60, and for Psychomotor Speed from age 53. Attention should be called to some interesting sex differences. Although these data suggest that men are more flexible than women on the Motor–Cognitive dimension, women's peak flexibility occurs later. An even more complex pattern occurs for the Personality–Perceptual dimension. Here women start out less flexible than men, but peak later, and from the 60s on, they are more flexible than the men:

TABLE 4.21. *T*-Score Means for the Cross-Sectional Rigidity–Flexibility Data, by Age, Sex, and Study

	1956			1963			1970			1977		
Age	M	F	T	M	F	T	M	F	T	M	F	T
						Motor–Cognitive Rigidity						
25	54.8	57.4	56.1	59.1	57.1	58.0	56.2	57.1	56.7	59.9	58.0	58.9
32	54.4	54.0	54.2	56.9	56.1	56.4	55.2	56.0	55.6	58.6	57.8	58.1
39	50.9	48.1	49.5	55.0	54.2	54.6	53.9	51.6	52.5	57.2	56.9	57.1
46	49.2	52.4	50.7	51.8	52.1	52.0	53.4	52.7	53.1	55.8	53.2	54.4
53	49.9	46.9	48.4	59.5	49.9	49.7	52.9	49.4	51.0	53.9	51.6	52.8
60	41.1	45.8	43.5	46.7	47.1	46.9	52.8	48.4	50.5	52.6	48.9	50.7
67	42.6	41.3	42.0	43.9	44.0	44.0	43.2	42.2	42.7	46.2	46.9	46.6
74	—	—	—	44.8	40.9	42.8	41.3	41.8	41.5	44.1	47.6	45.8
81	—	—	—	—	—	—	43.9	38.0	41.0	43.0	41.9	42.4
						Personality–Perceptual Rigidity						
25	54.6	55.0	54.8	54.6	52.6	53.5	54.9	56.0	55.5	57.1	55.8	56.4
32	53.0	53.7	53.4	54.2	51.9	52.9	57.2	54.8	55.9	58.1	53.2	55.4
39	52.8	49.1	50.9	53.5	51.9	52.7	50.9	51.1	51.0	54.0	52.2	53.1
46	51.5	51.9	51.7	50.4	51.5	50.9	56.3	53.9	55.1	56.1	51.6	53.7
53	49.4	50.4	49.9	48.5	49.2	48.9	53.4	51.7	52.4	51.9	50.2	51.8
60	47.2	47.7	47.4	47.1	48.4	47.8	50.4	47.9	49.1	53.8	50.8	52.3
67	44.9	45.4	44.3	43.7	44.6	44.1	47.2	47.7	47.5	44.4	49.6	47.1
74	—	—	—	40.7	40.6	40.7	42.4	45.1	43.7	46.8	46.4	46.6
81	—	—	—	—	—	—	45.0	45.0	45.0	41.2	44.8	43.1
						Psychomotor Speed						
25	52.5	58.5	55.5	51.5	55.5	53.8	55.4	60.2	58.1	54.3	59.2	56.7
32	50.8	58.0	54.6	50.0	55.0	52.8	57.0	58.3	57.8	58.8	61.5	60.2
39	52.4	54.6	53.5	50.4	52.9	51.7	53.8	54.8	54.4	54.0	59.8	56.9
46	52.7	55.0	53.7	46.5	52.6	49.5	54.3	58.0	56.1	51.5	53.5	52.6
53	49.6	54.3	52.0	44.7	48.8	47.0	54.3	56.5	55.5	51.3	50.3	50.8
60	45.2	51.3	48.3	43.5	46.6	45.1	50.2	51.7	51.0	47.4	50.4	48.9
67	44.0	46.2	45.1	40.7	44.0	42.3	42.5	47.3	45.1	45.8	48.6	47.3
74	—	—	—	41.7	42.0	41.9	39.1	45.0	41.9	36.8	43.6	40.0
81	—	—	—	—	—	—	38.6	41.8	40.1	37.5	40.3	39.0

TABLE 4.22. Cumulative Age Changes from 7-Year Longitudinal Data for the Rigidity–Flexibility Variables, in *T*-Score Points[a]

From mean age	To mean age 32	39	46	53	60	67	74	81	88
Motor–Cognitive Rigidity									
25	1.26	1.65	1.77	1.08	2.23*	2.29*	1.51	−1.39	−3.34
32		.39	.51	−.18	.97	1.03	.25	−2.65	−4.60
39			.21	−.57	.58	.64	−.14	−3.04*	−4.99
46				−.69	.46	.52	−.26	−3.16*	−5.11
53					1.15	1.21	.43	−2.47	−4.42
60						.06	−.72	−3.62*	−5.57
67							−.78	−3.68*	−5.63
74								−2.90	−4.85
81									−1.95
Personality–Perceptual Rigidity									
25	.69	−.10	−.33	−1.20	−1.33	−2.57	−5.41*	−8.52*	−14.58*
32		−.79	−1.02	−1.89	−2.02	−3.26*	−6.10*	−9.21*	−15.27*
39			−.23	−1.10	−1.23	−2.47*	−5.31*	−8.42	−14.48*
46				−.87	−1.00	−2.24*	−5.08*	−8.19*	−14.25*
53					−.13	−1.37	−4.21*	−7.32*	−13.38*
60						−1.24	−4.08*	−7.19*	−13.25*
67							−2.84*	−5.95*	−12.01*
74								−3.11	−9.17*
81									−6.06
Psychomotor Speed									
25	.11	1.08	.91	.69	−.62	−2.75*	−6.13*	−9.49*	−14.84*
32		.97	.80	.58	−.73	−2.86*	−6.24*	−9.60*	−14.95*
39			−.17	−.39	−1.70	−3.83*	−7.21*	−10.57*	−15.92*
46				−.22	−1.53	−3.66*	−7.04*	−10.40*	−15.75*
53					−1.31	−3.44*	−6.82*	−10.18*	−15.53*
60						−2.13	−5.51*	−8.87*	−14.22*
67							−3.38*	−6.74*	−12.09*
74								−3.36*	−8.71*
81									−5.35

[a]Positive values indicate gains; negative values indicate decrements.
*$p < .01$.

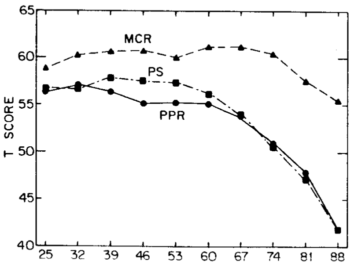


FIGURE 4.7. Longitudinal change on the rigidity–flexibility measures from 7-year data, estimated for a cohort born in 1952.

TABLE 4.23. Predicted Mean Values of Performance on the Rigidity–Flexibility Variables from 7-Year Longitudinal Data for a Cohort Born in 1952, in *T* Scores

	Motor–Cognitive			Personality–Perceptual			Psychomotor Speed		
Age	M	F	T	M	F	T	M	F	T
25	59.9	58.0	58.9	57.1	55.8	56.4	54.3[a]	59.2	56.7
32	61.9	58.8	60.2	58.4[a]	55.6	57.1[a]	53.9	59.5	56.8
39	62.5	59.1	60.6	58.2	55.1	56.4	55.3	60.3	57.8[a]
46	62.8	59.7	60.7	56.4	56.0[a]	55.1	53.9	61.1[a]	57.6
53	62.7	58.5	60.0	55.2	55.6	55.2	53.5	61.0	57.4
60	63.3[a]	60.1	61.2	55.5	55.0	55.1	52.1	59.8	56.1
67	62.6	60.7[a]	61.2[a]	53.6	54.3	53.9	49.9	57.7	54.0
74	62.1	58.6	60.4	50.5	51.5	51.0	46.0	54.8	50.6
81	61.3	55.1	57.5	46.6	50.0	47.9	43.2	51.0	47.2
88	55.9	55.6	55.5	38.6	45.7	41.9	38.5	45.1	41.9

[a]Age of most flexible performance.

Finally, on Psychomotor Speed, women perform better at all ages and peak considerably later than do the men.

Concurrent Relationship between Rigidity-Flexibility and the Intellectual Abilities

Our first question concerning the relationship between rigidity-flexibility and the intellectual abilities deals with the amount of variance shared by the two domains. Table 4.24 provides correlations for all ages investigated at first test. Note that there are moderate to substantial correlations between Psychomotor Speed and all ability measures except for Space. Motor-Cognitive Rigidity correlates moderately with all measures, with the most substantial relationships found with Verbal Meaning and Reasoning. Somewhat lower correlations, mostly during midlife, were found between Personality-Perceptual Rigidity and Verbal Meaning, Reasoning, and Word Fluency. Of considerable interest is the finding that, for all three correlates, values typically increased to about age 60 and then showed some decline. It might be inferred, therefore, that cognitive styles have their major impact upon ability performance in midlife.

Rigidity-Flexibility as a Predictor of Future Ability Level

From the longitudinal data on rigidity-flexibility and the intellectual abilities, it is possible to estimate cross-lagged correlations, which permits a cautious test of time-dependent causal relationships between the two domains. A study by Witt and Cunningham (1979) implied that intellectual performance on crystallized-type measures at a later point could be predicted from intellectual speed at an earlier point. Obviously, our Psychomotor Speed measure lends itself to an independent test of their conclusions. Data from our four-occasion sample ($n = 120$) were employed for this analysis, with subjects' average age being 43 years on the first occasion and 64 years on the final occasion. All four occasions were utilized in an analysis using Humphreys and Parsons's (1979) approach, while only the first and last occasions were considered when computing cross-lags corrected for changes in reliability according to Kenny's (1975) method. Analyses were conducted for the relationship between all three rigidity-flexibility factor scores and the ability measures.

Table 4.25 shows the corrected cross-lagged correlations coefficients (according to Kenny's procedures) that appeared to be most readily interpretable. The results shed some doubt upon Witt and Cunningham's (1979) findings. Psychomotor Speed predicted significantly later performance on Number, probably our most highly speeded test. On the other hand, Verbal Meaning and Reasoning predicted significantly later performance on the Psychomotor Speed measure. Reasoning also predicted significantly later performance on the measure of Motor-Cognitive Rigidity. But Motor-Cognitive Rigidity predicted later performance on Word Fluency. To our surprise, Personality-Perceptual Rigidity predicted

TABLE 4.24. Concurrent Correlations between the Rigidity-Flexibility and Intellectual Ability Measures at First Test

Age	n	Verbal Meaning	Space	Reasoning	Number	Word Fluency
			Motor-Cognitive Rigidity			
25	302	.22	.36	.30	.21	.18
32	319	.32	.30	.32	.24	.10
39	378	.38	.27	.43	.21	.21
46	376	.53	.32	.48	.27	.34
53	379	.45	.33	.50	.37	.28
60	346	.48	.30	.48	.39	.37
67	366	.47	.32	.48	.34	.35
74	234	.39	.19	.41	.34	.29
81	104	.39	.31	.33	.34	.12
			Personality-Perceptual Rigidity			
25	302	.21	.03	.09	−.02	.20
32	319	.20	.18	.24	−.01	.11
39	378	.12	.10	.10	−.01	.07
46	376	.30	.03	.21	.02	.14
53	379	.28	.18	.24	.17	.27
60	346	.29	.14	.30	.13	.25
67	367	.23	.10	.22	.15	.14
74	235	.22	.12	.24	.13	.12
81	107	.03	.07	−.01	.00	−.01
			Psychomotor Speed			
25	302	.60	.16	.57	.46	.49
32	319	.55	.19	.48	.30	.43
39	378	.54	.09	.53	.34	.45
46	376	.64	.27	.57	.39	.49
53	379	.64	.21	.60	.48	.61
60	346	.65	.25	.57	.54	.52
67	367	.62	.23	.57	.48	.54
74	234	.54	.18	.40	.45	.49
81	105	.53	.15	.33	.35	.56

TABLE 4.25. Cross-Lagged Correlation Coefficients between the Rigidity–Flexibility Measures and the Intellectual Ability Variables after Correction for Changes in Reliability

	Motor–Cognitive Rigidity	Personality–Perceptual Rigidity	Psychomotor Speed
	1956	1956	1956
Verbal Meaning, 1977	.31	.56**	.58
Space, 1977	.34	.27*	.20
Reasoning, 1977	.34	.55**	.46
Number, 1977	.25	.33*	.59*
Word Fluency, 1977	.36*	.40*	.46
	1977	1977	1977
Verbal Meaning, 1956	.37	.20	.68*
Space, 1956	.27	.06	.32
Reasoning, 1956	.50*	.27	.61**
Number, 1956	.24	.12	.41
Word Fluency, 1956	.12	.23	.42

Note. Cross-lags followed by asterisks are significantly greater than their falsification (Pearson–Filon test); $^{*}p > .05$, $^{**}p > .01$.

significantly later performance on all ability measures, with the proportion of variance accounted for ranging from about 7% for Space to 31% for Verbal Meaning. Keeping in mind all the cautions about the limitations of cross-lagged correlations (cf. Rogosa, 1979), it might still be concluded that the progression of intellectual ability from middle to old age is not so much related to earlier speed of performance as it is to behavioral flexibility. That is, it appears that persons who at midlife show flexible personality styles are more likely to perform at high ability levels in early old age.

Summary and Conclusions

The reader has by now accompanied me through most of the highlights of the 21-year scientific journey that was required to gain a clear understanding of the progress of adult development of the psychometric abilities. What remains is for me to state succinctly what I think can be concluded from these studies in response to the four major questions raised in the introduction.

Does Intelligence Change Uniformly or in Different Ability Patterns?

The answer to this first question is quite unambiguous: There clearly is no uniform pattern across the abilities, and although some overall index of intellectual aptitude may be of theoretical interest, such a global measure is not likely to be of practical utility in monitoring changes in function across the adult life span for individuals or groups. Although our data do lend some support to the notion that fluid, or active (Cunningham, 1980), intellectual abilities decline earlier than the crystalized, or passive, abilities, there are important ability-by-sex and ability-by-cohort interactions that complicate matters. For example, in the most recent study, it appears that women decline first on the active abilities, but men do so on the passive abilities. It may well be, then, that patterns of socialization unique to a given sex role within a historical period may be the major determinant of the pattern of change in abilities across the adult life span.

At What Age Is There a Reliably Detectable Age Decrement in Ability and What Is Its Magnitude?

At the risk of possible overgeneralization, it is my general conclusion that reliably replicable age changes in psychometric abilities of more than trivial magnitude cannot be demonstrated prior to age 60, but that reliable decrement can be shown to have occurred for all abilities by age 74. This statement must be further qualified by noting that, when IACs are examined, a few individuals show reliable change over a 7-year period prior to age 60, but that even at age 81, less than half of all observed individuals have shown such reliable change in the preceding 7 years. If we consider the magnitudes of change, we may note that, prior to age 60, no decrement in excess of .2 *SD* can be observed, whereas by age 81 the magnitude of decrement is approximately one population standard deviation for most variables. In other words, it is typically the period of the late 60s and the 70s during which many individuals seem to experience significant ability decrement. Even so, it is typically only by age 81 that one can show that the average older person will fall below the middle range of performance for young adults.

What Are the Patterns of Generational Differences and What Is Their Magnitude?

Our studies clearly demonstrate that there are substantial generational trends in psychometric intelligence. Because the effects of cohort trends differ across abilities, these effects are least noticeable for composite ability indexes. Even here, though, persons born prior to World War I appear to be at a disadvantage when compared to those born at a later time. For the abilities of Space and Reasoning, the disadvantage for the older cohorts extends to those born as late as 1931. That is, cohort differences affect persons now in their 50s or older. For Verbal Meaning, cohorts born in 1917 or earlier are at a disadvantage compared to those born later. On the other hand, Number skills reach the highest level for cohorts with mean birth years from 1910 to 1924, with more recently born cohorts at some disadvantage at comparable ages to their elders. And for Word Fluency, there is actually a negative cohort gradient; that is, more recent cohorts are at a disadvantage compared to those born earlier, except for a reversal in the positive direction for those born after World War II. Equally important was the finding that these generational differences equal or exceed in magnitude age changes across comparable time intervals. Notice in particular that apparent age differences on the active (fluid) abilities prior to the 60s are largely a function of generational differences and that age differences on the passive (crystallized) abilities in advanced age appear smaller than would be warranted by actual within-individual age changes because of the generational trends favoring, to some extent, the earlier-born cohorts.

What Accounts for Individual Differences in Intraindividual Change across Adulthood?

As has been stressed throughout this chapter, there are vast individual differences in intellectual change across adulthood, ranging from early decrement for some persons to maintenance of function into very advanced age for others. Our studies have begun to shed some light on what factors might be implicated in such individual differences. First, it appears that CVD and arthritis lead to an earlier lowering of performance, the former probably through its disruption of optimal synchrony between cortical and autonomous nervous system functions, and the latter through its impact upon motor behavior involved in test performance. Second, it is clear that a favorable environment as characterized by an advantaged SES is related not only to high levels of intellectual functioning, but also to the maintenance of such functioning into late life. The mechanism involved here is likely to be the maintenance of varied opportunities for environmental stimulation. I find myself concluding that the use-it-or-lose-it principle applies not only to the maintenance of muscular flexibility, but to the maintenance of flexible life-styles and a related high level of

intellectual performance as well. Third, it appears that a flexible personality style in midlife tends to predict a high level of performance in old age. Some of these variables are clearly subject to genetic control, but others may be subject to environmental and educational intervention. I believe that such intervention holds inordinate promise (cf. Schaie & Willis, 1978; Willis & Schaie, 1981).

Some Final Comments

This presentation of an extensive and detailed inquiry into the course of psychometric abilities over the adult life span must be ended with certain cautions. First, the reader must be reminded that all our work has been descriptive or in the nature of quasi-experiments. Whatever causal inferences were made must therefore be taken as based upon what has been observed to have happened in the past; it may not necessarily be predictive for future generations. Second, we have described intellectual change across adulthood measured by means of devices that were originally developed for adolescents and young adults. It has been shown that such measures, though not inappropriate, may place older study participants at a disadvantage for reasons unrelated to their actual competence with respect to the dependent variables of interest (cf. Schaie, 1978; Schaie, Gonda, & Quayhagen, 1980). Third, the abilities here discussed are synthesized abstractions of behavioral competence; their expressions in socially significant contexts will differ, depending upon the situation in which they are exercised (Scheidt & Schaie, 1978). Nevertheless, I believe that this body of evidence at the present state of the art, provides a reasonable base for making policy recommendations on such diverse issues as determining the age ranges for which adult education may be most profitable or specifying the ages at which workers in industries requiring certain abilities may start to be at a disadvantage. I am fully cognizant that the projections made will be time limited and that new evidence will have to be collected continuously to account for the impact on behavior of our rapidly changing technological environment. I hope that new studies will profit from the insights gained by the successes as well as the failures of the efforts described here.

Acknowledgments

Research reported in this chapter was most recently supported by Research Grant #AG-480 from the National Institute on Aging. Earlier phases of the study were supported by grants from the National Institute of Child Health and Human Development (HD-367 and

HD-4476). The enthusiastic cooperation of the staff and members of the Group Health Cooperative of Puget Sound is gratefully acknowledged.

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