Individual Differences in Rate of Cognitive Change in Adulthood

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Abstract

This paper reviews some findings on longitudinal age changes in cognitive behavior within adults studied over a period of 28 years. Differential rates of cognitive change for several mental abilities are examined from young adulthood to late middle age, early middle age to young-old age, and late middle age to old-old age. Individual differences in rate of change are found to differ markedly over all three age ranges. Cluster analyses are presented for the abilities of Verbal Meaning, Spatial Orientation and Inductive Reasoning that identifiy different patterns of change. These findings provide added support to an individual differences approach to human aging.

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Introduction

Extensive research on psychometric intelligence over the adult life course has made us familiar with the finding that most abilities tend to peak in early midlife, plateau until the late fifties or early sixties, and then show decline, initially at slow pace, but accelerating as the late seventies are reached. Some controversy remains on the specific ages at which certain abilities peak and on the ages at which significant decline can first be detected (cf. Botwinick, 1977; Willis, 1985). Data from cross-sectional studies typically result in more pessimistic findings for variables for which positive cohort trends have been observed, and unduly optimistic findings for those variables where cohort trends have been negative. Most age-comparative work is flawed also because of the fact that it is difficult or impossible to match samples differing widely in age with respect to other variables that might critically effect the dependent variable of interest. Longitudinal studies control for cohort effects and of course provide within subject comparisons. Nevertheless they may provide under or over-estimates of mean age changes, depending upon whether they are favorably or unfavorably attrited (Schaie, 1983a; Schaie & Hertzog, 1982).

While the above-mentioned research literature has been useful in informing us on group trends, such trends do not necessarily represent the patterns of cognitive change for all or most individuals. Much of the discussion at today's convocation has centered about models of biological, social and psychological aging that would help us understand the aging process in broad strokes. While I would fully subscribe to the usefulness of such models, I now wish to add the caution, that the vast individual differences observed in all such processes require us also to consider the many variations in which individual aging may be expressed (cf. Birren & Renner, 1977; Birren & Cunningham, 1985). Although a cumulation of deleterious age changes is inevitable for all of us as we age, there are many factors, whether genetically or environmentally programmed, that influence the rate at which age changes occur. To do so I believe it is necessary to engage in a process of successive disaggregation that will lead us to understand how individual aging may differ from the groups norms that we often must rely on for purposes of policy formation. The specific purpose of this presentation, therefore, is to take a step forward in advancing the study of cognitive development in adulthood beyond the analysis of average group profiles that describe differences in behavior between or within groups of individuals differing in age. For this purpose, I shall present some detailed analyses on those participants in the Seattle Longitudinal Study (SLS) for whom data are now available for five measurement points over a period of 28 years. These longitudinal data allow not only comparison of levels of performance within individuals, but permit fitting slope parameters that will inform us on rates of change for individuals and groups having common characteristics. Because of time limitations I will confine my discussion to three major cognitive abilities: Verbal Meaning, Spatial Orientation and Inductive Reasoning. These particular variables were chosen because they are essential skills in communicating with other, in moving about the environment, and in virtually all problem solving involved in daily living (Willis & Schaie, 1986).

I will begin by presenting traditional data on group means to show that reliable average age changes indeed do occur in this data set. Next these data will be disaggregated into three sub-sets to show that average age changes over the past 28 years differ when considering those who are now middle-aged, young-old or old-old. I will then examine average rates of change obtained by fitting the linear slopes for each of our study participants. Next I will examine types of change patterns obtained by clustering study members, and finally I will present some individual profiles to call attention to the fact that there are wide individual differences both in slope and direction of age changes in cognitive behavior.

Characteristics of the the Data Base

The Subject Population

Some 30 years ago I began my inquiry into adult cognitive functioning by drawing a sample of 500 subjects evenly distributed by sex and age across the range from 20 to 70 years, by means of randomly sampling from the approximately 18,000 members of a health maintenance organization in the Pacific Northwest. The sample represented a broad distribution of educational and occupational levels, probably well representing the upper 75 per cent of the socio-economic spectrum. Of the original sample, 88 persons participated at all assessment points. The residual sample consists of 40 men and 48 women with an average age of 68.8 years (SD = 10.3; Range 50 to 95). All participants were community dwelling and were not suffering from any acute disease as reported by their health plan physician.

The Measurement Variables

The variables to be discussed here involve the first three Primary Mental Abilities identified by the Thurstones (1941). They were assessed with the SRA Primary Mental Abilities test (Thurstone & Thurstone, 1949; Schaie, 1985). Verbal Meaning (V) involves the ability to recognize and comprehend words; it is a measure of a person's recognition or passive vocabulary. This ability is assessed by providing individuals with a stimulus word and asking them to match it from a multiple choice list. Verbal

Meaning is thought to be a crystallized ability that is acquired and maintained by exposure to culture-determined experiences. Spatial Orientation (S) is the ability to rotate objects mentally in two-dimensional space. This ability is involved, for example, in visualizing the direction one might enter a highway after having inspected a map, or in assembling a piece of furniture by following a set of instructions. Spatial Orientation is measured by providing the subject with an abstract stimulus figure and then asking the subject to select rotated examples of that figure that would match the stimulus upon mental rotation. Inductive Reasoning is the ability do identify regularities and to infer principles or rules. It is a critical component of most problem solving tasks. This ability is measured by asking subjects to complete a letter series task. Both Spatial Orientation and Inductive Reasoning are thought to be fluid abilities that are involved in the mastering of novel experiences.All of the measures are slightly speeded paper and pencil tasks.

The Assessment Procedure

The measures just described were administered to small groups of subjects as part of a broader test battery that originally required approximately two hours in a single session, but has since grown to a 5-hour battery spread over two sessions. The Primary Mental Ability measures, however, have always been given in the same position during the first part of the testing session.

50, 64 and 71, and three cohorts compared at age 57. Figures 2, 3 and 4 present these data by ability.

Insert Figures 2, 3 & 4 about here

The data for Verbal Meaning (Figure 2) reflect interesting age by cohort interactions. There is a substantial difference in favor of the middle cohort over the oldest cohort at all comparable ages. The peak age of performance (age 57) is the same for both cohorts, but the slope over these ages is slightly steeper for the middle cohort. Interestingly enough, the peak age for the youngest cohort actually occurs at age 43. For that cohort there is statistically significant cumulative increment to age 43 and a cumulatively significant decrement from that point to age 57. The young-old cohort, by contrast, does not show significant decline until age 64. And for the oldest cohort statistically significant cumulative decline is observed only be age 78.

The cohort pattern for Spatial Orientation (Figure 3) is more systematic in that each successive cohort is found to perform at a higher level at all comparable ages. Nevertheless, this ability also shows different peaks and rates of decline for the three cohort groups. The middle-aged cohort shows a shallow rise to age 50 and decline (although not statistically significant) by age 57. The young-old cohort appears to show slight decrement throughout, Subjects were first tested in 1956 and were retested in 1963, 1970, 1977 and 1984/85.

Findings on Average Age Changes

We begin our exploration by examining the progression of our subjects across the 28 years of our study. As will be noted from Figure 1, the average ages of our residual sample at the five measurement points were 41, 48, 55, 62 and 69 years, respectively. For convenient comparison across the three ability measures, all raw scores were rescaled in T-score form (M = 50, SD = 10) using the parameters obtained for a broad sample of 2810 subjects at first test with an average age of 53 years (Schaie, 1983b). Scaling in this fashion permits us to examine not only change within our long-term panel, but also helps us to understand the magnitude of change by placing it within the context of a broader population frame.

Insert Figure 1 about here

As would be expected in a favorably attrited panel, our residual subjects on average were about 1/2 of a standard deviation above the population mean when they were first studied; by the last measurement point they are still slightly above the population mean. For the total sample statistically significant decline can be detected by age 62. Verbal Meaning actually continues to increase slightly until age 55. The decline by age 69, amounts to .33 SD from the initial level, and .46 SD from peak level. Spatial Orientation appears to show decline by age 55; however, seven-year age changes on this variable are not statistically reliable until age 69 is reached, although cumulative decline reaches significance by age 62. The magnitude of change for Spatial Orientation amounts to .34 SD from initial level. Inductive Reasoning remains level until age 55 and then declines; the magnitude of decline amounting to .40 SD. Fitting a straight line through the average age trends indicates that the annual average rate of decline over the age range from 41 to 69 years amounts to .012 SD for Verbal Meaning and Spatial Orientation and to .014 SD for Inductive Reasoning.

Age Changes Differentiated by Cohort Level

Because of the wide age/cohort range represented in our sample, these age trends may conceal important differences in change patterns for successive cohorts and different age ranges. The data were therefore disaggregated first into three sub-samples, those who at the last time of measurement were middle-aged (N = 30; age M = 57, SD = 3.5), young-old (N = 39; age M = 71, SD = 3.5), and old-old (N = 19; age M = 85, SD = 3.9). This disaggregation yields longitudinal segments that cover the age range from 29 to 85, with two cohort comparisons at ages 43, that reaches statistical significance by age 64, but then remains level to age 71. The oldest cohort, by contrast, peaks at age 64 and shows statistically significant only by age 78.

The pattern of higher performing successive cohorts also holds for Inductive Reasoning (Figure 4). The youngest cohort appears to peak at age 36; however, age changes for this group are not statistically significant. The young-old cohort peaks at 57, with statistically significant decrement first detected at age 64. The oldest cohort also peaks at 57, but statistically significant decrement is not detected until age 71.

Magnitudes of average decline are virtually trivial for the middle-aged cohort, are quite modest for the young-old cohort, but of substantial for the old-old cohort. These magnitudes as well as annualized rates of change obtained by fitting straight lines to the group averages are provided in Table 1 from the initial measurement point and from peak performance levels.

Insert Table 1 about here

Individual Differences in Rate of Change

A much more complicated story unfolds when we begin to examine individual patterns of change over the 28-year period. For all three abilities and across all three cohorts individuals may be found whose slope coefficients reflect either more severe decrement than the group average, or by contrast, whose performance over time proceeds in a positive fashion. For example, the annual linear rate of decline on Spatial Orientation for our subjects as a group was estimated to proceed at the rate of .012 SD units. The range of individual slope coefficients, however, ranges from a maximum annual decline of .101 SD to a maximum annual gain of .027 SD units. In other words, at least one of our subjects declined approximately eight times as fast as the group average, and others showed ability gains rather than decline.

Cohen (1977) has suggested that effect sizes expressed in population standard deviation units should be considered small (of little interest) if they are less than .2 SD units, are of moderate importance if they reach .5 SD units, and of substantial interest if they exceed 1 SD. Employing these criteria we find that approximately 32 per cent of our subjects show moderate or larger decline on Verbal Meaning; similar figures are 34 per cent for Spatial Orientation, and 37 per cent for Inductive Reasing. The flipside of these data, of course, is the fact that approximately two thirds of our participants showed little or no decline. Figure 5 employs the Cohen criteria in a more detailed breakdown by cohort for the ability of Spatial Orientation. Note that there is a virtually normal distribution of gain, stability and loss for the middle-aged cohort, increasing loss but still marked stability for the young-old, but moderate to substantial loss for most of the old-old.

Insert Figure 5 about here

Typical Patterns of Change

The above demonstration of wide individual differences in rate of change needs to be extended further to attend to the substantial individual differences in patterns of change. Some individuals, of course, remain stable throughout. Others show an early decline, followed by recovery to the prior level of functioning, whether by serendipitous events, or as the intended consequence of programmed intervention (cf. Schaie & Willis, 1986). Some persons decline at a regular rate from young adulthood on, others show early decline, followed by a late life plateau, or they only begin to show decline quite late in life.

Our next step in the process of diaggregating the group data, therefore, consisted of conducting a cluster analysis (Spath, 1980; Ward, 1963) on the 39 members of our young-old cohort to determine whether we could develop a reasonable typology of profile types. We selected the young-old group because it appeared to contain the greatest diversity of profiles including all of the alternatives discussed earlier. The clustering algorithm was first used to assign each of our subjects to one of two major profile types. Further clustering then resulted in assignment to one of four sub-tupes. Figure 6 gives an example of the tree-structure resulting from the cluster analysis for Spatial Orientation.

Insert Figure 6 about here

Major Profile Types. The clustering algorithm employing the euclidian distances between all pairs of profiles yields an admixture of level and shape of these profiles. The following figures consequently compare the average profiles for the high-scoring and low-scoring members of the young-old cohort as compared with the profile for the entire cohort. The major profile types emphasize level differences, but also call attention to the interaction between level of cognitive function and long-term change. This interaction is particularly noteworthy for Verbal Meaning (Figure 7). Note the group profile that peaks at age 57 and declines thereafter. This group trend is replicated in more pronounced form by Type I that includes most of the lower performing individuals. By contrast, Type II includes most of the higher performing individuals, with a virtually shallow profile until age 64 and only minimal decline thereafter. The average annual rate of change for Type I is almost three times as large as for Type II (.016 SD vs. .006 SD).

For Spatial Orientation (Figure 8), the group profile suggests steady decline until 64 with a plateau over the next seven-year period. When disaggregated, the high-scoring individuals plateau until age 57, then decline to age 64, and plateau again. The low-scoring individuals, on the other hand, show early decline by age 57, and a lower plateau thereafter.

For Inductive Reasoning (Figure 9), the group profiles of modest increment to age 57, and decline thereafter, is virtually replicated by the high-scoring members of the group. By contrast, low-scoring individuals appear to plateau in midlife, and decline thereafter.

Rates of decline for Space and Reasoning do not differ as much by type as for Verbal Meaning. Nevertheless, in both instances, the rate of the lower-scoring type is about 1 1/2 times that of the higher scoring type.

Insert Figures 7, 8 & 9 about here

Subtype Profiles. As a next step we identified four subtype profiles for each of the three abilities. These subtypes come considerably closer in reproducing the variety of individual change patterns present in our data, while smoothing some of the irregularities in the individual data. For Verbal Meaning (Figure 10), the subtypes primarily identify different profiles among high-scoring individuals (Subtype A is virtually identical with major type I). Subtype B represents a pattern of early decline, by age 57, and subsequent recovery by age 71. Subtype C replicates the group norms; i.e. peak attainment at age 57 and decrement thereafter. Subtype D, by contrast represents virtual stability from midlinfe into early old age. The average rate of change for subtypes B and D is virtually zero, that for subtype C is modest (.011 SD), while the rate of change for Subype A is substantial (.022 SD).

Subtype profiles for Spatial Orientation (Figure 11) appear to be ordered by performance level, but also represent differences in change pattern. A linear fit for Subtype A suggests a positive trend throughout (annual change = + .008 SD), while Subtype B represents individuals declining at a steady rate from middle adulthood (annual change = .022 SD). Subtype C represents early decline, to age 57, followed by a plateau, while Subtype D reflects a stable low level of performance throughout.

Finally, for Inductive Reasoning (Figure 12) the subtypes indicate different combinations of ability level and age at which decline is first noted. Subtypes B and D reflect virtual stability until age 64 and decline thereafter; the former from a high level and the latter from a low level of adult performance. Subtypes A and C, on the other hand, represent individuals with an earlier onset of decline; the former with a less pronounced rate of decline from a higher level. Rate of decline is greatest for Subtype D (.017 SD), with a more moderate annual rate of about .010 SD for the remaining subtypes.

Insert Figures 10, 11 & 12 about here

Some Individual Profiles

I will conclude my data presentation by including individual profiles for four individuals on Verbal ability. I have chosen these profiles to illustrate several specific points. The first two profiles (Figure 13) represent two young-old ladies who throughout life functioned at very different levels. Subject 155510 is a high-school graduate who has been a home-maker all her adult life, and whose husband is still alive and well-functioning. She started our testing program at a rather low level, but her performance has had a clear upward trend. The comparison participant has been professionally active as a teacher. Her performance remained fairly level and above the population average until her early sixties. Since that time she has been divorced and retired from her teaching job; her performance in 1984 dropped to an extremely low level, that may reflect her experiential losses, but could also be a function of increasing health problems (cf. Gribbin, Schaie, & Parham, 1980; Hertzog, Schaie, & Gribbin, 1978).

The second pair of profiles (Figure 14) shows the 28-year performance of two old-old men now in their eighties. Subject 153003, who started out somewhat below the population average, completed only grade school, and worked as a purchasing agent prior to his retirement. He showed virtually stable performance until the late sixties, his performance actually increased after he had retired, but he is beginning to experience health problems, has recently become a widower, and his latest assessment was below the earlier stable level. By contrast, subject 153013, a high school graduate who held mostly clerical types of jobs, showed gain until the early sixties and stability over the next assessment interval. By age 76, however, he showed substantial decrement that continued through the last assessment, which occurred less than a year prior to his death.

Insert Figures 13 & 14 about here

The point I wish to make, of course, is that none of the four profiles could be directly predicted from our knowledge of group means, although each of theses profiles is quite similar to one of the subtypes exhibited earlier. Similarly, predictions of age changes for these individuals from the group-based estimates or rate of change would have been quite misleading.

Some Concluding Thoughts

I have tried to lead you systematically from a representation of a data set that reflects conventional comparisons of average within-group age changes through a progressive disaggregation of these data. The purpose of this disaggregation was to reflect different levels of analysis selected in a manner that would bring us as close as possible to a reasonable representation of aging phenomena that occur in identifiable individuals, rather than remaining statistical abstractions. I could have made the data on individual differences even more dramatic had I relied only on cross-sectional data. But that would have defeated the purpose, for the essential information about individual aging can only be elicited from following the same persons as they age.

Once we begin to disaggregate our data by rate of change, it then becomes possible to address more meaningfully the question as to why some individuals age so much faster than others. I have given you some hints when I contrasted individual profiles of subjects who changes slowly or precipitously. Time does not allow me to go more deeply here into some of the variables that have been identified in previous work to distinguish those who age most rapidly from those whose behavior changes only minimally. Let me simply mention that the most important variables identified thus far have been good cardio-vascular health (Hertzog, Schaie, & Gribbin, 1978), active and involved life styles (Gribbin, Schaie, & Parham, 1980), as well as flexible attitudes and intact interpersonal support systems (Schaie, 1984). In addition, there are obviously individual differences in the maintenance of energy level and of adequate sensory functions that are related to adequate performance on the cognitive measures we have investigated (cf. Schaie, 1981).

There finally is a practical dilemma that remains to be addressed. All of the data I have presented to you are, of course, retrospective in nature. If we wish to forecast future behavior of individuals or groups, we must use some model, or reference norms, that allow us to make such forecasts. Fortunately, there appear to be enough regularities in the data I presented you that offer guidance as well as cautions. First of all, we might note, that most of the subtypes we have identified reflect stable performance or increment into late middle age. It would therefore be reasonable to argue that the best predictor of accelerated aging may well be the detection of substantial decrement in the forties or early fifties. It is also important to note that accelerated aging appears only in a sub-set of those individuals who in midlife have functioned at a high level of performance. Apparently, rates of age change, at least until the seventies are reached, in the absence of pathology, are quite small for those who are intellectually advantaged. Complicating these matters further is the finding that there are individuals who show significant decrement at about the time they retire, but who then plateau for another decade. The lowered performance of these individuals may reflect disuse and may thus be reversable (Schaie & Willis, 1986), or it may reflect the fact that the individual has established a new adaptation level consonant with reduced demands of his or her personal environment (Schaie 1977/78).

We conclude then that rate of change in cognitive behavior as we age is a highly individuated phenomenon. Estimates derived from group norms reflect different rates for different abilities, and suggest that there are differential cohort trends in rate as well as levels of performance. More importantly, I hope this presentation has provided strong arguments to support the proposition that there is no uniform rate of cognitive aging that will adequately describe changes within indivduals over time. Instead there are clearly differentiable patterns a more detailed analysis of which now invites our attention with the ultimate objective not only of understanding these differences but to design interventions that might make it possible to increase the proportion of the population that manages to maintain high levels of cognitive function to the end of their lives.

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Table 1

Magnitude of Age Changes in Standard Deviation Units by Ability and Cohort

	From Initial Level			From Peak Level		
	Verbal Meaning	Spatial Orient.	Induct. Reason.	Verbal Meaning	Spatial Orient.	Induct. Reason.
Middle-aged	+ .07	- .15	- .07	- .20	- .30	- .23
Young-Old	- .30	- .29	- .39	- .41	- .29	- .48
Old-Old	- .73	- .74	- .96	- .73	- .92	- .96

	Annual Rate of Change		
	Verbal Meaning	Spatial Orient.	Induct. Reason.
Middle-Aged	+ .002	- .003	- .005
Young-Old	- .010	- .011	- .012
Old-Old	- .035	- .026	- .033

Figure Captions

Figure 1. Age changes over 28 years for the total sample for the abilities of Verbal Meaning, Spatial Orientation and Inductive Reasoning.

Figure 2. Age changes over 28 years for the middle-aged cohort.

Figure 3. Age changes over 28 years for the young-old cohort.

Figure 4. Age changes over 28 years for the old-old cohort.

Figure 5. Proportion of subjects by cohort who gained, remained stable or lost performance skills on Spatial Orientation.

Figure 6. Tree diagram for the cluster analysis of Spatial Orientation data for the young-old cohort.

Figure 7. Mean profiles for group average and major types for the young-old cohort on Verbal Meaning.

Figure 8. Mean profiles for group average and major types for the young-old cohort on Spatial Orientation.

Figure 9. Mean profiles for group average and major types for the young-old cohort on Inductive Reasoning.

Figure 10. Subtype profiles for the young-old cohort on Verbal Meaning.

Figure 11. Subtype profiles for the young-old cohort on Spatial Orientation.