The Short-term Longitudinal Study of Age Changes in Cognitive Behavior[1]

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Introduction

The developmental literature is replete with apologetic statements by investigators for their use of cross-sectional designs usually followed by the exhortation that longitudinal studies would be more desirable but indicating that the practical demands of the particular situation prohibited the latter experimental design. The arguments for the inherent advantages of the longitudinal method have always bothered me and seemed to rest on rather weak grounds. Nevertheless, it has taken me nearly a decade to develop a successively sharpened and, I hope, increasingly cogent series of arguments and data to show why neither the conventional cross-sectional nor the longitudinal method can hope to produce empirical findings which can be interpreted without ambiguity (Schaie, 1959b; 1965; 1967; Schaie & Strother, 1967).

In brief, the reason for rejecting the conventional approaches, is the fact that the cross-sectional method compares scores for samples of Ss at different ages who belong to different generations (cohorts) but who are

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being measured at the same given point in time. Consequently, the inferred sub-group differences might be due to the fact that these groups do indeed differ in maturational levels (age differences), or such differences could be attributable to differential representation of genetic or experiential factors in the various sub-samples (cohort differences). Even worse is the likely possibility that differences may be due to both age and cohort components or that lack of differences may be attributable to compensatory effects if age and cohort gradients move in opposite directions.

Data obtained via longitudinal methods are equally suspect, since here one compares scores for a sample of Ss belonging to the same cohort but where measures are of necessity taken at many different stages of environmental impact. Differences between scores can therefore be a function of maturational changes or due to the effect of environmental experience upon the sample (time differences). And, of course, maturational and environmental treatment effects can be confounded, or if moving in opposite directions, can lead to a report of no age changes. In the traditional repeated measurement design, moreover, differences can be attributable also to the effect of the initial measurement upon the subsequent performance of the sample.

In the series of papers referred to above I have detailed three new research designs, each of which requires the short-term longitudinal study of a cross-sectional and longitudinal approaches. The first of these designs, labeled the cohort-sequential method, requires the measurement of a minimum two cohorts (or generations) at a minimum of two chronological ages. If it can be assumed that there have been no environmental treatment effects, it is then possible to separate with confidence the components of variance due to maturation from those attributable to differences in prior experience or genetic composition.

A second design, called the time-sequential method, requires assessment of samples at a minimum of two ages and two times of measurement. In this design, if it can be assumed that there are no significant differences in prior experience or genetic composition, it is then possible to differentiate between the effects of maturation and of environmental treatment. Lastly, there is a third design, the cross-sequential method, which requires measuring samples from two cohorts at two times of measurement, and which permits separating the effects of treatment from prior experience or genetic composition, provided it is safe to assume that maturational change is insignificant. It might further be noted that the above assumptions can readily be checked by collecting data so as to permit analysis via two of the three designs, and that moreover there is no particular virtue in obtaining repeated measurements on the same samples in preference over taking repeated independent random samples from a defined population.

I have used these new designs to re-examine a set of old data to show that the conventional designs lead to rather peculiar and misleading inferences (Schaie & Strother, 1967) and Riegel (1967) has recently applied one of the models to advantage in analyzing some of his data. This paper, however, will attempt to summarize the application of the time-sequential and cross-sequential models to a short-term longitudinal study of age changes in cognitive behavior over the age range from 21 to 70 years of age. More detailed presentations of specific facets of this study may be found in a series of research papers (Schaie, 1958; Schaie & Strother, 1964a; 1964b; 1964c).

Objectives of the Study

The major objectives of our study related to two distinct issues. The first of these is concerned with an attempt to estimate within-generation long term age gradients on the basis of short-term sequential studies. This is basically the question of determining the stability of age difference patterns over subsequent periods of time and involves solution of the paradox that the experimenter can rarely survive his experiment if he tries to cover extensive portions of the human life-span. The above objective had been a goal also for Bell (1953). Bell, however, stopped short of dealing with the basic problems of confounded dimensions and consequently did not succeed in providing solutions suitable for life-span research.

A second objective of these studies was to deal with the concern about the effects of time-lag long ago expressed by Kuhlen (1940) and made most succinct in one of his last papers (1963). Our designs permit attention to these problems by examining the effects of cultural change upon psychological test performance and by raising the question whether age differences in cross-sectional studies are attributable to time-lag or are due to true age-related variation.

Design of the Study

The basic design for full-scale short-term longitudinal inquiry to be carried over a wide age range and which was applied to our inquiries consists of the following elements:

1. Draw a random sample from each cohort over the age range to be investigated and measure at time _k_ (Score A).
2. Get a second measurement on all available subjects originally measured at Time _k_ at another Time _l_ (Score B).
3. Draw a new random sample from each cohort over the age range tested at Time _k_ plus one cohort below that range and test at Time _l_ (Score C).

This design permits application of the cross-sequential and time-sequential independent random sampling models (using scores A and C) and the cross-sequential repeated measurement model (using scores A and B).

Data for the first measurement point were obtained in 1956 and for the second measurement point in 1963. All Ss were drawn from a population base constituted by the 18,069 individuals who were over 16 years of age and members of the Group Health Cooperative of Puget Sound, a prepaid medical plan, with a membership broadly representative of the upper three-fourth of the socio-economic structure of the State of Washington.

The population pool was stratified into five year age intervals by sex and potential volunteers were obtained by random draws from each stratum. Quota sampling continued until 25 men and 25 women had been obtained in each five year interval from 21-70. Of the 500 Ss tested in 1956, 302 Ss were successfully re-examined in 1963. In addition new random draws from the original strata resulted in further samples of 25 men and 25 women for each five year interval from 21 to 75. Demographic characteristics of the 1956 and 1963 random draws showed close agreement, except for income differences due to inflationary trends and increase in standard in living for all population groups, and with respect to residential and job mobility, since the attrition of the population pool over a seven year period must be expected to be related to mobility characteristics. Tables 1 to 3 give the analysis of variance models required for the analysis of the resulting data.

The cross-sequential and time-sequential designs differ mainly in that in the former one pairs samples drawn from the same cohort but tested at different point in time while in the latter one pairs samples of identical age tested at different points in time. Thus for each pair of samples, the cross-sequential design equates generational differences but allows age differences equivalent to the magnitude of the interval between times of measurement, while the time-sequential design equates age differences but allows cohort differences of a magnitude prescribed by the measurement interval.

The instruments used in this study included the five sub-tests of the SRA Primary Mental Abilities Test (Thurstone & Thurstone, 1949), the Test of Behavioral Rigidity (Schaie, 1955; 1960) and a scale of social responsibility (Gough et. al., 1952; Schaie, 1959a). Variables measured by these tests include Verbal Meaning, Space, Reasoning, Number, Word Fluence, and index of intellectual ability, index of educational aptitude, motor-cognitive rididity, personality-perceptual rigidity, psychomotor speed, and social responsibility. Seven year test-retest reliability of these measures for our population ranged from a low of .64 for motor-cognitive rigidity to a high of .94 for the composite index of intellectual ability.

Construction of Age Gradients

The cross-sequential design permits the estimation of cross-sectional and longitudinal age differences at each age interval included in the age range sampled. Based upon the actual mean scores available for each age level it is therefore possible to construct comparable cross-sectional and longitudinal age gradients. It has been pointed out previously that traditional cross-sectional and longitudinal gradients are not directly comparable because the former plots the state of many different cohorts as the same point in time while the latter present data on a single cohort at many points in time. The cross-sequential approach overcomes this problem by providing data which permit construction of comparable gradients.

This is achieved by averaging cross-sectional estimates over the same period which provides the estimates for the segments of the longitudinal gradients.

In our case the cross-sectional estimates are yielded by averaging data from our 1956 and 1963 samples (independent or repeated measurement) and by constructing the longitudinal comparison gradients from segments provided by examining changes over the intervening time period. It will be noted that each segment comes from a different cohort but covers the same intervening period of time. By means of a comparison of these two gradients it is then possible to differentiate between those effects of developmental change which are attributable to maturation from those attributable to differences between generations, since the effects of environmental experience are held constant for both gradients.[2]

Result and Implications

When developmental data are studied by means of designs which permit unconfounding maturational changes from differences between generations or environmental treatment effects, it becomes clear that most descriptive data on age changes now in the literature must be viewed with great caution. Indeed, in most instances, now data collections with more efficient designs will be in order. In Table 4 I have summarized conclusions as to the nature of the adult developmental gradient for the Primary Mental Abilities derived from the past literature (in part based on my own studies) on the basis of conventional cross-sectional and longitudinal data. I have contrasted these

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[2]The results from the repeated measurement data will tend to show less decrement since practice effects are permitted to operate and since attrition may be inversely related to level of ability.

conclusions with those gained from use of the short-term longitudinal studies using my sequential designs and in Table 5 have further contrasted data on age of peak function derived from conventional cross-sectional and the short-term longitudinal approaches.

It is clear that time of measurement and cohort differences are highly effective in confounding the meaning and inferences to be attached to data from conventional cross-sectional and longitudinal studies. My own data suggest that in cross-sectional data the maturational component of age differences is systematically over-estimated for unspeeded measures of cognitive behavior. On the other hand, maturational changes for highly speeded measures or those which involve the expression of attitudes appear to be systematically under-estimated. It appears from our data that there must be substantial changes over generations which involve increased ability for successive cohorts on intellectual tasks but decreased response speed and fluency as well as modification of attitudes in a socially undesirable direction.

Conventional longitudinal methods, contrariwise, tend to underestimate maturational decrement on unspeeded tasks and overestimates such decrement for speeded tasks and measures of socially desirable attitudes. These effects seem to be due to the observation (and I again refer to Kuhlen's [1963] penetrating comments) that there is a positive time-lag for the development of intellectual abilities and a negative time-lag for response speed, fluency and socially desirable attitudes.

The above observations have important implications for the development of social policies regarding retirement and man-power utilization. They suggest that conventional longitudinal studies are useless as a basis for policy development because they adduce information on the behavior over its lifespan of an organism which belongs to a generation with different characteristics and which has lived under different environmental impacts then would be true for any future generations or time spans. The conventional cross-sectional approach will be useful only for developing policies appropriate to the immediate state of affairs but will not be helpful in predicting future developments since they of necessity ignore within-generation changes. Only short-term longitudinal studies using appropriate sequential designs can provide predictive data based on most recent and relevant information.

The power of the sequential design for short-term longitudinal studies using independent random sampling approaches is further illustrated by the fact that the amount of time required to conduct a study covering information over the entire life-span of the organism is only restricted by the available funds and manpower to collect data on sufficient samples to cover all segments equivalent to the minimal time interval required to detect any behavioral change.

While I do not wish to retreat one iota from the above basic conclusions about experimental strategies for the study of developmental phenomena, I do wish to call attention to the fact that in our study thus far time-lag has been investigated only over a single time period and that replication is therefore in order. Another round of testing is in fact being contemplated for 1970, employing both the independent random sampling and repeated measurement approaches. In view of the reasonably close agreement on the shape of age gradients obtained from both methods, however, I would like to suggest that the effort usually spent in longitudinal studies on maintaining a sample over long periods of time could better be invested in a careful definition of the population base and the inclusion of larger sub-samples. Consequently, independent random sampling designs such as ours are highly recommended for future longitudinal investigations.

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Table 1

Analysis of Variance Design for the Cross-Sequential Analysis of Repeated Measurement Data for a Cross-sectional Sample Examined in Two Points in Time (N = 302)

Source of Variation	Degrees of Freedom	
Between Subjects		301
Between Cohorts	9	
Between Sexes	1	
Cohort x Sex	9	
Residual Between	282	
Within Subjects		300
Between Measurement Times	1	
Time x Cohort	9	
Time x Sex	1	
Time x Cohort x Sex	9	
Residual Within	280	
Total Variation		601

Table 2

Analysis of Variance Design for the Cross-sequential Analysis of Independent Random Sampling Data for Comparisons at Two Points in Time (N = 1000)

Source of Variation	Degrees of Freedom
Between Cohorts	9
Between Sexes	1
Between Times of Measurement	1
Cohort x Sex	9
Cohort x Time	9
Sex x Time	1
Cohort x Sex x Time	9
Residual	960
Total Variation	999

Table 3

Analysis of Variance Design for the Time-sequential Analysis of Independent Random Sampling Data for Comparisons at Two Points in Time (N = 1000)

Source of Variation	Degrees of Freedom
Between Ages	9
Between Sexes	1
Between Times of Measurement	1
Age x Sex	9
Age x Time	9
Sex x Time	1
Age x Sex x Time	9
Residual	960
Total Variation	999

Table 4

Comparison of Inferences Drawn from Cross-sectional, Longitudinal and Short-term Longitudinal Studies[1]

Variable	Cross-sectional	Longitudinal	Short-term longitudinal
Verbal Meaning	Sharp decrement from middle adulthood to old age	Modest gain throughout life from young adult plateau	Modest decrement from young adult plateau; increment in successive cohorts reaching asymptote
Space	Sharp decrement from young adult peak to old age	Modest decrement from adult plateau	Almost no decrement until advanced age; steep positive cohort gradient is reaching asymptote
Reasoning	Sharp decrement from young adult peak to old age	Modest gain from young adult gain till old age	Modest decrement from middle adulthood to old age; positively accelerating cohort gradient
Number	Modest gain and loss before and subsequent to midlife plateau	Modest gain from early adulthood to plateau at advanced age	Very modest decrement from plateau in middle adulthood; positively accrelerated cohort gradient
Word Fluency	Moderate decrement from plateau extending over major portion of adulthood	Moderate gains from young adult levels	Sharp decrements from young adult levels; steep decrements for successive cohorts

[1]Inferences from cross-sectional data are based on data by Kamin (1957), Jones (1959), and Schaie (1958). No long term longitudinal studies on the PMA variables were found, but inferences are based on an examination of analogous data available from studies by Bayley (1967), Bayley & Oden (1953), and Owens (1953).

Table 5

Adult Peak Performance Plateau as Estimated from Cross-sectional and Short-term Longitudinal Studies[1]

Variable	Cross-sectional[2]	Short-term Longitudinal Repeated Measurement	Short-term Longitudinal Independent Random Sampling[3]
Verbal Meaning	26 - 35	41 - 65	21 - 45
Space	21 - 35	21 - 65	21 - 65
Reasoning	21 - 35	26 - 55	21 - 50
Number	31 - 55	36 - 65	41 - 55
Word Fluency	41 - 50	21 - 30	21 - 35
Composite Intellectual Ability	26 - 35	21 - 45	26 - 45
Educational Aptitude	26 - 35	36 - 60	21 - 45
Motor-cognitive Rigidity	21 - 25	51 - 70	56 - 70
Personality-Perceptual Rigidity	21 - 50	21 - 55	21 - 40
Psychomotor Speed	21 - 40	21 - 35	21 - 25
Social Responsibility	46 - 55	41 - 60	26 - 55

[1]The peak plateau is determined by including all ages means for which do not differ significantly from the peak age at or beyond the 5% level of confidence.

[2]From Schaie (1958).

[3]From Schaie & Strother (1964a).

[4]From Schaie & Strother (1964b).