Successful aging

Perspectives from the behavioral sciences

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4 The optimization of cognitive functioning in old age: Predictions based on cohort-sequential and longitudinal data

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Introduction

Social scientists who are concerned with examining the hypothesis that optimization can occur with advancing age and who direct their efforts to discover the factors that allow some but not all individuals to optimize their abilities to maintain high-quality lives generally would seem to make three implicit assumptions. The first assumption has a negative flavor: Declines from asymptotic levels attained during early adulthood are assumed to occur in old age in both biological and behavioral functioning, whether at the level of observed performance or of reserve capacity. The second assumption, by contrast, is more positive: Individuals are thought to differ widely in their adaptation to experienced losses, and patterns of individual maintenance in decline may be both varied and subject to multiple influences. The third assumption concerns the model chosen for the study of aging pheonmena: Decline with age is often thought to be gradual, continuous, and irreversible in nature. Evidence with respect to these assumptions has long been examined in the area of cognitive functioning, the topic of this chapter.

Whether older adults can maintain levels of adaptation that allow continuation of independent living and the expression of accomplishments in late life is necessarily contingent upon the maintenance of levels of intellectual functioning that have not fallen significantly below the normative levels expected by our society. It is quite true that many individuals throughout much of their life manage to cope at below-average levels of competence. However, it is these very individuals who are at greatest risk of requiring institutional care, when even slight age-related change lowers

their competence from a marginal to an unacceptable level. Moreover, maintenance of leadership roles in society and continued productivity in competitive creative or scientific endeavors would seem to demand that the older person so engaged remains at high levels of functioning when compared with younger peers.

Strong evidence exists that a substantial proportion of individual differences in performance on everyday tasks (Willis & Schaie, 1986a) and in the perception of competence in real-life situations (Schaie, Gonda, & Quayhagen, 1982) can be accounted for by performance levels on measures of the primary mental abilities. The occurrence of average declines in mental abilities with advancing age has been reliably established (see Schaie, 1983). But there remains much controversy as to the patterns of individual differences in such decline. Individual differences in performance patterns, moreover, may be particularly profound in persons at high ability levels (Schaie, 1984, 1988b). In addition, previous research (Schaie, 1983, in press) has demonstrated differential cohort trends over time that influence the proportion of individuals of advanced age who remain capable of optimal functioning.

In view of the above considerations, I will argue that optimization in old age in the area of basic intellectual skills does not imply the attainment of new levels of high performance. Rather, I would suggest that the name of the game is indeed preservation of the levels that one has attained at an earlier age. Furthermore, in the face of cumulative environmental insults and biological constraints, optimization of intellectual functioning in old age should be expected to be selective rather than generalized.

In this chapter, I will examine evidence from my longitudinal–sequential studies of adult intelligence that can help determine the most likely predictors of optimal cognitive functioning in late life. As part of the Seattle Longitudinal Study (SLS) of adult cognitive functioning, we have tried to identify a large number of endogenous and exogenous variables that might have either positive or negative effects upon the maintenance of an individual's cognitive functions as he or she ages. The variables included here are those that in previous work have been demonstrated to explain many of the individual differences in intellectual changes with advancing age. The variables to be examined here include the effects of cardiovascular disease, cognitive styles, perceptual speed, associative memory, and several demographic antecedents. Before doing so, however, I will review the nature of the data base upon which my analyses and conclusions rely. In addition, I will examine in some detail evidence that suggests that there are a number of different patterns in which intellectual change in old age occurs. This approach is dictated by the recognition that an optimal adaptive pattern in old age may not necessarily be restricted to the maintenance of prior levels of functioning in all areas. Instead, if we give credence to the position that older individuals engage in selective optimization (e.g., P. B. Baltes & M. M. Baltes, 1980), we would expect a variety of patterns of selective maintenance of skills, which might well depend on alternative antecedent correlates. Finally, I will comment briefly on the implications of cohort trends in abilities for the optimal functioning of older adults.

Description of the data base

The data to be discussed come from the SLS, a multiwave panel study that uses as its population frame the membership of a metropolitan health maintenance organization (see Schaie, 1983). All 3,442 participants at first test were community-dwelling adults who were randomly selected from each 7-year age stratum included in each panel. These data were collected in 1956 (N = 500; ages 22–70), 1963 (N = 997; ages 22–77), 1970 (N = 705; ages 22–84), 1977 (N = 612; ages 22–84), and 1984 (N = 628; ages 22–84). At each successive data point, as many of the survivors of the previous wave as possible were reexamined. Thus we have 1357 participants for whom 7-year longitudinal data at Time 2 are available for four data sets: 1963 (N = 303; ages 29–77), 1970 (N = 420; ages 29–84), 1977 (N = 340; ages 29–91), and 1984 (N = 294; ages 29–91). Fourteen-year longitudinal data at Time 3 are available for 723 participants in three data sets: 1970 (N = 162; ages 36–84), 1977 (N = 337, ages 36–91), and 1984 (N = 224; ages 36–91). Twenty-one year longitudinal data at Time 4 exist for 355 participants in two data sets: 1977 (N = 130; ages 43–91) and 1984 (N = 225; ages 43–91). Finally, there is one 28-year longitudinal data set in 1984 at Time 5 (N = 97; ages 50–91). The age and sex distribution of this sample by 7-year age strata is provided in Table 4.1.

All participants were in good health when tested and were representative of the upper 75% of the socioeconomic stratum. For the total data base, educational levels averaged 13.27 years (range: 4–20 years), and occupational status averaged 6.25 on a 10-point scale, using census classifications ranging from unskilled labor to professional.

Throughout the study, the five primary mental abilities identified by L. L. Thurstone and T. G. Thurstone (1941) to exhibit the greatest variance (see also Schaie, 1985) were assessed. The Test of Behavioral Rigidity (Schaie & Parham, 1975) and a demographic information form were also used. Beginning in 1977, we added some measures of perceptual speed, and in 1984, measures of associative memory. Health history data have been abstracted for subsets of our data base that allow study of the effects of specific disease entities. All subjects were tested in small groups

Table 4.1. *First-time participants in the Seattle Longitudinal Study classified by chronological age and gender*

Mean age	Males	Females	Total
25	157	200	357
32	169	205	374
39	209	239	448
46	216	225	441
53	210	235	445
60	202	224	426
67	219	230	449
74	161	151	312
81	78	83	161
Total	1,621	1,792	3,413

in sessions that for the first three waves lasted about 2 hours, for the fourth wave about 3 hours, and for the fifth wave in two sessions of 2.5 hours each (necessary because multiple markers of the abilities and other additional measures were added). For the purpose of this chapter, our primary focus will be upon the five primary mental abilities: Verbal Meaning, the ability to comprehend words, a measure of recognition vocabulary; Spatial Orientation, the ability to mentally rotate objects in two-dimensional space; Inductive Reasoning, the ability to infer rules from examples that contain regular progressions of information; Number, the ability to manipulate number concepts, as measured by checking simple addition problems; and Word Fluency, a measure of recall vocabulary. Inductive reasoning and spatial orientation involve the solution of novel problems, whereas the other abilities represent more acculturated knowledge. In terms of the second-order ability domains involved, inductive reasoning is a measure of fluid ability, spatial orientation is a measure of visualization ability, and the other abilities are largely crystallized in nature (see Horn, 1970).

Because the emphasis of this volume is upon optimization of functioning in advanced age, we will limit our discussion to that part of our data base that extends from late midlife into old age. That is, we will consider only the 1,793 individuals who were 50 years of age or older when they entered the study. For this subset, longitudinal data are available on 1,179 individuals. Of these, 229 persons participated in cognitive training programs involving strategy training on either the Inductive Reasoning or Spatial Orientation ability (Schaie & Willis, 1986; Willis & Schaie, 1986b, 1988). For ease of comparison, all data have been scaled in T-score

Table 4.2. *Seven-year age changes for the primary mental abilities*

	Verbal Meaning	Spatial Orientation	Inductive Reasoning	Number	Word Fluency	Composite
From age 53 to age 60 (N = 417)						
Mean	0.48	0.54	0.20	0.68	1.23	0.62
S.D.	5.32	6.33	4.79	5.27	6.34	3.03
From age 60 to age 67 (N = 359)						
Mean	2.08	2.02	2.09	2.27	1.78	2.06
S.D.	6.36	6.33	4.99	5.46	6.46	3.25
From age 67 to age 74 (N = 284)						
Mean	3.01	2.59	2.42	2.53	2.46	2.59
S.D.	6.92	5.95	5.06	5.84	6.12	3.11
From age 74 to age 81 (N = 129)						
Mean	3.82	2.94	2.06	4.08	3.48	3.27
S.D.	6.96	5.81	4.30	5.34	6.10	3.32

Note: All average changes are decrements expressed in *T*-score points.

form (mean = 50, standard deviation = 10) based on the scores of 2,810 subjects at first test. Thus, in population terms, changes or differences reported here imply an order of magnitude of one tenth of a standard deviation unit for each *T*-score point.

Patterns of decline from late middle age into old age

We will begin our discussion by considering the amount of average decrement from late midlife and by examining the various patterns of decline shown by different individuals. To maintain substantial sample sizes, we will base these data on 7-year longitudinal changes cumulated across the four samples (1956, 1963, 1970, and 1977 entry waves) for which longitudinal data are available (also see Schaie, 1988a, for an analysis of the empirical consequences of this approach).

Patterns of average ability changes

Table 4.2 lists average changes in *T*-score points for the five primary mental abilities as well as for a linear composite (analogous to a global IQ estimate). Average decrements from age 53 to 60 are statistically significant for Number (men only) and Word Fluency as well as for the composite score. Although the magnitude of decrement over this age

Table 4.3. *Twenty-eight-year changes for the primary mental abilities*

	Verbal Meaning	Spatial Orientation	Inductive Reasoning	Number	Word Fluency	Composite
From age 25 to age 53 (N = 15)						
Mean	+3.67	1.87	+0.47	1.93	1.07	0.07
S.D.	4.95	8.14	4.52	6.51	8.29	2.74
From age 32 to age 60 (N = 21)						
Mean	1.14	2.71	2.24	1.86	2.91	2.33
S.D.	2.95	7.20	5.65	4.30	9.89	3.45
From age 39 to age 67 (N = 17)						
Mean	1.06	1.12	2.59	3.29	6.65	3.12
S.D.	4.98	8.01	5.37	5.52	6.29	3.44
From age 46 to age 74 (N = 24)						
Mean	3.96	4.29	5.62	3.04	8.12	5.04
S.D.	9.72	8.38	5.00	4.29	5.52	3.57
From age 53 to age 81 (N = 16)						
Mean	8.75	7.69	8.19	7.69	11.25	8.75
S.D.	5.07	6.05	8.08	5.51	8.39	4.52

Note: All changes are in *T*-score points. Values carrying the plus sign represent increments; all others, decrements. These data are based only on the survivors of the sample first tested in 1956 (in contrast to Table 4.2, which is based on pooled data across all longitudinal samples).

range is virtually trivial, there is substantial variability, suggesting that at least some individuals do show significant decrements over this age range. Beyond age 60, 7-year decrements are statistically significant for all abilities ($p < .001$) and increase up to 4.08 population standard deviations for the 7-year interval from age 74 to 81.

Data are also available for a small subset of 93 persons for whom cumulative change can be examined over a 28-year period. Table 4.3 reports these cumulative changes for 28-year periods, beginning from ages 25–53 and ending at ages 53–81. For the youngest group there is a significant increment for Verbal Meaning ($p < .01$), but no other significant change. From age 32 to 60, it is only the composite measure that shows a statistically significant ($p < .01$) but very small cumulative decrement. Even from age 39 to 67, it is only the Word Fluency and composite measures that show statistically significant decrements ($p < .01$). However, statistically significant cumulative decrements of moderate magnitude are found for all variables except Verbal Meaning from age 46 to 74, and large cumulative decrements prevail for all variables from age 53 to 81.

It should be noted that variability is quite large, both for the 7-year and the cumulative 28-year data. Inspection of frequency distributions of observed *individual* changes therefore indicates that many individuals at all ages show little or no decrement on specific abilities over the periods monitored. Variability is considerably less on the composite measure, supporting the notion that although there may be decline in some ability or abilities for most individuals over age 60, the pattern of such decline is indeed quite variable.

Individual patterns of ability changes

Although continuous data are preferred to describe parametric changes in populations, the use of such data involves the assumption that change at the individual level is also linear and continuous in nature. We should like to question this assumption and argue that individual change occurs in a much more sporadic fashion (we will document this point later on). For the purpose of studying individual differences in ability decline, it may therefore be more useful to study decline as events, recognizing that the reliability of the absolute difference embodied in an individual change score is likely to be limited. Thus, converting our continuous data into discrete events will most likely result, not in what some might consider to be a regrettable information loss, but rather in data that are more suitable for the study of patterns of individual change (also see Schaie, 1989a).

We can best examine the question of what proportion of individuals show which pattern of decline by specifying criteria that allow identification of individuals who show decremental change that exceeds possible measurement error. We do so by creating a 1 standard error of measurement (SEM) confidence band about our participants' base scores (see Dudek, 1979).[1] Those individuals whose 7-year change falls below this interval are considered to have reliably experienced age decrement; all others are considered to have maintained their previous level of performance. This is a rather conservative estimate, with an error rate of .16 in favor of accepting the prevalence of reliable decrement and, thus, if anything, it is biased against diagnosing excessive numbers of individuals as stable when they are not. The procedure advocated here does not depend on the reliability and/or distribution of change scores; instead, it simply determines whether or not a Time 2 score could or could not have been another estimate of the Time 1 score, given the specified confidence interval about the Time 1 score.

I will first examine the proportion of individuals who show significant

Table 4.4. *Proportions of individuals showing decline in specific abilities*

Ability	53–60	60–67	67–74	74–81
Verbal Meaning	15.2	24.8	26.8	35.7
Spatial Orientation	21.1	27.0	29.6	32.6
Inductive Reasoning	14.0	26.5	23.6	27.9
Number	17.2	26.2	26.2	31.8
Word Fluency	23.6	28.4	27.5	37.2
Composite	18.9	34.3	43.0	50.4

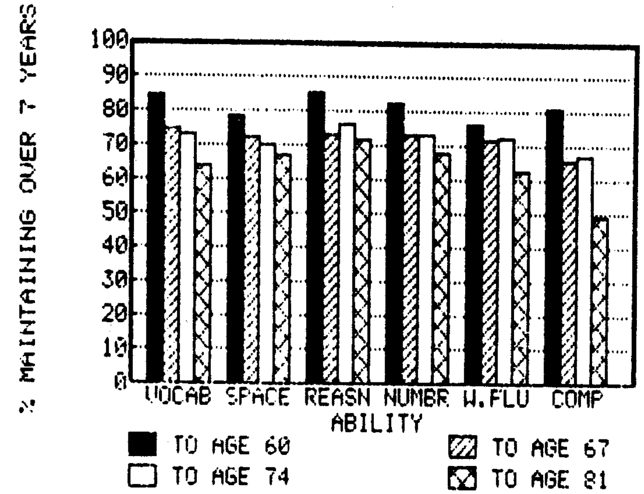

Figure 4.1. Proportion of individuals maintaining or improving performance levels on specific abilities over 7 years.

decline over 7 years on specific abilities as well as on the overall composite score (see Table 4.4). Note that the incidence of significant decrement for specific abilities is quite limited until age 60; until age 74 affects less than a third of our subjects; and even by age 81 is limited to between 30% and 40% of the persons studied. For the composite score, significant decline is somewhat higher and increases by about 10% per decade. For the purpose of this chapter, it seems appropriate to state these findings more positively. As graphed in Figure 4.1, depending upon age-group, from 60% to 85% of all subjects remain stable or improve on specific abilities. And for the composite score, approximately 50% even of the oldest group

Table 4.5. *Proportions of individuals showing decline of abilities*

Number of abilities	53–60	60–67	67–74	74–81
None	41.3	26.7	24.3	15.5
One	35.3	35.1	37.7	37.2
Two	17.0	22.0	21.8	24.8
Three	4.9	10.3	11.3	14.0
Four	1.2	5.0	3.9	6.2
All five	0.5	0.8	1.1	2.3

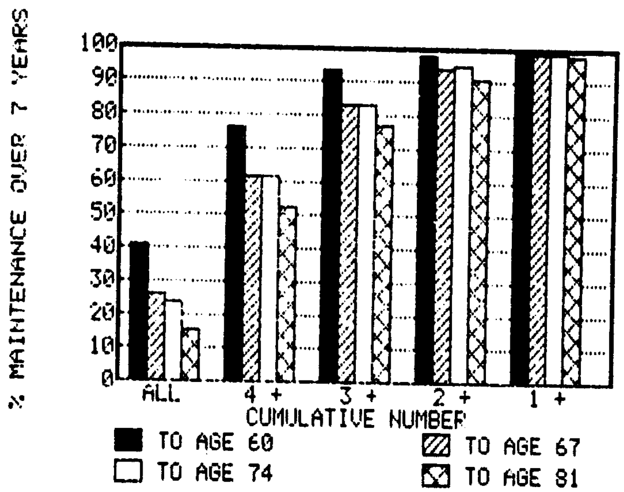

Figure 4.2. Proportion of individuals maintaining or improving performance levels on multiple abilities over 7 years.

did not show evidence of statistically significant decline over the preceding 7 years.

Let us next consider whether cognitive decline is a global or a highly specific event. Table 4.5 lists the proportion of individuals maintaining all of the five abilities monitored over a 7-year period compared with individuals who decline on one or more ability. In fact, very few individuals show global decline. These data are graphed again in Figure 4.2 to show the cumulative proportion of study participants who maintain or improve their level of cognitive functioning in advanced age on one or

Table 4.6. *Proportions of individuals showing different decline patterns over four consecutive 7-year periods*

	Periods of decline				
Ability	None	One	Two	Three	Four
Verbal Meaning	50.5	36.1	11.3	2.1	0.0
	(69.1)	(24.8)	(5.2)	(0.0)	(0.0)
Spatial Orientation	35.1	47.4	16.5	1.0	0.0
	(64.9)	(30.9)	(3.1)	(1.0)	(0.0)
Inductive Reasoning	35.1	56.3	11.6	0.0	0.0
	(58.8)	(39.2)	(2.1)	(0.0)	(0.0)
Number	35.1	47.4	15.5	2.1	0.0
	(61.9)	(32.0)	(6.2)	(0.0)	(0.0)
Word Fluency	27.8	42.3	28.9	1.0	0.0
	(53.6)	(29.9)	(15.5)	(1.0)	(0.0)
Composite	32.0	43.3	18.6	6.2	0.0
	(44.3)	(35.1)	(15.5)	(3.1)	(0.0)

Note: Values in parentheses are adjusted for prior or consecutive periods of reliable increment.

more abilities. It is particularly noteworthy that by age 60, three fourths of our study participants maintained their level of functioning over 7 years on at least four out of the five abilities monitored and that this level of maintenance was true even at age 81 for slightly more than half of the sample.

One may ask, of course, to what extent there is cumulative decrement from one 7-year period to the next. We address that question, again using our small 28-year subset ($N = 93$; mean age = 68.3). Elsewhere we have reported individual profiles of change on this data set, showing that the accumulation of small changes in a linear fashion is quite atypical (Schaie, 1989b). This finding becomes even clearer when we consider cumulative change as multiple change events within individuals. Table 4.6 shows the proportions of our subjects who remained completely stable over a 28-year period or who showed one, two, or three periods of decrement. Note that there was no subject who showed significant decrement over all four 7-year periods (for Inductive Reasoning, no subject showed more than two decrement periods). Data are even more positive when we adjust proportions by not counting as a decrement those instances where the significant decrement is followed by a compensatory significant increment during the next period. These data suggest that individual linear decline is quite atypical and that the population estimates for ability maintenance based on our 7-year data are only minimally inflated by successive decrement events.

What are the processes and mechanisms that govern the selective pattern of optimization apparent from the above data? At this point, we have little to offer at the theoretical level of analysis, except to refer to models of adaptive cognitive aging that have the individual responding to the most urgent presses and needs of the concurrent environment (see Schaie, 1977/78). At the empirical level, however, one might argue that studying individual differences in endogenous and exogenous variables that possibly affect cognitive maintenance will also provide information about the process of optimization. Rather than engage in what I think to be premature theoretical speculations, I will now turn to a description of what we know about the many variables that affect differential cognitive aging.

Variables that mediate maintenance of cognitive functioning

I will now discuss those variables that may be particularly important in mediating the maintenance of high levels of functioning. In our work, we have attended particularly to the presence or absence of cardiovascular disease (e.g., Hertzog, Schaie, & Gribbin, 1978), demographic variables such as education and occupation (Schaie, 1983, 1988, in press), complexity of life-styles (Gribbin, Schaie, & Parham, 1980), the role of perceptual speed (Schaie, 1989c), verbal memory, and the contributions of cognitive styles as expressed through measures of flexibility-rigidity (Schaie, 1983; Willis, 1989). Not all of these variables, of course, have the same conceptual status. For example, it is quite possible that the effects of cardiovascular disease on cognitive maintenance may simply represent the results of life-styles that are unfavorable for both cardiovascular health and maintenance of cognitive function. Likewise, occupational and educational factors may well be the root cause of flexible behaviors and attitudes that favorably affect cognitive maintenance. The complex models that need to be tested to resolve these matters go beyond the scope of a single chapter. I will therefore limit myself to describing the effects or variables that have a direct impact on cognitive maintenance.

I will first consider some of the predictors of high levels of cognitive functioning at various advanced ages for the full data set described earlier. For many of the variables to be considered, however, we will need to refer to the data set employed in our training studies (Schaie & Willis, 1986; Willis & Schaie, 1986b, 1988), for which we have the most detailed data on all of these variables. These studies involved subjects over 64 years of

age who received 5 hours of training in cognitive strategies at the ability factor level for either Inductive Reasoning or Spatial Orientation. This data set is particularly valuable because we can examine the effect of possible predictors on both decline and remedial intervention in the elderly.

Base level as predictor of later performance

Because decline in ability is so specific, it is necessary to examine the various abilities separately, in order to test whether base level performance predicts later performance. We use a discriminant function approach to determine whether we can identify variables that distinguish those who maintain their previous performance levels from those who decline. We include the base levels of the five mental abilities as well as the factor scores of Motor–Cognitive Flexibility, Personality–Perceptual (Attitudinal) Flexibility, and Psychomotor Speed from the Test of Behavioral Rigidity (Schaie & Parham, 1975). We also enter gender and cohort membership into this analysis to control for possible confounds due to sample composition. Regression coefficients (beta weights) and multiple correlations (all of which are statistically significant) are reported in Table 4.7. The most striking finding is that at every age level the likelihood of maintaining optimal levels of function appears to be inversely correlated with previous levels. That is, the higher the base level on a given ability, the more likely it is that significant decline will occur; and this inverse relationship appears to be strongest in our oldest age-group. Note, however, that this inverse relationship, in most cases, is strictly a within-variable relationship. Because our decline criteria incorporate the stability coefficients (which are uniformly high), it seems unlikely that these findings can be attributed to statistical regression effects. We have previously examined the validity threat due to statistical regression by means of time-reversal analysis (see Baltes, Nesselroade, Schaie, & Labouvie, 1972; Campbell & Stanley, 1966). In that study we concluded that the observed relationships represent a valid developmental phenomenon and cannot be dismissed as statistical artifacts (Schaie & Willis, 1986).

There are some other base level predictors that contribute to the discriminant functions. High base level on Spatial Orientation appears to be positively related to maintenance on Verbal Meaning, as is high level on Psychomotor Speed. Other base level predictors appear to be quite age-specific. For example, both Motor–Cognitive Flexibility and Attitudinal Flexibility base levels are positively related to several abilities from age 60 to 67 but do not reach significance at other ages. Cohort level has no predictive value, and gender effects are significant only from age 53 to

Table 4.7. *Discriminant functions for the maintenance or decline of the primary mental abilities over 7 years (regression coefficients and multiple correlations)*

Predictors	53–60	60–67	67–74	74–81
Verbal Meaning				
Verbal Meaning	−.347***	−.449***	−.531***	−.508***
Spatial Orientation	.120*	.115*	−.015	.127
Inductive Reasoning	.072	.080	.116	.090
Number	.042	−.034	.136*	.000
Word Fluency	.011	−.064	−.005	.086
Motor–Cognitive Flexibility	.071	.191**	.041	.123
Attitudinal Flexibility	.018	.057	−.016	−.055
Psychomotor Speed	.195**	.142*	.121	.119
Sex	−.001	.024	−.045	.005
Cohort	.055	.033	−.007	−.054
Multiple R	.270***	.350***	.395***	.404**
Spatial Orientation				
Verbal Meaning	.039	−.097	.078	−.230*
Spatial Orientation	−.337***	−.401***	−.411***	−.433***
Inductive Reasoning	.065	.105	.101	.152
Number	.067	.018	.017	.018
Word Fluency	−.101	−.138*	−.020	−.066
Motor–Cognitive Flexibility	.059	.167**	.043	−.014
Attitudinal Flexibility	−.047	.127*	−.002	.118
Psychomotor Speed	.031	.007	−.128	.177
Sex	−.108*	.007	−.039	.040
Cohort	−.005	.062	.078	−.049
Multiple R	.319***	.350***	.373***	.520***
Inductive Reasoning				
Verbal Meaning	.025	.144	.016	.164
Spatial Orientation	.022	.013	.010	−.027
Inductive Reasoning	−.272***	−.384***	−.525***	−.683***
Number	−.029	.011	−.057	.052
Word Fluency	.058	−.025	−.027	−.037
Motor–Cognitive Flexibility	−.007	.032	.113	.100
Attitudinal Flexibility	.021	−.128*	.013	.028
Psychomotor Speed	−.046	.037	.227**	.090
Sex	.022	−.007	−.118*	−.060
Cohort	.025	.034	.097	−.015
Multiple R	.233**	.335***	.435***	.519***

Table 4.7. *(cont.)*

Predictors	53–60	60–67	67–74	74–81
Number				
Verbal Meaning	−.225**	.025	.111	−.020
Spatial Orientation	.002	.086	−.030	−.084
Inductive Reasoning	.111	.054	.173*	.116
Number	−.239***	−.388***	−.394***	−.408***
Word Fluency	.171**	.038	.127	−.027
Motor–Cognitive Flexibility	.076	.070	−.011	.156
Attitudinal Flexibility	−.009	−.087	−.026	−.073
Psychomotor Speed	−.059	.028	−.078	.080
Sex	−.029	.045	.008	−.031
Cohort	−.069	−.006	.000	−.035
Multiple R	.318***	.345***	.354***	.378*
Word Fluency				
Verbal Meaning	.052	.052	.035	.269*
Spatial Orientation	.098	−.012	.020	.094
Inductive Reasoning	−.039	.086	−.032	.086
Number	.034	.047	.076	.072
Word Fluency	−.368***	−.329***	−.381***	−.507***
Motor–Cognitive Flexibility	.095	−.027	.130	.022
Attitudinal Flexibility	.078	.047	.009	−.188*
Psychomotor Speed	.058	.070	.083	.131
Sex	.069	−.092	−.014	.007
Cohort	−.048	.063	.004	.068
Multiple R	.321***	.334***	.338***	.504***

*$p < .05$. **$p < .01$. ***$p < .001$.

60 for Spatial Orientation and from age 67 to 74 for Inductive Reasoning, in both instances favoring men.

The effects of cardiovascular disease

We have previously studied the effects of cardiovascular disease on mental ability performance and found that those individuals who were at risk from such disease tended, on the average, to decline earlier than did individuals not so affected (see Hertzog, Schaie, & Gribbin, 1978). I would like to report here a recent analysis of the relationship between cardiovascular disease, significant decline over a 14-year period, and significant remediation of decline in a group of 109 subjects (ranging in

Table 4.8 *Incidence of treatment of cardiovascular disease and decline or training gain on inductive reasoning*

	Disease incidents[a]	Disease episodes[b]
Change status		
Total incidence		
Stables	6.89	3.46
Decliners	16.50	6.00
Days in hospital only		
Stables	0.54	0.13
Decliners	6.34	0.85
Gain (decliners only)		
Gain	7.31	3.34
No gain	19.50	7.77

[a]Number of clinic visits and days in hospital.
[b]Number of continuous spells of illness.

age from 62 to 94) who received cognitive training on the Inductive Reasoning ability. Medical histories for these subjects were examined over the 7-year period preceding their pretraining evaluation. All clinic visits and illness episodes (continuous spells of illness) were recorded and coded by disease. The disease experience was then examined for individuals who had declined or remained stable in Inductive Reasoning and for individuals who had experienced or failed to experience significant training gain.

It is of interest to note that no significant relationships could be found between total numbers of disease incidents or episodes and mental ability, suggesting that overall health indices may not be very useful predictors of cognitive behavior. The findings are much more suggestive when we restrict our analysis to the occurrence of cardiovascular disease (including hypertension). These data are shown in Table 4.8. Individuals experiencing significant decline on Inductive Reasoning, on the average, had more than twice the number of cardiovascular-system–related treatment visits ($p < .01$) and about 1 and 1/2 times more cardiovascular illness episodes ($p < .05$) than those who remained stable. Even more dramatic were the incidents of hospitalization for cardiovascular disease, with the decliners averaging approximately 10 times as many hospitalizations as those who remained stable ($p < .01$). Note that because it was necessary for our subjects to be able to perform on paper and pencil tests, we do not include any individuals who experienced strokes severe enough to result in significant sensorimotor impairment.

The relation between cardiovascular disease and significant training gain further supports the finding that this syndrome is of importance in behavioral plasticity in the elderly. When we divide the group who showed significant decline on Inductive Reasoning into those who show and those who fail to show significant gains from cognitive training, we find that those who gain have experienced, on the average, less than half the number of clinic visits or illness episodes than those who do not gain ($p < .01$). Moreover, those who gain from training experienced their first cardiovascular system disease diagnosis approximately 2 years later than those who failed to show significant training gain.

Some important demographic status variables

Although many demographic status variables are not informative in predicting the occurrence of maintenance or decline of cognitive functioning, they do remain important in advanced age as contributors to the prediction of absolute levels of functioning (Schaie, in press). We therefore examined the effects of gender, education, and occupational level (scaled as a continous variable from unskilled to professional) for the four 7-year longitudinal samples with end points at ages 60, 67, 74, and 81 (see Table 4.9). Because the three status variables are correlated with each other, we present standardized regression weights for each (partialing out the effects of the two others) rather than the raw correlations with the ability measures.

Throughout, gender is related to Spatial Orientation favoring men and to Word Fluency favoring women (because of the smaller sample size, the regression weights are not statistically significant for the oldest group, but they are in the expected direction). The number of years of education is positively related throughout to Verbal Meaning, Inductive Reasoning, and Word Fluency. For the two oldest groups, there is also a positive relationship with Number. Occupational level relates positively to Inductive Reasoning and Number. Note, however, that this relationship disappears for the oldest group, where few individuals remain engaged in active occupational pursuits.

The role of perceptual speed and verbal memory

Just as ability decline seems to occur in an individualized, rather than a uniform and universal, fashion, so do the otherwise well documented declines in speed of performance.[i] We have recently documented that although decline with age in perceptual speed assumes linear form for populations, such decline is more likely to occur in a stair-step fashion for

Table 4.9. *Regression weights for gender, education, and occupation showing the effects on level of functioning of the primary mental abilities at 7-year longitudinal end points*

Predictors	53–60	60–67	67–74	74–81
Gender				
Verbal Meaning	.063	.115*	.056	.072
Spatial Orientation	−.252***	−.203***	−.192**	−.152
Inductive Reasoning	.100*	.124*	.074	.073
Number	−.038	.051	−.035	−.026
Word Fluency	.158**	.176**	.140*	.172
Years of education				
Verbal Meaning	.458***	.333***	.507***	.261*
Spatial Orientation	−.010	.164*	−.038	.094
Inductive Reasoning	.309***	.235***	.355***	.252*
Number	.036	.084	.251**	.228
Word Fluency	.272***	.142*	.223**	.292*
Occupational level				
Verbal Meaning	.063	.091	.010	.088
Spatial Orientation	.072	−.057	.010	−.018
Inductive Reasoning	.180**	.151*	.221*	.069
Number	.154*	.153*	.199*	.087
Word Fluency	.048	.147*	.131	−.104

*$p < .05$. **$p < .01$. ***$p < .001$.

individuals. We have also shown that much of the age-related longitudinal change in other ability variables may be attributable to concurrent change in perceptual speed (see Schaie, 1989c). It follows, therfore, that the base level and the change in perceptual speed might well be important predictors of ability decline. Because we have thus far collected perceptual speed data only for one 7-year period, we combined base level data for 542 individuals who were in the 53 years or older groups. The measures of perceptual speed used in this study are the Finding A's and Incomplete Pictures tests from the ETS *Kit of Factor-Referred Cognitive Tests* (Ekstrom, French, Harman, & Derman, 1976). In our analyses, we use the linear combination of the two markers as the optimal estimate of perceptual speed.

In order to appraise the predictive ability of these data for individuals, we once again use our SEM-defined criteria to examine the joint occurrence of decline events in perceptual speed and ability functioning over 7 years (Figure 4.3). When we do so, we find, for all abilities except Spatial

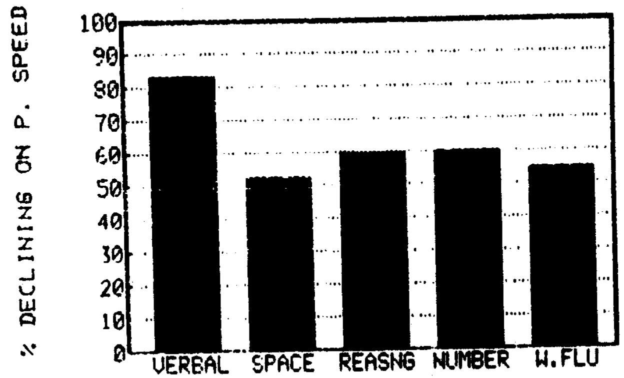

Figure 4.3. Joint occurrence of decline in perceptual speed and in other primary mental abilities.

Orientation, a lower occurrence of ability decline in those individuals whose perceptual speed has not declined. However, the base level of perceptual speed attains a significant relation with ability maintenance only for Inductive Reasoning. As would be expected, there is a high correlation between base level perceptual speed and end point ability functioning. Cross-lagged correlation analysis (Kenny, 1975), however, identified significantly greater cross-lags from speed to ability only for Word Fluency ($p < .05$). On the other hand, significantly greater cross-lags were identified from Spatial Orientation and Inductive Reasoning to perceptual speed.

Although we do not as yet have longitudinal data on verbal memory, we can examine the relationship between concurrent associative memory performance (immediate and 1-hour-delayed recall of a word list) measured at one point in time (1984) and the 7-year longitudinal change in the abilities. These data are available for a small set of people ($N = 111$; mean age = 72). The observed relationships suggest small but significant negative correlations between ability maintenance and memory functioning. This phenomenon is somewhat more general across abilities for delayed recall than for immediate recall (see Table 4.10).

Consequences of cohort differences in ability performance

Although we have noted that cohort level does not contribute to the prediction of individual differences in maintenance of function, there are still consequences of changes in population by cohort that are relevant to our

Table 4.10. *Correlation of concurrent measures of associative memory with magnitude of ability change over seven years*

Abilities	Immediate recall	Delayed recall
Verbal Meaning	−.248**	−.303**
Spatial Orientation	−.355***	−.366***
Inductive Reasoning	−.109	−.224*
Number	−.149	−.204*
Word Fluency	−.078	−.117

*$p < .05$. **$p < .01$. ***$p < .001$.

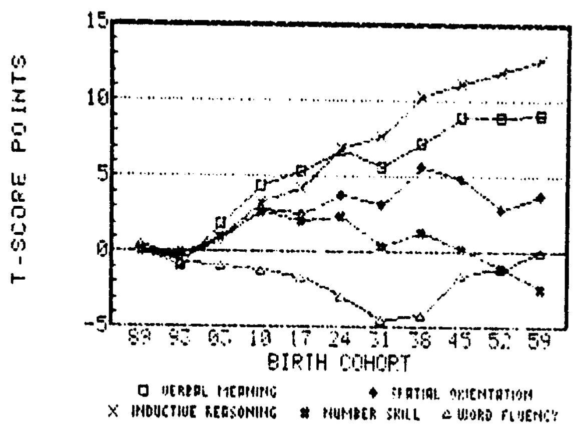

Figure 4.4. Cumulative cohort gradients for the primary mental abilities of Verbal Meaning, Spatial Orientation, Inductive Reasoning, Number, and Word Fluency for cohorts with mean birth years from 1889 to 1959.

discussion. Whether or not older individuals are perceived as functioning optimally will, of course, depend not only on intra-individual change but also on the levels of functioning of younger, comparison groups at any particular point in time. Both positive and negative ability changes across cohorts will therefore affect the extent to which older individuals will be perceived to be at a relative disadvantage. Our own work and that of others has consistently shown the prevalence of cohort differences in abilities throughout this century (see P. B. Baltes, Cornelius, & Nesselroade, 1979; Flynn, 1984; Parker, 1986; Schaie, 1983, in press). Figure 4.4 shows cohort gradients for the abilities discussed in this presentation.

These gradients were obtained by averaging differences between each successive pair of cohorts at all ages for which data are available for the same age levels (typically four age levels). Differences between successive cohorts as expressed in *T*-score points (.1 standard deviation) were cumulated from the oldest cohort, with mean birth year of 1989, up to the most recently measured cohort, with mean birth year of 1959.

It will be noted immediately that the cohort gradients differ markedly across abilities in both slope and shape. Inductive Reasoning comes closest to showing a linear positive cohort progression. Even here there are departures from linearity, with relatively steep increments up to the 1931 cohort and far slower and decelerating increments thereafter. Nevertheless, the cumulative increment across the currently available population is well in excess of a population standard deviation. The next most substantial pattern of positive increment across successive cohorts is shown by Verbal Meaning. After an initial modest dip, this ability rises until the 1924 birth cohort. After another modest dip, there is a further rise to an asymptote attained by the 1945, 1952 and 1959 cohorts. Spatial Orientation also shows a basically positive cohort progression, but with a much flatter and variable profile. This ability reaches an initial asymptote for the cohorts from 1910 to 1931. A further rise to a new peak occurs in 1938, which is followed by a drop to the earlier asymptote in 1952, but with recovery to the higher level by the most recent cohort.

A very different pattern is shown for Number. Here, a peak is reached by the 1910 cohort at a level that is maintained through the 1924 cohort. Thereafter, an almost linear negative slope is found that continues through the most recent cohort, which is below the 1889 base. Word Fluency, moreover, actually shows a negative cohort gradient up to the 1938 cohort, with recovery to the level of the base cohort by the most recent cohort studied.

It should also be noted that the increment of cohort differences has slowed markedly over the past two decades. Cumulative magnitudes of cohort differences between those now in midlife and those in early old age are no greater than the amount of training gains demonstrated for older adults who had not experienced age-related decline (Schaie & Willis, 1986; Willis & Schaie, 1986b). It seems reasonable then to assume that much of the cohort-related aspect of the older person's intellectual disadvantage when compared with younger peers may well be amenable to compensation by suitable educational interventions.

Because of the recent leveling off of some cohort changes and the curvilinear nature of cohort changes for some abilities, we must project substantial reduction in future observed cross-sectional ability differences between young and old adults. Indeed, for an ability such as numerical skill, we can look forward to a period when older adults will be advantaged when compared with younger persons. In addition to the positive inferences drawn from these data, there are also some negative ones. First, we need to note that the effects of positive cohort shifts are no longer apparent once the eighties are reached for any ability other than recognition vocabulary (see Schaie, in press). Apparently, age-related changes do take their toll for most of us in very old age, and environmental interventions at this time are perhaps not very effective in prolonging full functioning into very advanced old age. Second, the asymptote reached by recent cohorts in educational attainment, given the substantial correlations of the abilities with education, may suggest that the positive shifts in potential experienced in early old age by successive cohorts over the past several decades may come to a halt by the end of this century.

Summary and conclusions

In this presentation, we have tried to summarize some new analyses of data from the longitudinal–sequential studies of cognitive functions contained in the SLS archives. We began by examining the extent of ability maintenance in old age and concluded that although decline in cognitive functioning occurs for many individuals as the sixties are reached, such decline is differential in nature. Virtually none of the individuals contained in our data set showed universal decline on all abilities monitored, even by the eighties. We conclude then that optimization of cognitive functioning in old age may well involve selective maintenance of some abilities but not others. Moreover, such optimization is highly individual. The dynamic process that governs the mechanisms leading to the optimization of specific ability dimensions still remains to be discovered.

We next examined a number of variables that may be useful in predicting individual patterns of maintenance and decline. Evidence points to cardiovascular disease as a possible mediator in the maintenance of abilities and as a possible determinant of successful remediation of ability decline in advanced age. Demographic characteristics that may be related to optimal maintenance of intellectual functioning into old age certainly include education, but occupational level was also seen as important, at least up to that stage when most older individuals leave the world of work. High levels of motor–cognitive and attitudinal flexibility appear to be conducive to maintenance of function in early old age. Contrary to the hope that age might be kinder to those of high ability, once decline does occur, it is most likely to reach significant magnitudes in those of high ability. Perhaps this is only fair, because in spite of modest

losses, those who start at a high level will still retain preeminence among their peers. Although there is an excess of expected ability decline among those who also decline in perceptual speed, there is evidence that prior level of speed is only modestly predictive of ability maintenance and that maintenance of ability levels may actually be more predictive of maintenance of perceptual speed. Current verbal memory level was found to be related to magnitude of ability change.

In our final section, we briefly examined cohort changes in ability and argued that the curvilinear patterns and slowing of positive cohort changes would be likely to lessen the competitive disadvantage experienced by average older adults when compared with younger peers, at least for the remainder of this century.

Although all of these data provide us with some clues as to the variables that should be studied to understand the vast individual differences in the maintenance of optimal functioning in old age, much more work is needed to integrate this material and expand it to include additional personality and life-style variables. Such work may eventually permit us to provide reasonably accurate predictions of the hazard of individual change in functioning with increasing age, as well as to predict more accurately the diverse patterns of optimizing cognitive performance that have been identified.

NOTES

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1 The SEM used for our classification purposes has the form of $\sigma_{1I}(1 - r_{12}^2)^{1/2}$. It should probably more precisely be identified as the standard error of prediction. This error estimate is slightly larger than the conventional SEM, which represents the standard deviation of observed scores if the true score is held constant. Dudek (1979, p. 336) has argued that "if one desires to set confidence intervals for obtained scores (say on a retest), then the appropriate standard error interval is σ_{1I}, and using the [conventional] standard error of measurement in such a situation could lead to a serious underestimation of the interval." The size of this interval is dependent on the homogeneity or heterogeneity of the sample as well as the stability coefficient over the time interval for which change in individuals is to be identified. We deal with this matter by

using as stable as possible parameters for our SEM estimates, basing the Time 1 standard deviation and the stability coefficients upon all subjects for whom 7-year longitudinal data are available (N = 1,793).

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