Cohort-Sequential Research on Intelligence in Aging:

Implications for Theories of Intelligence

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INTRODUCTION

Popular stereotypes and earlier scientific consensus held that the course of adult intellectual development could best be described by a peak being reached in young adulthood, followed by a brief middle-aged plateau and subsequent steep decline. This view has been seriously challenged over the past decade by calling attention to the dramatic effects of inter-generational differences in life experience and performance characteristics which obscure intra-individual changes on most complex behaviors (cf. Baltes, Cornelius & Nesselroade, 1978; Baltes & Labouvie, 1973; Labouvie-Vief, 1977; Schaie, 1979; Schaie & Labouvie-Vief, 1974).

From a theoretical point of view, the earlier formulation of the course of age changes in intelligence implies a model which posits irreversable decrement from some point of peak attainment; decrement which remains uniform across successive generations, even if there are changes in level of function at peak age. As has been demonstrated earlier (Baltes, 1968; Schaie, 1965, 1973, 1977) it is not possible to test the irreversable decrement model either by analysis of data from conventional cross-sectional or longitudinal studies. The former will lead to the acceptance of the model if there are positive generational differences or to its rejection if there are negative generational differences, even when there are no discernable ontogenetic changes within the population examined. The latter will similarly result in acceptance of the model if there are positive secular trends related to the decrement variable, or rejection if there are such negative trends. Moreover, a single cohort longitudinal study, will not protect the researcher against the strong possibility that the described change may be cohort-specific; e.g. only relevant for individuals whose childhood was experienced during the great depression or who were perhaps nutritionally deprived during a period of war or other adversity (Elder, 1974; Schaie, 1972).

A direct test of the decrement model of age changes in adulthood requires the application of the cohort-sequential method (cf. Baltes, Reese & Nesselroade, 1977; Schaie, 1977). This method permits separation of differences between cohorts (generations) from ontogenetic changes occurring within cohorts. If population parameters, unbiased by dropout, are to be estimated such data will involve the repeated random sampling of cohorts from a specified population frame. If changes within individuals are to be assessed, it is further necessary to examine longitudinal repeated measurement data for at least two cohorts followed over the same age range.

The first data of the kind needed to assess the decrement hypothesis for measures of intellectual functioning which meet the above specifications were published recently by Schaie and Parham (1977) for a seven-year time interval. These data suggest that for variables not seriously affected by speed of performance, cohort differences predominate until the sixties, with ontogenetic changes becoming predominant by the eighties. But the latter findings are further limited by recent studies showing the effect of cardio-vascular disease on intellectual performance (Eisdorfer & Wilkie, 1977; Hertzog, Gribbin & Schaie, 1978). Another concern has been the question whether during adult development a seven-year span is sufficient to detect relatively small but nevertheless reliable changes.

The present report presents new findings based on seven sets of two samples, each carried over a fourteen year period. The first sample was followed from 1956 to 1970 and the second from 1963 to 1977. The youngest set was monitored from age 25 to 39 and the oldest from age 67 to 81. These data also permit estimates of within panel (longitudinal repeated measurement) age changes based on four samples for each seven year age interval. Further, available health history data permits us to segregate from our panels those individuals who have known cardiovascular disease, and to estimate separate ability age change functions for individuals without such disease. Finally, new estimates on intellectual performance changes within individuals as a proportion of performance at age 25 will be provided based on our fourteen-year change observations.

METHOD

Subjects. The present report is part of a 21 year study of adult intellectual development, sampling procedures for which have been reported previously (Schaie, 1959; 1979). Briefly, participants were originally drawn randomly within sex and year of birth in 1956 (birth years 1886 to 1934) and 1963 (birth years 1893 to 1941). Of the 500 participants originally tested in 1956, 162 (73 men and 89 women) were retested in 1963 and 1970; and of 995 participants first tested in 1963, 252 (103 men and 149 women) were retested in 1970 and 1977. Table 1 indicates distribution of these samples by sex, cohort and age range covered.

Measurement Variables. As part of a larger battery, participants were tested with the Thurstones' (1949) Primary Mental Abilities Test (PMA) Form 11-17. The present report will discuss participants' performance on the subtests measuring five intellectual ability factors: Verbal Meaning (V), a measure of vocabulary recognition; Space (S), a test of spatial orientation; Inductive Reasoning (R); Number skills (N), a measure of simple addition skills; and Word Fluency (W), a measure of vocabulary recall.

Design and Data Analysis. Seven sets of two cohorts each were available, each for a fourteen-year age range 25 to 39; 32 to 46; 39 to 53; 46 to 60; 53 to 67; 67 to 74; and 74 to 81 Univariate ANOVAS were performed for each set, as well as MANOVAS which permitted segregation of linear age changes (fourteen year trends) and quadratic age changes (differential change by seven-year segments). Each analysis involved a 2 x 3 x 2 (Cohort x Age x Sex) design. In addition, a 2 x 7 x 2 (Cohort x sample set x sex) MANOVA was done to obtain overall estimates of age and cohort effects and the related linear and quadratic effects. For the above analyses raw scores were converted to T scores (Mean = 50; standard deviation = 10), to permit cross-scale comparison, using as reference the first occasion data (N = 2200) for all participants tested in our study through 1970. Data from these very stable panels (i.e. individuals monitored over 14 years) were then used to compute revised estimates of cumulative change with age as a proportion of performance at age 25. Finally, to determine differential effects of individuals with cardio-vascular disease we identified participants with diagnoses of cerebrovascular disease and/or atherosclerosis during the second seven-year segment of the fourteen-year period. These participants were then deleted and performance changes were recomputed for individuals free of severe cardiovascular disease.

RESULTS

Univariate Analyses of Variance.

Our major finding is that of remarkable consistency in results for the two sets of longitudinal studies. That is two samples of individuals followed over the same age range but born seven years apart showed similar ontogenetic patterns. Except for the 46 to 60 year study on Word Fluency there were no within set cohort differences significant at the 1% level of confidence. Age change findings averaged across the two studies are reported in Table 2.

Verbal Meaning. Participants showed significant gains over the age ranges from 25 to 39 and from 32 to 46, while significant decrement was found from age 53 to 67 and from 67 to 81. The interaction for the 46 to 60 year old set indicated gain for the older cohort and stability for the younger.

Space. An early gain trend did not reach significance at the 1% level, while reliable decrement was found only in the 67 to 81 year set, although decremental trends appeared somewhat earlier. For four of the seven sets there were reliable sex differences in favor of the males.

Reasoning. Again early gain trends did not reach statistical significance while decrement reliable at the 1% level of confidence was noted for the 60 to 74 years and the 67 to 81 year set.

Number. Significant gain was found from 25 to 32, while decrement was reliable for the 53 to 67 and the 67 to 81 sets. In the 39 to 53 year old group there was gain in the first seven-year period and then drop to the earlier level in the second seven-year period.

Word Fluency. Significant decrement on this variable was found for the data sets involving the age ranges from 46 to 60, 53 to 67 and 67 to 81. In the set covering the range from 46 to 60 there was furthermore a large within set cohort difference in favor of the older cohort. Substantial age by cohort interactions favoring the older cohorts were also found.

Multivariate Analyses of Variance

The most noteworthy aspects of this set of analyses is concerned with the decomposition of the age and age by cohort effects into their linear and quadratic components. It is of interest to note that during the age ranges where significant increment is found such increment, over a fourteen-year period, is primarily linear for Verbal Meaning and Space, but quadratic (i.e. accelerating) for Number. The decremental age changes are primarily linear for Space, Reasoning and Word Fluency, but have quadratic components (accelerating decrement during the second seven-year interval) for Verbal Meaning and Number.

<u>Overall Analysis of Variance</u>

In order to appreciate the overall contrasts between age and cohort effects from the cohort-sequential analysis, it is instructive to consider results of the analysis combining all seven sets. Table 3 provides estimates of mean squares indicating the relative size of effects attributable to cohort, age and their interaction. The latter two are further partitioned into their linear and quadratic components. Table 3 also provides estimates of ω^2 for the main effects of their interaction. Cohort effects are large for Verbal Meaning, Space and Inductive Reasoning, and there is a sizable effect for differential age changes within cohorts for Verbal Meaning. All effects account for only limited variance for both Number and Word Fluency.

<u>Cumulative Age Changes</u>

From the within-cohort changes over a fourteen-year period it is now possible, for a rather stable panel, to estimate cumulative age changes over the range from 25 to 81 years of age. As suggested elsewhere (Schaie, 1979; Schaie & Parham, 1977) the practical significance of age change is best conveyed when we chart performance at successive ages as a proportion of performance at a base age. Table 4 provides performance indices where 100 is average performance at age 25. Note that performance does not drop below this level for Verbal Meaning and Space until age 81, for Inductive Reasoning and Number until age 74 and for Word Fluency until age 60.

Psychometric tradition suggests that performance within the middle 50 percent of the population is thought to be characteristic of average performance (cf. Matarazzo, 1972, pp. 124-126). We therefore estimated the lower bound of this average range (25th percentile), to denote the level below which an older group should fall before it can reasonably be argued that there has been decrement of sufficient magnitude to suggest that the average member of the older group falls below the average range of the young comparison group. Table 4 and and Figure 1 indicate that a decrement of such magnitude is reached for Word Fluency at age 74, for Verbal Meaning and Number by age 81, but that the average 81 year old in our panel is still within the average range of 25 year olds on Space and Inductive Reasoning.

Cumulative Age Changes Adjusted for Cardiovascular Disease

To deal with the question of the impact of cardiovascular disease on change in intellectual function we deleated data on the 106 participants for whom we had diagnoses of cerebrovascular disease or atherosclerosis. Cumulative age changes were then recomputed on the basis of the remaining 308 participants and are presented in the lower part of Table 4 and in Figure 2. We now find that even at age 81 none of the performance indices fall below the lower quartile of the 25 year old comparison group. The effects of cardiovascular disease, as would be expected, are most noteworthy at the two oldest ages monitored. For individual's without cardio-vascular disease age related cognitive decrement appears to proceed at a slower rate and decrement reaches magnitudes of practical significance at later ages. Figure 3 provides bar graphs comparing the magnitude of change, with open bars representing the total sample and solid bars representing samples after deletion of those with known disease.

DISCUSSION

The data we have discussed here represents the systematic monitoring of adult intellectual development from young adult (age 25) into old age (age 81). It is based only on individuals each of whom have been followed for at least fourteen years, whose health history during this period has been known, and data were presented which for each age segment studied are based on two samples born seven years apart. We believe that our samples followed over fourteen years are particularly useful to describe stable long-term changes in adult intellectual functioning because of our observation that subject attrition becomes fairly random after the participants have returned to our study subsequent to the first seven years (see Gribbin & Schaie, at this congress). Admittedly, they represent a subset of the original random samples, but they are still of sufficient breadth to represent the upper two thirds of the American demographic pattern.

On the basis of our replicated data we are prepared to conclude that we have reliability demonstrated that there is within-individual increment on most functions at least until the late forties, and that the practical significance of age decrement before the early sixties can readily be dismissed (also see Botwinick, 1977). But we are also convinced that at least on psychometric tests initially developed for young adults decremental changes begin in the mid-sixties and become substantial for most individuals by the early eighties. Nevertheless, we continue to maintain that although these changes can be demonstrated reliably for some variables by the sixties, that their practical significance is limited until very old age. It is also clear that more decremental change is observed in individuals with cardiovascular disease than without, although even in samples without such disease as shown earlier, decremental changes are clearly demonstrated by the eighth decade of life.

Once again it should be stressed that our data indicate age changes do not have uniform patterns, and that at all ages there are some individuals who do not follow the typical pattern of the group and show either early decline or late-life growth.

We believe these data are particularly relevant to a constructive analysis of the facts as they relate to a recently publicized controversy regarding the universality of intellectual decline (Horn & Donaldson, 1976; Schaie & Baltes, 1977) and the applicability of crystallized-fluid intelligence theory (Horn, 1970, 1978) to developmental processes. In their earlier paper Horn and Donaldson (1976) claimed that reanalysis of our data indeed showed universal decline for all, and moreover that our data fitted the crystallized-fluid model, because our measures of fluid intelligence (by Horn's identification), namely Space and Inductive Reasoning supposedly showed earlier and steeper decline then did the remaining measures deemed to be crystallized. We will not dwell here on the basic flaws of the developmental implications drawn from crystallized-fluid theory on the basis of inadequate cross-sectional data, since that has been done recently and most elegantly by Willis and Baltes (1978). What we rather wish to do is to show that our data falsify the crystallized-fluid model with respect to its developmental implications.

Figures 1 and 2 clearly show that Space (perhaps the best measure in the PMA of fluid intelligence) shows the highest midlife peak and the least decline over performance at young adulthood. By contrast, Number (a clear measure of crystallized intelligence) shows the greatest late life decrement. Moreover, we note that Word Fluency (the most speeded of our tests) shows the greatest difference in performance between the total old sample and the disease-free sample. Similarly, there is less decrement for Inductive Reasoning than for either Number or Word Fluency. Inspection of Table 3 may give us some further clues to the meaning of these findings. Note that the overall cohort variance is greatest for Inductive Reasoning and Space. And note further that the reason for this finding may be thought in the dramatic shift in American education over the cohort frame examined in our study from eductive (memorization) types of learning to inductive (analytical) types of instruction. It follows then that in the kind of cross-sectional data examined by Horn and Cattell when they proposed their developmental concomitants of crystallized-fluid theory, indeed different cohort flows were represented for these abilities. Their observation thus is correct with respect to the cohort structure of abilities but wrong with respect to ontogenetic change.

But before we get too heated about all these issues let me again call attention to the fact that all our work thus far has been concerned with measuring intellectual changes in adults with measures conducted for the young (cf. Schaie, 1978). We are just beginning a new odyssey with measures specifically designed for the old, to be validated against life-situations indigenous to older individuals. But that is another story and it remains to be told at a future congress.

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Footnote

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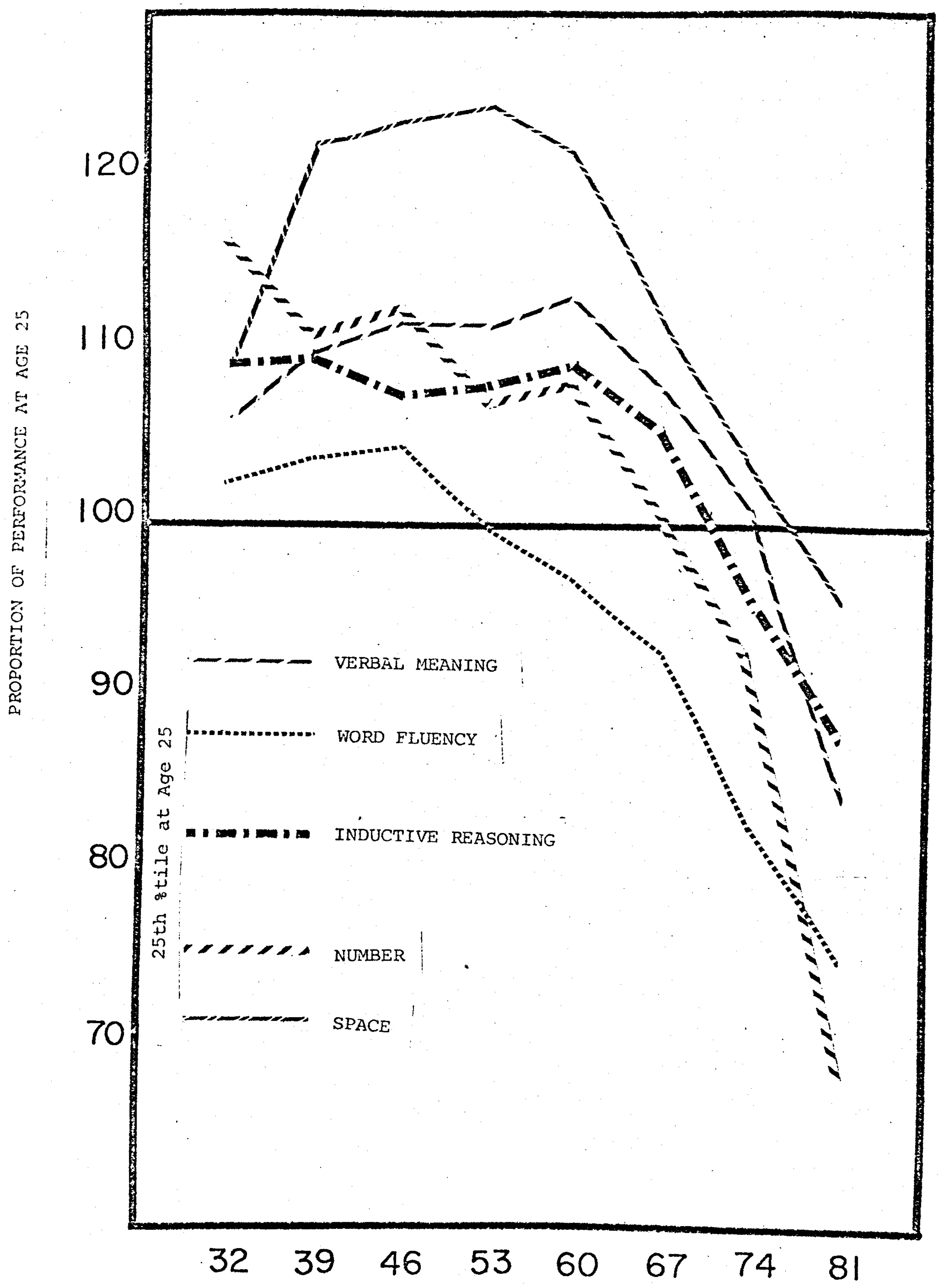

FIGURE 1. CUMULATIVE AGE CHANGES IN INTELLECTUAL ABILITIES

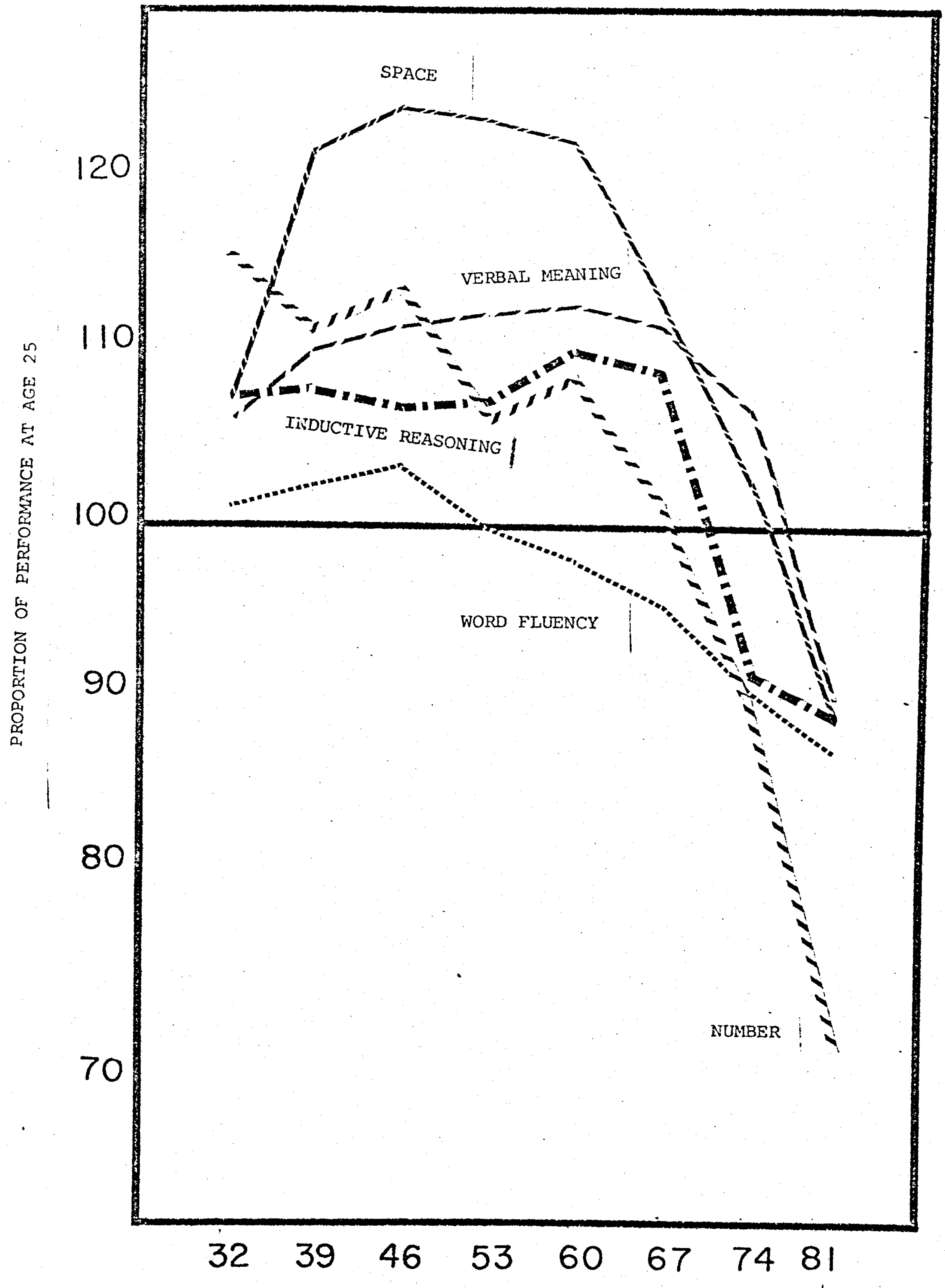

FIGURE 2. CUMULATIVE AGE CHANGES FOR PERSONS

WITHOUT CARDIOVASCULAR DISEASE

TABLE 1

Frequencies of Participants by Cohort, Sex and Data Set

		First Cohort			Second Cohort			Both Cohorts		
Set	Age	M	F	T	M	F	T	M	F	T
I	25, 32, 39	10	11	21	8	14	22	18	25	43
II	32, 39, 46	11	15	26	14	27	41	25	42	67
III	39, 46, 53	11	15	26	23	28	51	34	43	77
IV	46, 53, 60	17,	15	32	25	26	51	42	41	83
V	53, 60, 67	13	15	28	17	31	48	30	46	76
VI	60, 67, 74	3	12	15	8	10	18	11	22	33
VII	67, 74, 81	8	6	14	8	13	21	16	19	35
TOTAL		73	89	162	103	149	252	176	238	414

Table 2. Summary of Fourteen-year Age Changes and Associated F Ratios from the Univariate Analyses of Variance (Change reported in T score points)

			Verbal Meaning		Space		Reasoning		Number		Word Fluency	
Data Set	N	Ages	Mean Change	F	Mean Change	F	Mean Change	F	Mean Change	F	Mean Change	F
I	43	25, 32, 39	+ 2.84	9.48*	+1.97	2.32	+1.74	2.36	+1.13	8.33*	+2.48	3.54
II	67	32, 39, 46	+ 1.66	7.48*	+1.32	2.10	+ .34	1.03	- .09	..	- .18	1.08
III	77	39, 46, 53	+ .46	..	- .21	..	+ .38	1.74	-1.17	7.48*	- .72	3.24
IV	83	46, 53, 60	+ .49	1.94	+ .04	..	- .25	1.44	-1.42	2.73	-2.73	10.70*
V	76	53, 60, 67	- 1.95	7.22*	-1.83	2.30	-1.18	3.89	-1.88	9.73*	-1.97	8.52*
VI	33	60, 67, 74	- 3.61	2.19	-2.45	2.63	-3.24	6.57*	-2.09	3.17	-3.18	3.88
VII	35	67, 74, 81	- 7.00	14.15*	-5.83	11.47*	-5.29	14,31*	-5.80	14.47*	-6.74	21.71*

* Significant at or beyond the 1% level of confidence.

Table 3. Overall Analysis of Variance

Mean Squares for Cohort, Age and Cohort by Age Interactions

	Cohort	Overall	Age Linear	Quardratic	Age by Cohort Overall	Linear	Quard ratic
Verbal Meaning	3,298*	204*	150*	258*	125*	235*	16
Space	3,484*	88	174*	2	78*	143*	12
Inductive Reasoning	4,351*	120*	219*	20	80*	129*	29
Number	710*	425*	376*	475*	60*	83*	37
Word Fluency	719*	588*	1,074*	102	93*	178*	9

*Significant at or beyond the 1% level of confidence

Proportion of Variance Accounted for (ω^2)

	Cohort (Age Differences)	Age (Age Changes)	Cohort by Age (Differential Age Changes Between Cohorts)
Verbal Meaning	21.7%	2.8%	21.0%
Space	23.8%	0.7%	3.6%
Inductive Reasoning	32.0%	2.0%	7.3%
Number	2.8%	6.4%	4.2%
Word Fluency	3.5%	5.4%	4.1%

Table 4. Estimated Performance Level as a Proportion of Performance at Age 25 Based on Cumulative Age Changes
(Decimals omitted; 100 = Average or 25 year old comparison group)

Variable	32	39	46	53	60	67	74	81	25th % til @ Age 25
	Ages								
Verbal Meaning	107	110	112	112	113	108	101	84	87
Space	109	122	123	124	121	113	105	96	71
Inductive Reasoning	109	110	108	108	109	106	94	86	81
Number	116	111	113	107	108	100	92	69	72
Word Fluency	101	103	104	100	97	93	84	74	86

Estimated Performance Level Based Upon Participants Without Cardiovascular Disease

Verbal Meaning	107	110	112	113	113	110	106	89	87
Space	109	122	124	124	123	114	104	92	71
Inductive Reasoning	109	110	108	109	110	110	92	89	81
Number	116	111	114	107	109	101	90	73	72
Word Fluency	101	103	104	100	98	96	91	87	86