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The Seattle Longitudinal Study: A thirty-five-year inquiry of adult intellectual development

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Titel fehlt ■ ■ ■
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Summary: The Seattle Longitudinal Study (SLS) over the past 35 years has investigated individual differences and differential patterns of change for selected psychometric abilities from young adulthood old age. It has determined the magnitude and relative importance of age changes and cohort differences in different abilities. A number of contextual, health, and personality variables have been identified that offer explanations for differential change and provide a basis for possible interventions. Cognitive similarity within parent-offspring and sibling pairs has been studied and cognitive interventions were designed that have successfully remediated carefully determined declines and have improved the cognitive functions of older persons who have remained stable. Most recently, we have begun to study age changes and differences in cognitive ability structure at the latent construct level, have conducted analyses of the relative effect of speed and accuracy in age-related decline and training gain, and have investigated the relevance of cognitive training to real life tasks.

Zusammenfassung: Die Seattle Longitudinal Study (SLS) untersucht bereits seit 35 Jahren individuelle Unterschiede und unterschiedliche Veränderungsmuster vom frühen Erwachsenenalter bis in das vorgeschrittene Alter. Die Größenordnung und relative Bedeutung von Altersveränderungen und Kohortenunterschieden in verschiedenen Fähigkeitsbereichen wurden untersucht. Eine Anzahl von Umwelts-, Gesundheits- und Persönlichkeitsvariablen wurden identifiziert, die zum Verständnis unterschiedlicher Alterswege und ihrer Einflußnahme auf den Altersvorgang hin beitragen. Die Familienähnlichkeit im kognitiven Verhalten wurde in erwachsenen Eltern-Kinder und Geschwisterpaaren untersucht, und kognitive Interventionen wurden entwickelt, die zur erfolgreichen Behebung von kognitiven Defiziten wie auch zur Verbesserung kognitiver Leistung von intakten älteren Menschen führen. Letztens begannen wir die Untersuchung von Altersveränderungen und Altersunterschieden auf der Ebene von Latenzvariablen, untersuchten die relativen Anteile von Geschwindigkeit und Sorgfalt bei Altersdefiziten und kognitiven Interventionsresultaten und beschäftigten uns mit der Relevanz von kognitiven Interventionen zu Aufgaben des täglichen Lebens.

Key words: Cohort differences – cognitive training – family similarity – intelligence – rigidity-flexibility

Schlüsselwörter: Familienähnlichkeit – Intelligenz – kognitives Training – Kohortenunterschiede – Rigidität-Flexibilität

Introduction

The Seattle Longitudinal Study (SLS) began as the author's doctoral dissertation at the University of Washington in 1956. Results of our previous work have been widely disseminated in the psychological and gerontological literature. A comprehensive report of the study through 1977 may be found in Schaie (28). That report has been updated by a number of reports from analyses of the 1984 and 1991 data collections (see below). A summary of the study in German through 1977 has previously been published in this journal (26). The SLS has charted the course of selected psychometric abilities from young adulthood through old age. It has investigated individual differences and differential patterns of change. In so doing it has focused not only on demonstrating the presence or absence of age-related changes and differences, but has attended also to the magnitude and relative importance of the observed phenomena. In the more recent phases of the study we have identified a number of contextual, health, and personality variables that offer explanations for differential change and that provide a basis for possible interventions. We have also studied cognitive similarity within parent-offspring and sibling pairs. Within the context of the SLS we have designed cognitive interventions that have been successful in remediating carefully determined declines and in improving the cognitive functions of older persons who have remained stable. Most recently, we have begun to study age changes and differences in cognitive ability structure at the latent construct level, have conducted analyses of the rel-

ative effect of speed and accuracy in age-related decline and training gain, and have investigated the relevance of cognitive training to real life tasks.

Design of the SLS

The data base

The data base for the SLS consists of data acquired during our major testing cycles (1956, 1963, 1970, 1977, 1984, 1991). The 1991 data collection, now in progress, extends from 1990 to 1992 and includes a cognitive training study conducted in 1983/84 (56) and its follow-up conducted in 1990/91. In addition, there were four collateral studies concerned with issues of life complexity (1974 [14]), shifting to an expanded sampling frame (1974 [15]); dealing with the "aging" of the test battery and the consequences of paying subject fees (1975 [11, 12]); and the family similarity study (51, 52).

All of our study participants are or were members of a health maintenance organization (HMO), the Group Health Cooperative of Puget Sound, in the Seattle, Washinton metropolitan area, or are family members of these individuals. The original sampling frame in 1956 consisted of approximately 18 000 potential adult subjects. These were stratified by age and sex, with 25 men and 25 women randomly selected for each year of birth from 1889 to 1939. Testing proceeded in small groups from 10 to 30 persons until a total of 500 persons (25 men and 25 women in each 5-year age interval from 21 to 70 years) had been tested (24).

In the 1963 cycle, 301 members of the original sample were retested. In addition, approximately 3000 new names were drawn randomly from the original sampling frame, deleting those individuals who had been tested in 1956. In the second wave of the study 996 persons aged 22 to 77 years tested (54, 55). A similar procedure was followed in 1970; retesting as many survivors as possible from the first two cycles, and initially examining a new randomly selected panel of 705 persons, aged 22 to 84 years (25, 44, 45, 50). Since the original sampling frame had been substantially depleted, a collateral study determined that it would be feasible to shift to a sampling with replacement model (15). Thus, in the 1977 cycle, in addition to retesting survivors of the first three waves, we sampled 3000 persons from what had now become a 210 000 member organization. During the fourth wave 612 new subjects (aged 22 to 84) were tested (28, 40).

During the 1984 cycle retests were conducted for 839 surviving participants of the first four waves as well as a subset of 160 participants of the 1974–75 collateral studies. Again a new random sample was drawn from the now 300 000 member health plan and 628 new subjects were tested (32, 34, 42, 59). Finally, in 1991, we retested survivors from all the previous cycles as well as 725 new subjects. Figure 1 summarizes the complete design.

The HMO from which our study participants are drawn has service contracts with governmental subdivisions and labor unions that attract both blue and white collar employees, but it also has a large individually recruited membership that includes independent crafts people, service occupations, as well as all levels of professionals. Although the absolute size

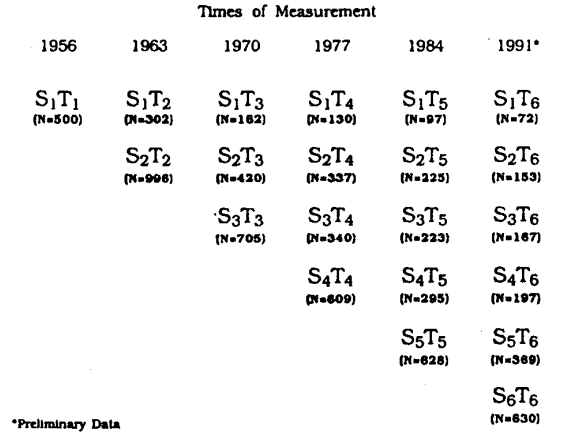

Fig. 1. Design of the Seattle Longitudinal Study.

of the HMO has increased markedly over the course of this study, its demographic composition has remained relatively stable, with the exception, of course, that average levels of education have increased and that the proportion of older participants has also grown in step with similar demographic changes in the general population. The Seattle metropolitan area is generally considered to be an inmigration area. As is well-known, its prosperity has often been related to the fortunes of the Boeing Corporation, the largest local employer. Because of the area's many attractive features, the economic fluctuations do not seem to have resulted in large-scale outmigrations that might have affected our samples. In any event, we have not observed any systematic attrition related to occupational characteristics that might have been specifically affected by related economic fluctuations.

The HMO membership as of January 1, 1987 included 316 632 individuals, of whom 219 958 were 22 years of age or older, the lower limit of our sampling frame. Approximately 53 % of this number was female. As compared with the census figures for King County, Washington, the membership (based on a recent survey of 1570 randomly selected members) followed the ethnic composition of the area, being approximately 89 % white. There was a slight excess of married and widowed members (60 % as against 55.6 %, and 8.5 % as against 6 % in the area population), and a correspondingly lower proportion of single persons (20 % as compared to 27.5 % for the area); the proportion of divorced members equalled that for the census area (9 %). Mean household size, home ownership, median household incomes, and age distributions of members were quite comparable to the area census figures. However, as indicated above, educational levels were somewhat higher; roughly 64 % of the membership had some education beyond high school, while that experience held only for 46 % of the census area. Concomitantly, only 9 % of the membership had less than a high school education; a status that occurred for 20 % of the population in the census area. From these figures, it would appear that, although our samples under-represent the lowest socio-economic segment of the population, we do have a reasonable representation characteristic of at least the upper 75 % range of the socio-economic spectrum.

Although the successive random draws from our sampling frame have been quite representative of the population described above, there has clearly been non-random attrition. We have studied the effects of attrition systematically and have found, as is true in other studies, that those who return for retest outperform those who do not return. However, we have also noted that these effects do not seem to be systematically related to the age of the participants, although reasons for drop-out may change across the age span. Furthermore, it appears that dropout effects are of greater magnitude subsequent to the first retest occasion. We have reported attrition effects for each of our cycles, and have proposed a number of corrections that remove the effects of attrition and other confounds from our estimates of cognitive age changes (1, 4, 13, 43, 31).

The measurement variables

During all six cycles of the SLS, our principal variables were the measures of Verbal Meaning, Space, Reasoning, Number and Word fluency, identified by Thurstone as accounting for the major proportion of variance in the abilities domain in children and adolescents (64) and contained in the 1948 version of the Thurstone's SRA Primary Mental Abilities Test (Form AM 11-17 [65]). A pilot study conducted prior to the first SLS cycle found this test to have adequate psychometric characteristics for work with adults (53).

The second set of variables collected consistently are the rigidity-flexibility measures from the Test of Behavioral Rigidity (23, 48), which also include a modified version of the Gough social responsibility scale (10). Limited demographic data were collected during the first three cycles.

These measures have been supplemented since 1974 with a more complete personal data inventory, the Life Complexity Inventory (LCI [14]) which includes topics such as major work circumstances (with home-making defined as a job), friends and social interactions, daily activities, travel experiences, physical environment and life-long educational pursuits.

In the 1975 collateral study (15) a number of measures from the ETS kit of factor-referenced tests (9) as well as the 1962 revision of the PMA (66) were added. Of these, the Identical Picture, Finding A's and Hidden Pattern tests (9) were included in the fourth (1977) SLS cycle. Because of our interest in exploring age changes and differences in factor structure, we included multiple markers for most abilities during the fifth (1984) cycle. We are thus now able to measure the primary abilities of Verbal Comprehension, Spatial Orientation, Inductive Reasoning, Numerical Computation, and Perceptual Speed at the latent construct level (30, 39, 60, 61). We further added measures of Verbal Memory (76), a criterion measure of "real life tasks", the ETS Basic Skills test (8), as well as a scale for measuring participants' subjective assessment of ability changes between test cycles (20, 62).

For most of our subjects who were retested in 1984, we have also abstracted their health histories over the entire period they have been in the study using the International Classification of Diseases (67), coding each outpatient visit or hospital day by diagnosis and by constructing annual illness

Table 1. The SLS measurement battery.

Constructs	Measures	Source
Inductive Reasoning	PMA Reasoning (1948)	Thurstone & Thurstone (65)
	ADEPT Letter Series (Form A)	Blieszner et al. (3)
	Word Series	Schaie (30)
	Number Series	Thurstone (66)
Spatial Orientation	PMA Space (1948)	Thurstone & Thurstone (65)
	Object rotation	Schaie (30)
	Alphanumeric Rotation	Willis & Schaie (72)
	Cube Comparisons	Ekstrom et al. (9)
Numerical Ability	PMA Number (1948)	Thurstone & Thurstone (65)
	Addition (N-1)	Ekstrom et al. (9)
	Subtraction & Multiplication (N-3)	Ekstrom et al. (9)
Verbal Ability	PMA Verbal Meaning (1948)	Thurstone & Thurstone (65)
	ETS Vocabulary (V-2)	Ekstrom et al. (9)
	ETS Advanced Vocabulary (V-4)	Ekstrom et al. (9)
Perceptual Speed	Identical Pictures	Ekstrom et al. (9)
	Finding A's	Ekstrom et al. (9)
	Number Comparison	Ekstrom et al. (9)
Verbal Memory	Immediate Recall	Zelinski et al. (76)
	Delayed Recall	Zelinski et al. (76)
	PMA Word Fluency	Thurstone & Thurstone (65)
Everyday Tasks	ETS Basic Skills	Educational testing service (8)
Rigidity-Flexibility	Test of Behavioral Rigidity	Schaie & Parham (48)
Life styles	Life Complexity Inventory	Gribbin et al. (14)
Subjective Perceptions	Family Environment	Moos & Moos (22)
	Work Environment	Moos (21)
	Ability Change	Schaie et al. (62)

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counts by illness incidents (single visits) and illness episodes (continuous series of visits for a specified diagnosis). Physician ratings of the relative severity of diagnostic entities along a normally-distributed eleven-point scale permitted construction of severity-weighted indices (17, 18, 63).

Finally, for the 1989/90 family study, we constructed modified versions of Moos' family environment and work environment scales (21, 22), in order to measure perceived environmental similarity among family members both for their current families and their families of origin (58). Table 1 lists the measures used in the study with appropriate citations to sources where these measures have been described in greater detail.

Summary of results from the SLS

Throughout the history of the SLS, we have focused on five major questions which we have attempted to ask with greater clarity and increasingly sophisticated methodologies at each successive stage of the study. This summary reviews these questions and indicates what we have learned from the SLS up to now to answer these questions. In the section that follows we will then provide information on the most recent extensions of the SLS.

1 Does intelligence change uniformly through adulthood or are there different life-course ability patterns?

Our studies have shown that there is no uniform pattern of age-related changes across all intellectual abilities, and that studies of an overall index of intellectual ability (IQ) therefore does not suffice to monitor age changes and age differences in intellectual functioning for either individuals or groups. Our data do lend some support to the notion that active or fluid abilities tend to decline earlier than passive or crystallized abilities. There are, however, important ability by age and ability by cohort interactions that complicate matters. In our most recent cross-sectional sequences, gender difference trends emerge that suggest that women may decline earlier on fluid abilities, while men do so on the crystallized abilities. Moreover, while fluid abilities begin to decline earlier, crystallized abilities appear to show steeper decrement once the late seventies are reached (28, 36, 40). With respect to perceptual speed, age changes begin in young adulthood, and show a virtually linear decrement trend (35).

While cohort-related differences in the rate and magnitude of age changes in intelligence remained fairly linear for cohorts entering old age during the first three cycles in our study, they have since shown substantial shifts. For example, rates of decremental age change have abated, while at the same time there appear to be negative cohort trends as we begin to study members of the baby-boom generation. It is beginning to appear that patterns of socialization unique to a given sex role within a specific historical period may be a major determinant for the pattern of change in abilities. More fine-grained analyses suggest that there may be substantial gender differences as well as differential changes for those who decline and remain stable, when age changes are decomposed into accuracy and speed (75). We have also demonstrated substantial relationships between the psychometric abilities and real life tasks (69, 73).

With multiple markers of abilities first available for the fifth cycle, we have conducted cross-sectional analyses of ability structure over a wide age range (41, 61). Our results suggest that it is possible to demonstrate configural but not metric factor invariance across a wide age/cohort ranges.

2 At what age is there a reliably detectable age decrement in ability and what is the magnitude of that decrement?

Data collected during the first three cycles suggested that average age decrements in psychometric abilities could not be demonstrated prior to age 60, but that such reliable decrement may be found for all abilities by age 74. Analyses from the most recent two cycles, however, suggest that small but statistically significant average decrement can be found for some, but not all, cohorts in the decade of the fifties (38, 40). More detailed analyses of individual differences in intellectual change, however, demonstrate that even at age 81 less than half of all observed individuals have shown reliable decremental change over the preceding seven years (29). In addition, average decrement before age 60 amounts to less than two-tenths of a standard deviation, while by age 81 average decrement rises to approximately one standard deviation for most variables (28, 29). The magnitude of decrement, moreover, is significantly reduced, when the effects of age changes in perceptual speed are removed (35).

The data from the SLS attain increasing importance in providing a normative base to determine at what ages declines reach practically significant levels of importance for public policy issues related to mandatory retirement, age discrimination in employment or for cases of population proportions that can live independently in the community. From the SLS data we were able to show that both level of performance and rate of decline show significant age by cohort interactions (26, 28, 40). Data from the fifth cycle indicate that these changes continue, but also behave differently depending upon the ability variable studied (31, 37, 38, 59).

3 What are the patterns of generational differences and what is their magnitude?

Results from the SLS have conclusively demonstrated the prevalence of substantial generational (cohort) differences in psychometric abilities (25, 28, 37, 38, 40, 44, 55, 70). These cohort trends differ in magnitude and direction by ability and can therefore not be determined from composite IQ indices. There has been an almost linear positive cohort shift for Inductive Reasoning, with more spasmodic positive shifts for Verbal Meaning and Spatial Orientation. On the other hand, a curvilinear cohort pattern has been found for Number skills, reaching a peak with the 1924 birth cohort and progressive negative slope thereafter. Cohorts born more recently are also at a disadvantage when compared with prior cohorts on the variable of Word Fluency (38). Cohort gradients for the five measures given throughout the study are shown in Fig. 2.

From these findings it can be concluded that cross-sectional studies used to model age change will overestimate age changes prior to the sixties for those variables that show negative cohort gradients, and underestimate age changes for

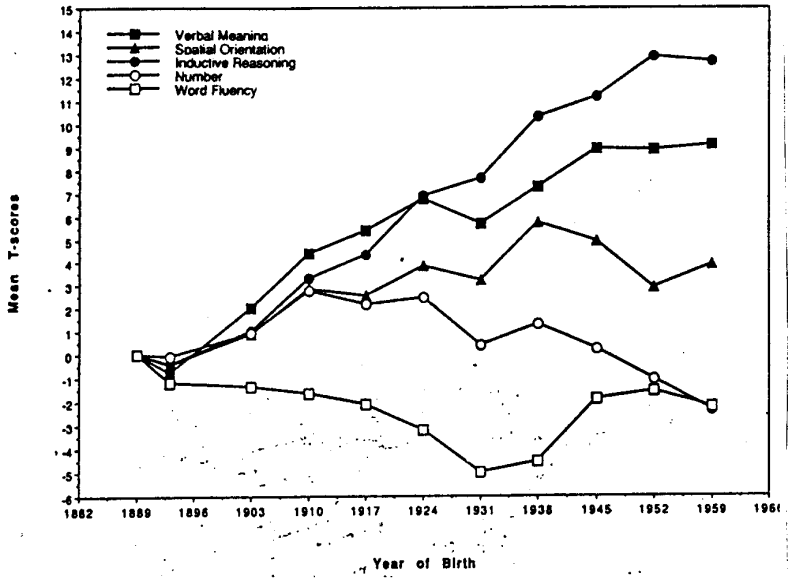

Fig. 2. Cumulative cohort differences between cohorts born in 1889 and 1959.

those variables with positive cohort gradients (e. g., for perceptual speed [35]). We have also been particularly interested in following the observed negative cohort trends on SAT scores, as the baby boomers enter our adult samples. By cycle 5 of the SLS we had observed only two cohorts in that category. The trends, however, are clearly negative extending to the variables we monitor in adulthood.

4 What accounts for individual differences in age-related change in adulthood?

The most powerful and unique contribution of a longitudinal study of adult developments is made due to fact that only longitudinal data permit investigation of individual differences in antecedent variables that lead to early decrement for some persons and maintenance of high levels of frunctioning for others well into very advanced age. Previous results from the SLS have implicated a number of factors that account for these individual differences, some of which have been shown to be amenable to experimental intervention. The variables most intensively studied thus far that have been implicated in reducing risk of cognitive decline in old age have included: a) Absence of cardiovascular and other chronic diseases (17, 18, 63); b) favorable environment mediated by high SES (14, 29, 63); c) involvement in a complex and intellectually stimulating environment (6, 14, 46); d) flexible personality style at midlife (29); e) high cognitive status of spouse (16); and f) maintenance of high levels of perceptual processing speed (35).

5 Can intellectual decline with increasing age be reversed by educational intervention?

Because longitudinal studies permit tracking stability or decline on an individual level, we have also been able to carry out interventions designed to remediate known intellectual decline, as well as to reduce cohort differences in individuals who have remained stable in their own performance over time, but who have become disadvantaged when compared to younger peers. The cognitive training study conducted with our longitudinal subjects suggested that observed decline in many community dwelling older people might well be a function of disuse and is clearly reversible for many. Indeed, approximately two-thirds of the experimental subjects showed significant improvement, and about 40 % of those who had declined significantly over 19 years were returned to their pre-decline level (42, 56, 74). In addition, we were able to show that we did not simply train the test, but rather trained at the ability (latent construct) level and that the training did not disturb the ability structure (60).

Summary of recent study findings

The Family Similarity Study

In the most recent phase of our study we have further entered the field of developmental behavior genetics and have investigated the degree to which ability performance is similar within families, and to validate our findings on cohort differences within natural families. Most work in developmental behavior genetics has been conducted by means of twin studies. It has only recently been recognized that, because of the unique characteristics of twins, broad generalizations from such studies will be limited and corroborative data are therefore needed from family studies of parent/offspring and nontwin siblings. Thus far such studies have been done only with parents and their young offspring and young sibs; our study is the first effort to explore systematic family similarity through adulthood, as well as testing for stability of such similarity over time.

All participants in the 1984 (5th cycle) were contacted and asked to provide the names and addresses of their adult children and siblings. A total of 3897 family members were contacted, of whom 1515 initially agreed to participate in the study. However, a substantial number of prospective participants did not live in or were not willing to travel to locations

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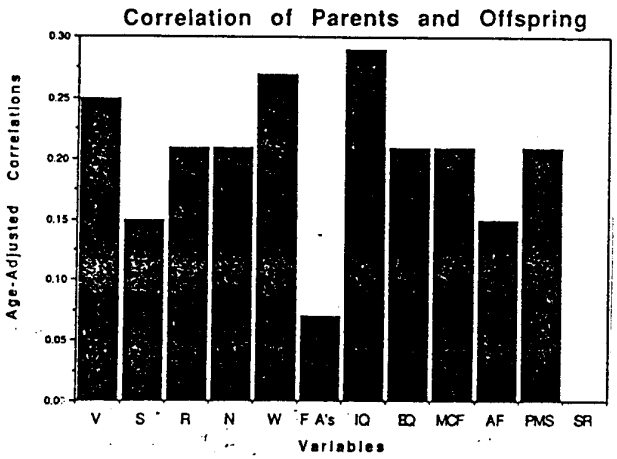

Fig. 3. Intra-pair correlations between parents and their adult offspring.

where standard test administrations could be conducted. A total of 1176 participants of the family study have been tested. Of these, 776 are adult offspring (465 daughters and 311 sons), and 400 siblings (248 sisters and 152 brothers) of SLS participants. All subjects were tested on the basic five PMA tests, the Finding A's test, and the Test of Behavioral Rigidity. They also completed a family contact scale, the family and work environment questionnaires, as well as the standard SLS personal data form.

Substantial family similarity of an average magnitude of about .25 was found for virtually all mental abilities and measures of flexibility. The similarities were found for parents and their offspring (adult children) and for siblings (brothers and sisters). The two exceptions to this finding were for the attitude measure of Social Responsibility and for a measure of perceptual speed; neither of which seems to display inherited characteristics. The size of the correlations were also comparable to those found between young adults and their children in other studies. Figure 3 shows the degree of similarity for each of the six abilities between parents and adult children. Similarity is represented as the genetic correlation

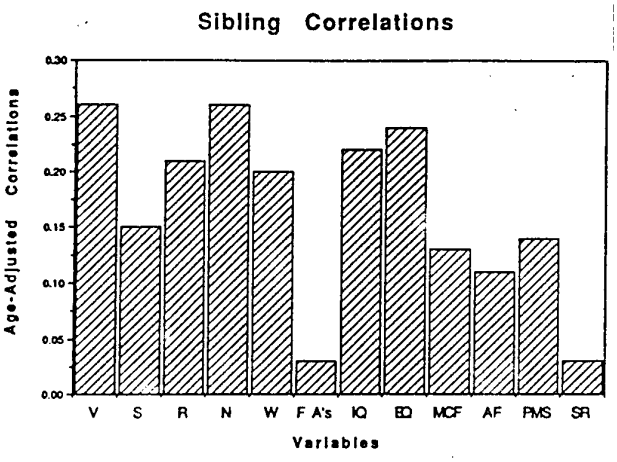

Fig. 4. Intra-pair correlations between adult siblings.

of parent and child. Figure 4 shows the degree of similarity between brothers and/or sisters. In addition to the individual abilities, the figures also present composite scores called "Intellectual Aptitude (IQ)" and "Educational Aptitude (EQ)".

If shared environmental influences are relatively unimportant in adulthood, then similarity within parent-offspring and sibling pairs should remain reasonably constant in adulthood across time and age. We studied this question with a group of persons for whom we have data over a 21-year period, and were able to confirm that family similarity indeed remains constant over the adult life-span. Contact frequency between family members has also been examined (2, 51, 52).

Health History Study

Health history abstracts for those subjects who entered the study prior to 1977 and who were included inour 1984 data collection are available for 845 participants. As part of the dissertation of Gruber-Baldini (17) this data set has now been fully analyzed for the incidence of disease, clustering of disease with cognitive decline, and for comorbidity. Analyses were also conducted (for the total sample and by gender) for the age of onset of diseases. Detailed analyses were conducted of the role of hypertension, cardiovascular disease, diabetes, arthritis, and malignant neoplasms in affecting cognitive decline with advanced age. Models were tested for effects on level of functioning as well as rate of change.

Cognitive Training Study

In our follow-up cognitive training study, just completed, we wished to assess maintenance of cognitive training effects for subjects trained 7 years earlier and to replicate training effects in a new cohort. A total of 313 subjects have been trained and tested. Of these, 135 were previously trained in 1983/84 and received booster training. The remaining 178 subjects were initially trained during the present cycle. Subjects initially trained in 1983/84 were given booster training on the same ability (inductive reasoning or spatial ability) that they had originally been trained on. Those trained initially in 1991/92 were assigned to training for the ability on which they had declined (1977 to 1991) if they remained stable or had declined on both, they were randomly assigned to one of the training conditions.

In 1990/91 subject trained in 1983/84 were functioning, on average, at their 1983/84 pretest level. In contrast, the comparison group (those trained on the other ability) was functioning significantly below their 1983/84 pretest level. In other words, there is a significant maintenance of function on the trained ability, even after a 7-year interval. In addition, significant, ability-specific training effects were obtained for the 1990/91 booster training, albeit the effect of the booster training had somewhat lower magnitude in these subjects who are now 7 year older.

Preliminary analyses of the replication (first time training) suggest that significant training effect and near transfer to alternate operational forms of the target tests can again be demonstrated, and that significant effects of training in excess of pretest-posttest practice can be demonstrated, as well at the latent variable level. We also replicate stronger training effects for the Inductive Reasoning that the Spatial Orientation

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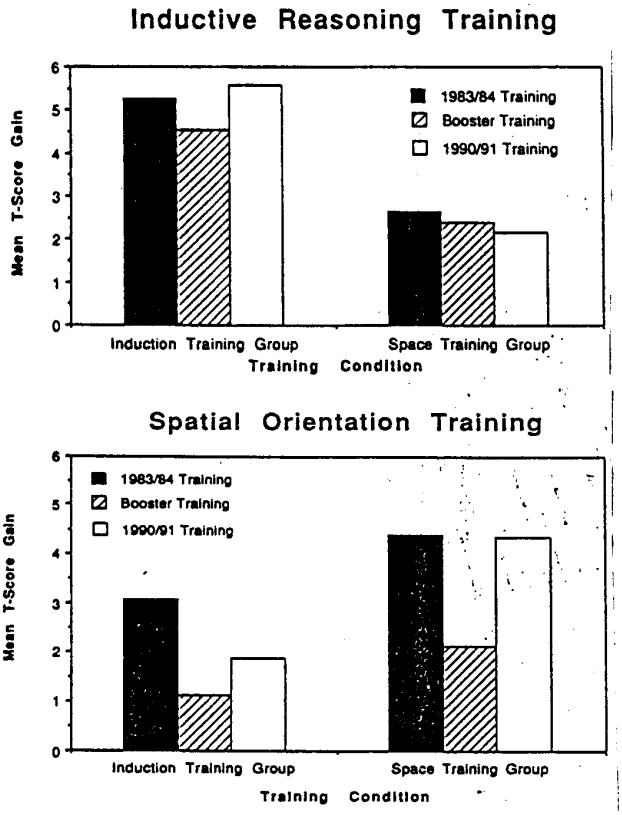

Fig. 5. Magnitude of training gain for original, replicated, and booster cognitive training on the abilities of Spatial Orientation and Inductive Reasoning.

Legend: V = Verbal; S = Space; R = Reasoning; N = Number; W = Word Fluency; FA's = Perceptual Speed (Finding A's); IQ = Ability Composite; EQ = Educational Aptitude; MCF = Motor-Cognitive Flexibility; AF = Attitudinal Flexibility; PMS = Psycho-Motor Speed, SR = Social Responsibility.

ability. Figure 5 compares training gains at the factor level for initial training in 1983/84 and 1990/91 and effects of booster training (1990/91) for Induction and Space training. The lower average level of gain in the booster training could be due to the fact that subjects, on average, are now in the old-old range, or that the residual of the earlier training brought them closer to their personal asymptote. Further analyses and additional data collections are needed to answer this question.

Other contributions from the Seattle Longitudinal Study

As the SLS data archive grows new questions arise that can be answered through secondary data analyses. Analyses in depth have been conducted on our longitudinal data on cognitive style, psychomotor performance and personality traits (47, 49, 57), the generalizability of age difference patterns within and across ability domains (59); structural analyses of the relation between flexibility-rigidity and the primary mental abilities (5, 39), cross-sectional and longitudinal studies of perceptual speed and its impact upon cognitive decline (35), studies of activity patterns through adulthood and their relation to mental abilities (19), participants' subjective perception of cognitive change over time (20, 62), applicability of event history analysis methods to the prediction of cognitive decline (34), individual change profiles in cognitive abilities (33), a cross-cultural comparison of American and Chinese PMA data (7), fine-grained analyses of cognitive training effects (71), and further contributions to issues of cohort differences and the relation between intellectual abilities (37, 38, 68, 70).

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