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The Seattle Longitudinal Study: Relationship Between Personality and Cognition

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Abstract

This article reviews the history, measures and principal findings of the Seattle Longitudinal Study. This study began in 1956 focusing upon age differences and age changes in cognitive abilities. Its sampling frame is a large HMO in the Pacific Northwest. The study has been expanded to investigate various influences on cognitive aging including, cognitive styles, personality traits, life styles, and family environment. Current interest is also in the early detection of risk for dementia. In addition, this article reports original analyses of the relation of personality dimensions to cognitive abilities (both concurrent and longitudinal). While personality remains relatively stable over the adult life span, modest proportions of variance are shared between various personality traits and the cognitive abilities.

INTRODUCTION

In this article we will provide an overview of the Seattle Longitudinal Study (SLS). Because this study has provided a major model for longitudinal-sequential studies of aging we emphasize the basic conceptual model, the design, and the measures utilized. But we also provide a summary of the major findings thus far obtained, including the major references to more detailed descriptions of these findings. We then turn to the topic of the relationship between personality traits and cognition and report results of analyses of new data collected during our most recent assessment wave as well as findings resulting from the integration of the new data with data previously collected.

The Seattle Longitudinal Study began as the senior author's doctoral, dissertation at the University of Washington in 1956 {Schaie, 1958, 2000b). Results of previous work on the SLS have been widely disseminated in the psychological and gerontological literature. Comprehensive reports of the study can be found in Schaie (1983[1956–1977]; 1996 [1956–1991], 2004, [1956–1998]).

In brief, 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. More recent phases of the study have identified contextual, health, and personality variables that offer explanations for differential change and that provide a scientific basis for possible interventions. We have also studied cognitive similarity within parent-offspring sibling pairs, and have recently begun to acquire data on a third generation (participants who have both a parent and a grand-parent participating in the SLS). Cognitive

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Further information on the Seattle Longitudinal Study can be obtained at http://geron.psu.edu/sls.

interventions have been designed that have been successful in remediating statistically reliable declines and in improving the cognitive functions of older persons who have remained stable. Age changes and age differences in cognitive ability structure have also been studied at the latent construct level, the relative effect of speed and accuracy in age decline and training gain has been examined, and the relevance of cognitive training to real life tasks has been investigated. Work in progress seeks to relate our behavioral data to neuropsychological diagnostic procedures, to study behavior-stractural-anatoraical relation-via data collected at autopsy and to investigate the cognitive change correlates of the Apolipoprotein-E marker gene and of serum cholesterol level. A schematic conceptual model for the study is shown in Figure 1.

DESIGN OF THE SLS

The Data Base

The data base for the SLS consists of data acquired during our seven major testing cycles (1956, 1963, 1970, 1977, 1984, 1991, 1998; see Fig. 2). The 1984, 1991 and 1998 data collections also included cognitive training follow-up studies (Schaie, 1996;Schaie & Willis, 1986b;Willis & Schaie, 1994). In addition there were four collateral studies concerned with issues of life complexity (1974; Gribbin, Schaie, & Parham, 1980), shifting to an expanded sampling frame (1974; Schaie, 1996) dealing with the “aging” of the test battery (1975; Schaie, 1996) and the family similarity study (1989–90 and 1996–97; Schaie, Plomin, Willis, Gruber-Baldini, & Dutta, 1992;Schaie, Plomin, Willis, Gruber-Baldini, Dutta, & Bayen, 1993;Schaie & Willis, 1995). Current data collections involve the neuropsychological testing of participants aged 60 or older, Apolipoprotein-E testing, and autopsy studies, as well as follow-up data collections on participants in the family study.

All of our study participants are or were originally members of an HMO, the Group Health Cooperative of Puget Sound, in the Seattle, Washington metropolitan area, or are family members of these individuals. The initial sampling frame in 1956 consisted of approximately 18,000 potential adult participants. 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 ten to thirty 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 (cf. Schaie, 1958).

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 22–77 years were (Schaie & Strother, 1968). 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 22–84 years (Schaie & Labouvie-Vief, 1974). 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 (1974; Schaie, 1996). Thus, in the 1977 cycle, in addition to retesting survivors of the first three waves, we sampled 3000 persons from what had by then become a 210,000 member organization. During the fourth wave 612 new participants (aged 22–84) were tested (Schaie, 1983). 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 random sample was drawn from the now 300,000 member health plan and 628 new participants were tested (Schaie, 1988, 1996). In the 1991 cycle 1117 surviving participants were reassessed and 693 new participants were tested from a new random sampling of the plan that now exceeds 400,000 members (Schaie, 1996). Finally, in the 1998 cycle we reassessed 1051 participants and added a new random sample of 724 participants.

The response rates of potential participants have ranged from 16% for the 1956 data collection to 11% for the most recent data collection, with best response for the middle aged and worst response for young adult males. However, the demographic characteristics of our sample do not differ significantly from their parent population.

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, have found, as is true in other studies (e.g., Palmore, Busse, Maddox. Nowlin, & Siegler, 1985; Rott, 1993; Sliwinski & Buschke, 1999), 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, dropout effects are of greatest magnitude subsequent to the first retest occasion, but lessen progressively the longer participants remain in the study. Less than 5% of our participants were lost through refusal to return. We have reported attrition effects for each of our study cycles, and have proposed a number of corrections that correct for the effects of attrition and other confounds from our estimates of cognitive age changes (cf. Schaie, 1996).

The main SLS database currently consists of the 9,476 complete records on 4,857 participants, of whom. 36 were tested seven times, 122 were six times, 223 were tested five times, 281 four times, 527 were tested three times, 1,004 were tested twice, and 2,664 participants were tested only once. Cumulatively this results in a total of 2,193 participants followed over 7 years, 1,189 over 14 years, 662 over 21 years, 381 over 28 years, 158 over 35 years, and 36 over 42 years. Five hundred and eighty participants of the training study received an additional test administration after a one-month interval (also see Schaie, 1996, 2004).

The *family study archive* contains 776 adult offspring of longitudinal participants (465 daughters and 311 sons). It also contains 400 siblings of the longitudinal participants (248 sisters and 152 brothers). These participants were first tested with the basic test battery in 1989–90. Of these participants, 886 persons were successfully retested in 1996–97 (385 daughters, 229 sons; 177 sisters, 95 brothers). In addition, 672 relatives not previously tested were added to the archives during 1996–97 (239 daughters, 134 sons; 162 sisters, 107 brothers).

THE MEASUREMENT VARIABLES

During all seven cycles of the SLS, our principal dependent 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 (Thurstone, 1938) contained in the 1948 version of the Thurstone's SRA Primary Mental Abilities Test (Form AM 11–17; Schaie, 1985; Thurstone & Thurstone, 1949). The second set of variables that has been collected consistently includes the rigidity-flexibility measures from, the Test of Behavioral Rigidity (Schaie & Parham, 1975), which also include a modified version of the Gough social responsibility scale (Gough, McCloskey, & Meehl, 1952). Limited demographic were collected during the first three cycles. The above measures are referred to as the "Basic Test Battery," and have been supplemented since 1974 with a more complete personal data inventory, the Life Complexity Inventory (LCI; Gribbin et al., 1980), 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. The battery was expanded in 1991 by adding the Moos Family Environment and Work Scales (Moos, 1981, 1986; Schaie & Willis, 1995), and a family contact scale. A Health Behavior Questionnaire (Maier, 1995; Maitland, 1997) was in 1993.

In the 1975 collateral study (Schaie, 1996) a number of measures from the ETS kit of factor-referenced tests (Ekstrom, French, Harman, & Derman, 1976) as well as the 1962 revision of

the PMA (Thurstone, 1962) were added. Of these the Identical Picture, Finding A's and Hidden Pattern tests (Ekstrom et al., 1976) were included in the fourth (1977) SLS cycle.

To be able to explore age changes and differences in factor structure, we included multiple markers for most abilities during the fifth (1984) cycle. We also added measures of Verbal Memory (Zelinski, Gilewski, & Schaie, 1993). This now permits us to measure the primary abilities of Verbal Comprehension, Spatial. Orientation, Inductive Reasoning, Numerical Facility, Perceptual. Speed and Verbal Memory at the latent construct level (cf. Schaie, Dutta, & Willis, 1991; Schaie, Maitland, Willis, & Intrieri, 1998). The expanded cognitive battery is described referenced in Table 1. Also added were a criterion measure of "real life tasks," the ETS Basic Skills test (Educational Testing Service, 1977), and a scale for measuring participants' subjective assessment of ability changes between test cycles (Schaie, Willis, & O'Hanlon, 1994). Beginning in 1997 we substituted the Everyday Problems Test (EPT, Diehl, Willis, & Schaie, 1995; Willis, 1992, for the Basic Skills test, since the more recent test was specifically constructed for work with adults and has been related to measures of the Instrumental Activities of Daily Living (IADL; Lawton & Brody, 1969).

We have abstracted the health histories of most of our participants who were retested in 1991 and/or 1998, and who have been tested two or more times, over the entire period they have been in the study using the International Classification of Diseases (U.S. Public Health Service, 1968), coding each outpatient visit or hospital day by diagnosis and by constructing annual illness counts by illness incidents (single visits) and illness episodes (continuous series of visits for a specified diagnosis). Records of drugs used concurrently with the psychological testing were also obtained and coded (American Society of Hospital Pharmacists, 1985). These data have been used to study the relation of health, cognition and mortality (e.g., Bosworth & Schaie, 1997; Bosworth, Schaie, & Willis, 1999).

SUMMARY OF RESULTS OF PREVIOUS WORK ON THE SLS

Throughout the history of the SLS, an effort now extending over 48 years, we have focused on five major questions with regard to the nature and antecedents of cognitive decline across adulthood, which we have attempted to ask with greater clarity and increasingly sophisticated methodologies at each successive stage of the study:

1. Does intelligence change uniformly through adulthood or are there different life course ability patterns?
2. At what age are there reliably detectable age decrements in ability and what is the magnitude of these decrements?
3. What are the patterns of generational differences and what is the magnitude of these differences?
4. What accounts for individual differences in age-related change in cognitive abilities in adulthood?
5. Can intellectual decline with increasing age be reversed by educational interventions?

More recently we have considered three other questions. The first concerns family similarity in level and rate of change of cognitive functioning. The second begins to bridge behavioral science biology by inquiring into structural anatomical and physiological changes that correlate with behavior. The third topic concerns the bridge between the study of normal aging and the precursors of dementia. This summary will review what we have learned from the SLS up to now to answer the five basic questions as well as provide some information on the family studies.

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 do 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 fluid abilities tend to decline earlier crystallized abilities. There are, however, important ability by age and ability by cohort interactions that complicate matters. In our most recent (cycles 4–7) 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 show steeper decrement once the late seventies are reached (cf. Schaie, 1996, 2004). With respect to perceptual speed, age changes begin in young adulthood, and show a virtually linear decrement trend (Schaie, 1989). Figure 3 provides a graphic view of our latest estimates of the longitudinal age changes on the six latent ability constructs.

While cohort-related differences in the rate 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, of decremental age change have abated, while at the same time negative cohort trends are appearing as we begin to study members of the baby-boom generation. 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 finegrained analyses suggest that there may be substantial gender differences for those who remain stable as well as differential changes for those who decline, when age changes are decomposed into those due to accuracy or speed (cf. Willis & Schaie, 1988). We have also demonstrated substantial relationships between the psychometric abilities and real life tasks (Willis & Schaie, 1986).

With multiple markers of abilities first available for the fifth cycle, we have conducted cross-sectional and longitudinal analyses of ability structure invariance over a wide age range (Maitland, Intrieri, Schaie, & Willis, 2000; Schaie et al., 1998). Two types of invariance may be distinguished. The first, configured invariance, implies that the same measurement variables load on the same factors across time or different groups. This is a minimal requirement that assures that the constructs of interest remain stable over time. Metric invariance implies the additional requirement that the factor loadings retain the same magnitude across time or groups. In this case we can be assured that the measurement metric remains constant. Our results suggest that it is possible to demonstrate configural but not metric factor invariance across a wide age/cohort range, but that metric invariance within cohorts over seven years prevails at all but the oldest ages.

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 of the SLS 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 three cycles, however, suggest that small but statistically significant average decrement for some abilities can be found for some, but not all, cohorts in the 50s (Schaie, 1996, in press). Analyses of individual differences, however, demonstrate that even at age 81 less than half of all observed individuals experienced reliable decremental change on a particular ability over the preceding seven years (Schaie, 1984). 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 (Schaie, 1984, 1996). The magnitude of decrement,

moreover, is significantly reduced, when the effects of age changes in perceptual speed are removed (Schaie, 1989).

The data from the SLS have attained 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 both level of performance and rate of decline show significant age by cohort interactions (Schaie, 1983, 1996, 2000a).

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 (Schaie, 1983, 1996; Willis, 1989). 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 negative slope thereafter. Cohorts born more recently are also at a disadvantage when compared with prior cohorts on the variable of Word Fluency. It can be concluded from these findings that cross-sectional studies overestimate age changes prior to the 60 s for those variables that show negative cohort gradients and underestimate age changes for those variables with positive cohort gradients (e.g., for perceptual speed; Schaie, 1989). The negative cohort trends observed on SAT scores have reappeared in our study as baby boomers entered adulthood. However, these trends, extending to the variables we monitor in adulthood, are confounded with period effects, suggesting somewhat lower performance over time for a fairly wide age range. Figure 4 provides a graphic view of cumulative cohort differences for the five mental ability measures used throughout the study from the cohort born in 1889 to that born in 1973.

What Accounts for Individual Differences in Age-Related Change in Adulthood?

The most powerful and unique contribution of a longitudinal study of adult development 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 functioning 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 (Bosworth & Schaie, 1997; Hertzog, Schaie, & Gribbin, 1978); (b) favorable environment mediated by high SES (Gribbin, Schaie, & Parham, 1980; Schaie, 1984); (c) involvement in a complex and intellectually stimulating environment (Gribbin et al., 1980; O'Hanlon, 1993; Schaie, 1984, 1996; Schaie & O'Hanlon, 1990); (d) flexible personality style at midlife (Schaie, 1984, 1996); (e) high cognitive status of spouse (Gruber-Baldini, Schaie, & Willis, 1995); and (f) maintenance of high levels of perceptual processing speed (Schaie, 1989).

Can Intellectual Decline with Increasing Age be Reversed by Educational Intervention?

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 studies conducted with our longitudinal participants suggested that observed decline in many community dwelling older people is likely to be a function of disuse and is therefore reversible for many. Indeed, approximately two thirds of the

experimental participants showed significant improvement, and about 40% of those who had declined significantly over 14 years were returned to their pre-decline level (Schaie & Willis, 1986; Willis & Schaie, 1986b). Training effects are long-lasting with the trained participants still at an advantage over their controls after 7 and 14 years (Schaie, 1996, 2004; Willis & Schaie, 1994).

What is the Degree of Stability of Family Similarity Over Age and Time and What is the Magnitude of Within-Family Cohort Differences?

In 1990–91 we were able to assess 776 adult offspring and 400 siblings of SLS participants. We found that family members shared approximately 25% of the variance 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 magnitude of parent-offspring and sibling similarity differed for specific abilities, the overall similarity was somewhat greater for parent-offspring pairs. The size of the correlations among family members were also comparable to those found between young adults and their children in other studies (cf. DeFries, Vandenberg, & McClearn, 1976). Generational differences within families were similar in magnitude to those reported earlier for unrelated individuals (Schaie, Plomin, Willis, Gruber-Baldini, & Dutta, 1992; Schaie, Plomin, Willis, Gruber-Baldini, Dutta, & Bayen, 1993). In 1996–97 we were able to complete a follow-up on 669 adult offspring and 334 siblings. An additional 466 offspring and 334 siblings were also added (cf. Schaie, 2004).

A revision of the Moos Family Environment and Work Environment scale was constructed. Separate forms were constructed to survey family environment in the family *of origin* and the *current family*. Psychometric analyses of these forms have demonstrated retention of construct validity for our revised forms, equivalence of structure across the family of origin and current family versions, as well as comparability across different age levels throughout adulthood. Substantial changes in perception of family environments over time was found to occur in both parent and adult offspring, with greater similarity found between the parent's current family and offspring's family of origin (same family) than between current families or families of origin for either generation (Schaie & Willis, 1995).

What is the Relation Between Cognition, Health and Mortality?

We have revisited the phenomenon of terminal decline, and have shown that lower levels of cognitive functioning and decline in crystallized abilities seven to fourteen years prior to death are important predictors of mortality (Bosworth, Schaie, & Willis, 1999; Bosworth, Schaie, Willis, & Siegler, 1999). Cluster analyses have identified five distinct patterns in which cognitive decline chronic disease predict mortality (Bosworth & Schaie, 1999).

The effects of structural and functional social support as well as age and previous health status on health outcomes was examined (Bosworth & Schaie, 1997). The latent outcome variable is marked by number of physician visits, hospital stays, and number of illness diagnoses over a 7 year period. Structural social support is marked by demographic variables and functional social support is measured by the Moos family environment scales (Moos, 1986). Results of this study suggest that social support variables account for only very small amounts of individual differences variance (primarily in those individuals with greatest disease incidence), while previous health status accounts for substantial, variance.

Recent Findings

Changes in Rate of Aging—We now have available 7-year longitudinal change data for parents and adult offspring assessed at approximately the same ages. These data have allowed us to supplement the findings on generational differences in level of performance to address the question of whether rates of aging have changes. The findings suggest that during young old age, the slopes of decline for several of the primary mental abilities have significantly flattened. This is the case for Verbal Meaning, Inductive Reasoning, Spatial Orientation, and Psychomotor Speed. (Schaie, 2004).

Early Detection of Risk for Dementia—Data on the CERAD neuro-psychology measures have been accumulated for over 500 study participants over the age of 60. From these data individuals were rated by neuro-psychologists as normal, to be monitored, probably demented, or demented. Using the methods of extension analysis (describe above) neuro-psychology measures were estimated from psychometric tests collected seven and fourteen years previously. We found that a significant proportion of study participants who were eventually diagnosed as demented could have been predicted from data collected 7 and 14 years earlier, (cf. Schaie, Caskie, et al., in press).

In summary, the Seattle Longitudinal Study has provided a model for longitudinal-sequential studies of cognition over the adult life course. It introduced the concept of cohort into cognitive aging research, and it has pioneered family studies of cognitive aging. It has substantively contributed to our understanding of the varied indigenous and exogenous influences on cognitive aging, including health, life styles, and personality characteristics. Most recently it has expanded to studies of early identification of risk for dementia and policy relevant studies of generational differences in rates of cognitive aging.

THE RELATION OF PERSONALITY AND COGNITION

Throughout the SLS we have collected limited personality data that have been derived from, the questionnaire part of the Test of Behavioral Rigidity (TBR; Schaie & Parham, 1975). Most recently we have also collected data on the NEO Personality Inventory (Costa & McCrae, 1992). In this section we report new analyses that speak to the relationship between personality traits and performance on tests of cognitive abilities.

METHODS

Participants

Included in these analyses are three different subsets from the SLS. The first set used for the analyses of concurrent relationships between personality factors and cognitive abilities consists of the 1,761 participants who were assessed during the SLS seventh data collection and who had both personality and cognitive ability scores. The second set used for the longitudinal analyses consists of the 1,055 participants who have personality factor and cognitive scores in both 1991 and 1998. Of these participants 667 have scores also in 1984, 419 in 1977, 285 in 1970 and 157 in 1963. The third set consists of 1,501 participants who completed the NEO and who have 1998 cognitive ability scores.

Measures

The measures include the cognitive ability scores described above (see Table 1), the cognitive factor scores, and the five NEO factor scores.

Personality Factor Scores—A factor analysis was conducted on the 75 questionnaire items in the Test of Behavioral Rigidity (TBR; Schaie & Parham, 1975) using 4326 test records

accumulated over the 1963–1984 study cycles. Initial analyses considering the number of factors unambiguously represented in the data resulted in an acceptable 13-factor model with good fit (χ^2[*df* = 1,191] = 3,548.16, *p*<.00l; *GFI* = .945, *RMSR* = .007). The 13-factor model was then tested by means of confirmatory factor analyses on the participants assessed in 1977 and 1984, and it continued to show an acceptable fit (χ^2[*df* = 1,191] = 4,302.98, *p*<.001; *GFI* = .941, *RMSR* = .007). A two-group analysis further investigated factorial invariance across time by constraining factor loadings and factor variance–covariance matrices to be equal across the two data sets. This analysis also yielded an acceptable fit (χ^2[*df* = 2,512] = 6,910.00, *p*<.00l; *GFI* = .945, *RMSR* = .007). (Maitland, Dutta, Schaie, & Willis, 1992).

The 13-factor model includes 8 factors that can be mapped upon the Cattell (1957; Cattell, Eber, & Tatsuoka, 1970) taxonomy of personality dimensions: Affectothymia, Superego Strength, Threctia, Premsia, Untroubled Adequacy, Conservatism of Temperament, Group Dependency, and Low Self-Sentiment. The remaining five factors are best described as attitudinal traits and were labeled Honesty, Interest in Science, Inflexibility, Political Concern, and Community Involvement.

The factors that were mapped upon one end of the trait continuum described by Cattell, have been described as follows (Cattell, Eber, & Tatsuoka, 1970):

Affectothymia – Outgoing, warmhearted, easygoing, participating tendencies.

Superego Strength – Conscientious, persistent, moralistic, staid.

Threctia — Shy, timid, restrained, threat-sensitive.

Premsia – Tender-minded, sensitive, clinging over-protected.

Untroubled Adequacy – Self-assured, placid, secure, complacent, serene.

Conservatism – Respecting traditional ideas, tolerant of traditional difficulties.

Group Dependency – A “joiner” and sound follower, group adherence.

Low Self-Sentiment – Uncontrolled, lax, follows own urges, careless of social rules.

The additional five attitudinal traits may be described as follows:

Honesty – Endorsement of items that reflect personal beliefs of honesty

Interest in science – Endorsement of an item couplet that reflects interest in science

Inflexibility — Endorsement of items that reflect lack of tolerance for disruption of routines

Political Concern – Reflects attitudes toward other countries

Community Involvement — Endorsement of positive attitudes about citizenship and civic responsibilities.

The NEO Personality Inventory—The scales in this inventory (Costa & McCrae, 1992) are described as follows:

***Neuroticism* (N):** This scale contrasts adjustment or emotional stability with maladjustment or neuroticism.

***Extraversion* (E):** Extraverts are sociable but also assertive, active and talkative. Introverts are reserved, independent and they prefer to be alone.

***Openness* (O):** Open individuals are curious, willing to entertain novel ideas and unconventional, values. They experience positive and negative emotions more intensely than do closed individuals.

***Agreeableness* (A):** Agreeable persons are altruistic, sympathetic to other and eager to help, expecting others to be equally helpful in return. Disagreeable persons are egocentric, sceptical of others' intentions and competitive rather than cooperative.

***Conscientiousness* (C):** High scorers are scrupulous, punctual and reliable. Low scores do not necessarily lack moral principles, but are less exacting in a-plying them, more hedonistic, and more lackadaisical in working towards their goals.

Procedures

The TBR Questionnaire (from which the 13 personality factor scores are derived) was administered either as part of the cognitive group testing sessions or as part of a take-home package. The NEO was administered as a mail survey.

Extension Analysis—In order to permit postdiction of past standing on the NEO we conducted an extension analysis that was designed to project the NEO scores into the TBR 13 factor space. An important application of confirmatory factor analysis is to use this procedure to implement the Dwyer (1937) extension method. As Tucker (1971) has demonstrated, it is not necessarily optimal to use factor scores on a latent variable to estimate their regression on an observed variable. However, confirmatory factor analysis permits the estimation of the location of some new observed variable or variables of interest within a previously known factor (latent construct) space. This is a situation that frequently arises in aging studies as samples are followed over long lime periods.

In the extension analysis, the 75 × 75 TBR personality item correlation matrix for the 1998 sample was augmented by the 5 NEO scores converted into *z*-score metric. The factor loadings for the 13 TBR factors were constrained to the values obtained from the original confirmatory factor analysis solution for the 13 personality factors for this sample. Factor loadings for the NEO scales were then freely estimated providing information on the projection of these measures into the previously established 13 personality factor space. This procedure produced an acceptable fit for the extended model ($\chi^2[df = 1{,}453] = 5924.22$, $p < .001$; *GFI* = 920, *RMSR* = .04).

Projections of the NEO into the 13 factor space have a + sign if a NEO scale is positively correlated with the personality factor or a − sign if it is negatively correlated.

Significant projections of the NEO ($p < .01$) into the 13 factor space were found for Neuroticism with Affectothymia (+), Superego Strength (−), Untroubled Adequacy (−), Conservatism (+), Inflexibility (+), and Community Interest (−). Extraversion projected significantly to Superego Strength (+), Premsia (+), Untroubled Adequacy (+), Conservatism (−), Low Self Esteem (−), and Community Interest (+). Openness projected to Premsia (+), Low Self Esteem (−) and Inflexibility (−). Agreeableness projected to Superego Strength (+) Threctia (+), Premsia (+), Untroubled Adequacy (+), Low Self Esteem (−), Honesty (+) and Community Interest (+). Finally, Conscientiousness projected to Affectothymia (−), Superego Strength (+), Untroubled Adequacy (+), Conservatism (−). Low Self Esteem (−), Inflexibility (−), and community Interest (+). Table 2 gives the concurrent correlations between the NEO scales and the 13

personality factors. Table 3 provides standardized factor loadings for the projection of the NEO into the 1.3 personality factor space.

RESULTS

Concurrent Relationships

We first examined concurrent relationships between the TBR personality factors and the NEO with the measures of the six latent ability constructs.

TBR Personality Factors

Stability of personality factor scores: As an initial step we conducted an analysis of the stability of the thirteen personality factors over time. Included in this analysis were the 1055 participants who had retest data over at least seven years. All stability coefficients were statistically significant ($p < .01$). The seven-year stabilities ranged from 0.32 for Affectothymia to 0.71 for Group Dependency. Fourteen-year stability ranged from 0.33 for Affectothymia to 0.69 for Interest in Science. Twenty-one year stabilities ranged from 0.20 for Affectothymia to 0.67 for Group Dependency. Twenty-eight year stabilities ranged from 0.24 for Political Concern to 0.65 for Interest in Science. And the 35 year stabilities ranged from 0.29 for Honesty to 0.66 for Group Dependency. Average stability coefficients were 0.59 over 7 years; 0.54 over 14 years; 0.49 over 21 years; 0.46 over 28 years; and 0.45 over 35 years (see Table 4).

We also examined the 7-year stabilities separately for four age groups: Young adult (age 29–49; *N*= 182): middle-aged (age 50–63; *N = 276);* young–old (age 64–77; *N* = 379); and old–old (age 78+; *N* = 182). All ages are given for the second measurement occasion. Average stability coefficients over seven years were 0.54 for the young adults, 0.58 for the middle-aged, 0.60 for the young–old, and 0.57 for the old–old. These stabilities range from somewhat lower to comparable values frequently seen in the personality literature (cf. Roberts & DelVecchio, 2000).

Concurrent relation between personality and ability factors: The concurrent correlations are provided in Table 5. Correlations range from small to modest. Consistently highest relationships for all abilities occurred with Conservatism (−), Untroubled Adequacy (+), and Group Dependency (−). Additional correlations significant at or beyond the .001 level of confidence were found for Inductive Reasoning with Affectothymia (+), Threctia (−), Premsia (+), Low Self Esteem (−), Honesty (+), Interest in Science (+), Inflexibility (−), Political Concern (+), and Community Interest (−); for Spatial Orientation with Affectothymia (+), Threctia (−), Premsia (+), Low Self Esteem (−), Interest in Science (+), Inflexibility (−), and Community Interest (−); for Perceptual Speed with Affectothymia (+), Premsia (+), Low Self Esteem (−), Interest in Science (+), Inflexibility (−), Political Concern (+), and Community Interest (−); for Verbal Comprehension with Affectothymia (+), Superego Strength (+), Premsia (+), Low Self Esteem (−), Interest in Science (+), Inflexibility (−), Political Concern (+), and Community Interest (+); and for Verbal Memory with Affectothymia (+), Premsia (−), Inflexibility (−), Political Concern (+), and Community Interest (−).

We also computed OLS regressions of the ability factor scores on the personality factor scores (see Table 6). Multiple *R*s range from 0.27 for Numeric Facility to 0.49 for Verbal Comprehension. Proportions of variance accounted for by personality in the ability factors are approximately 20% for Inductive Reasoning, 11% for Spatial. Orientation, 18% for Perceptual Speed, 7% for Numeric Facility, 24% for Verbal Comprehension, and 14% for Verbal Memory.

The NEO: Concurrent correlations were computed also between the five scales of the NEO personality inventory and our six ability factors. These correlations are provided in Table 7.

Again, correlations range from small to modest. Consistently highest relationships for all abilities (except Numeric Facility) occurred with Openness. Additional correlations significant at or beyond the .001 level of confidence were found for Inductive Reasoning with Extraversion (+) and Agreeableness (−); for Spatial Orientation with Agreeableness (−); for Perceptual Speed with Extraversion (+); for Numeric Facility with Extraversion (+) and Conscientiousness (+); and for Verbal Memory with Extraversion (+).

OLS regressions of the ability factor scores on the NEO scales are shown, in Table 8. Multiple *R*s range from 0.12 for Numeric Facility to 0.40 for Verbal Comprehension. Proportions of variance accounted for by the NEO personality factors in the ability factors are. approximately 10% for Inductive Reasoning, 6% for Spatial Orientation, 12% for Perceptual Speed, 2% for Numeric Facility, 16% for Verbal Comprehension, and 12% for Verbal Memory.

Longitudinal Relationships

We next examined the longitudinal relationship between personality factors and current cognitive performance. The assumption here is that personality is relatively stable and that one would therefore expect a long-term effect on cognition. We first examine this hypothesis using personality predictors that precede the current cognitive performance by 7, 14, 21, 28 and 35 years. We then present the results of extending the NEO into the thirteen personality factor space and estimate (postdict) past NEO scores from the thirteen personality factors.

TBR Personality Factors—OLS regressions of the ability factor scores obtained in 1998 on each of the personality factor scores were competed using personality factor scores obtained in 1963, 1970, 1977, 1984, and 1991. The pattern of statistically significant predictors remained fairly constant across increasing time intervals, although the *p* levels declined with shrinking sample sizes. Group dependency (−) was the strongest personality predictors for most abilities, followed by Conservatism (−). Untroubled adequacy (+), Premsia (+), and Low Self Esteem (−). Table 9 reports regression coefficients and proportions of variance accounted for in the 1998 cognitive ability factors by earlier standing on the 13 personality factors. The proportions did not vary markedly across the increasing length of the prediction interval. Average proportion of cognitive ability variance predicted was 15.8% over 7 years, 13.6% over 14 years, 13.0% over 21 years, 15.5% over 28 years, and 14.8% over 35 years. The predictability was highest for Verbal Comprehension (20–37%) and lowest for Spatial Orientation (7–13%) and Numeric Facility (6–15%).

Postdicting the NEO—Our final analyses are concerned with obtaining postdicted NEO scores by bootstrapping via the 13 personality factor extension analysis, thereby obtaining an estimated longitudinal NEO data set for study participants in 1991 and 1998. Estimation procedures involved computing NEO scores by multiplying the 13 factor scores by weights obtained from the orthonormalized factor loadings in Table 3 and restandardizing resulting scores to a mean of 50 and *SD* of 10. Within participant changes over 7 years were then computed and aggregated across successive 7-year age cohorts. The resulting longitudinal age gradients were then centered on average scores at age 53 and are depicted in Figure 5. Considerable caution is in order in interpreting the findings using these NEO proxy estimates. However, they do represent within subject change data across much of the adult life span. While cross-sectional data usually depict few personality differences adulthood, these data suggest much more dramatic developmental trends. For neuroticism we see a sharp increase until midlife with virtual stability thereafter. Openness shows a modest until age 46, a plateau until the late sixties and decline thereafter. Extraversion shows steady decline from the forties, Agreeableness shows steep increment with age, finally, Conscientiousness declines until the fifties followed by a virtual plateau.

DISCUSSION

There have been many suggestions that the study of cognition and aging might be advanced by introducing personality constructs as possible covariates that might explain some proportion of age-related changes and differences in cognitive performance. In the earlier literature (cf. Mischell, 1973) it was often argued that most measures of personality traits were not sufficiently stable nor showed, high enough correlations with cognitive measures to make it likely they could account for substantial proportions of age-related variance. The former criticism has largely been addressed by more recent rigorous measurement development (e.g., Costa & MacCrae, 1992), but the latter concern requires further empirical investigations. In this article, we try to lay the necessary groundwork for studying these questions by examining the relationship between two personality trait measures and measures of cognitive performance in a large sample covering the adult age range.

Interestingly enough we can show that there are modest but significant concurrent relationships between personality trait measures and ability construct that account for up to 20% of shared variance. Both our 13 personality factor measures and the NEO could be related to the cognitive ability constructs, albeit the 13-factor measure accounted for more of the shared variance than did the NEO. The personality dimensions that were found to be most substantively related to high performance on cognitive ability factors were high Untroubled Adequacy, low Conservatism and low Group Dependency from the 13 PF measure, and high scores of Openness on the NEO.

We were also able to show that there is moderate stability across time for the personality measures that is fairly comparable with the stability found in much of the personality literature (cf. Roberts & DelVecchio, 2000). It might be argued therefore, that prediction of cognitive change over age would benefit from the inclusion of personality traits as predictors of distal levels of cognitive performance. This argument is bolstered by the fact that some of the personality-cognition relations could be established over as long as a 35-year interval.

Given suitable longitudinal data, we also show that it is possible to utilize methods of extension analysis to bootstrap older to newer measurement domains, and thus try to reconstruct what changes on the newer measures would have been like had they be available at the earlier measurement points. Findings from the analyses using the estimated NEO data must be taken with caution since the multiple correlations of the personality factor scores with the NEO scales range from 0.39 to 0.59 (highest for the estimated scores for Openness and Conscientiousness, lowest for Agreeableness). Nevertheless, it is noteworthy that the estimated longitudinal data suggest greater developmental changes in personality over the adult life course than has previously been suspected as well as being generally consistent in changes from young adulthood documented in other studies (cf. Costa & McCrae 1993, Soldz & Vaillant, 1999).

Perhaps, most importantly, we also demonstrated even though the Seattle Longitudinal Study did not originally focus on the assessment of personality traits, it was possible to utilize suitable estimation procedures that permit longitudinal, analyses bearing upon the contributions of personality constructs in understanding adult cognition.

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References

American Society of Hospital Pharmacists. (1985). *Drug Information 85.* Bethesda, MD: American Society of Hospital Pharmacists.

Blieszner R, Willis SL, Bakes PB. Training research in aging on the fluid ability of inductive reasoning. Journal of Applied Developmental Psychology 1981;2:247–265.

Bosworth HB, Schaie KW. The relationship of social environment, social networks, and health outcomes in the Seattle Longitudinal Study: Two analytic approaches. Journal of Gerontology: Psychological Sciences 1997;52B:P197–P205.

Bosworth HB, Schaie KW. Survival effects in cognitive function, cognitive style, and sociodemographic variables in the Seattle Longitudinal Study. Experimental Aging Research 1999;25:121–139. [PubMed: 10223172]

Bosworth HB, Schaie KW, Willis SL. Cognitive and sociodemographic risk factors for mortality in the Seatttle Longitudinal. Journal of Gerontology: Psychological Sciences 1999;54B:P273–P282.

Bosworth HB, Schaie KW, Willis SL, Siegler IC. Age and distance to death in the Seattle Longitudinal Study. Research on Aging 1999;21:723–738.

Cattell, R.B. (1957). *Personality and motivation structure and measurement.* New York: World Book.

Cattell, R.B., Eber, H., & Tatsuoka, M.M. (1970). *Handbook for the 16 PF.* Champaign, DL: Institute for Personality and Ability Testing.

Costa, P.T., Jr., & McCrae, R.R. (1992). *Manual for the NEO.* Odessa, TX: IPAR.

Costa, P.T., Jr., & McCrae, R.R. (1993). Stability and change in personality from adolescence through adulthood. In G.A. Halverson, G.A. Kohnstamm, & R.P. Martin (Eds.), *The developing structure of temperament and personality from infancy to adulthood.* Hillsdale, NY: Erlbaum.

DeFries JC, Vandenberg SG, McClearn GE. The genetics of specific cognitive abilities. Annual Review of Genetics 1976;10:197–207.

Diehl M, Willis SL, Schaie KW. Older adults' everyday competence: Observational assessment and cognitive correlates. Psychology and Aging 1995;10:478–92. [PubMed: 8527068]

Dwyer PS. The determination of the factor loadings of a given test from the known factor loadings of other tests. Psychometrika 1937;2:1.73–178.

Educational Testing Service. (1977). *Basic skills assessment test – reading.* Princeton, NJ: Educational Testing Service.

Ekstrom, R.B., French, J.W., Harman, H., & Derman, D. (1976). *Kit of factor-referenced cognitive tests* (Rev. ed.). Princeton, NJ: Educational Testing Service.

Gough HG, McCloskey H, Meehl PE. A personality scale for social responsibility. Journal of Abnormal and Social Psychology 1952;42:73–80. [PubMed: 14907250]

Gribbin K, Schaie KW, Parham IA. Complexity of life style and maintenance of intellectual abilities. Journal of Social Issues 1980;36:47–61.

Gruber-Baldini AL, Schaie KW, Willis SL. Similarity in married couples: A longitudinal study of mental abilities and flexibility-rigidity. Journal of Personality and Social Psychology: Personality Processes and Individual Differences 1995;69:191–203.

Hertzog C, Schaie KW, Gribbin K. Cardiovascular disease and changes in intellectual functioning from middle to old age. Journal of Gerontology 1978;33:872–883. [PubMed: 744860]

Lawton MP, Brody EM. Assessment of older people: Self-maintaining and instrumental activities of daily living. Gerontologist 1969;9:179–185. [PubMed: 5349366]

Maier, H. (1995). *Health behaviors in adults: Interrelationships and correlates.* University Park, PA: The Pennsylvania State University, Unpublished doctoral dissertation.

Maitland, S.B. (1997). *Family similarity in health behaviors.* The Pennsylvania State University, Unpublished doctoral dissertation.

Maitland, S.B., Dutta, R., Schaie, K.W., & Willis, S.L. (1992, November). *Trait invariance and cohort differences of adult personality*. Paper presented at the Annual meeting of the Gerontological Society of America, Washington.

Maitland SB, Intrieri RC, Schaie KW, Willis SL. Gender differences in cognitive abilities: Invariance of covariance and latent mean structure. Aging, Neuropsychology and Cognition 2000;7:32–53.

Mischel W. Towards a cognitive social learning reconceptualization of personality. Psychological Review 1973;80:252–283. [PubMed: 4721473]

Moos, R.H. (1981). *Work Environment Scale manual.* Palo Alto, CA: Consulting Psychologists Press.

Moos, R.H. (1986). *Family Environment Scale manual* (2nd ed.). Palo Alto, CA: Consulting Psychologists Press.

O'Hanlon, A.M. (1993). *Inter-individual patterns of intellectual change: The influence of environmental factors.* University Park, PA: The Pennsylvania State University, Unpublished doctoral dissertation.

Palmore, E., Busse, E.W., Maddox, G.L., Nowlin, J.B., & Siegler, I. (1985). *Normal aging III* Durham, NC: Duke University Press.

Roberts BW, DelVecchio WF. The rank-order consistency of personality traits from childhood to old age: A quantitative review of longitudinal studies. Psychological Bulletin 2000;126:3–25. [PubMed: 10668348]

Rott C. Three components of intellectual development in old age: Results from the Bonn Longitudinal Study of Aging. Zeitschrift für Gerontologie 1993;26:184–190.

Schaie, K.W. (1958). Rigidity-flexibility and intelligence: A cross-sectional study of the adult life-span from 20 to 70. *Psychological Monographs, 72,* No. 462 (Whole No. 9).

Schaie, K.W. (1983). The Seattle Longitudinal Study: A twenty-one year exploration of psychometric intelligence in adulthood. In K.W. Schaie (Ed.), *Longitudinal studies of adult psychological development* (pp. 64–135). New York: Guilford Press.

Schaie KW. Midlife influences upon intellectual functioning in old age. International Journal of Behavioral Development 1984;7:463–478.

Schaie, K.W. (1985). *Manual for the Schaie-Thurstone Adult Mental Abilities Test* (*STAMAT*). Palo Alto, CA: Consulting Psychologists Press.

Schaie, K.W. (1988). Variability in cognitive function in the elderly: Implications for social participation. In A. Woodhead, M. Bender, & R. Leonard (Eds.), *Phenotypic variation in populations: Relevance to risk assessment* (pp. 191–212). New York: Plenum.

Schaie KW. Perceptual speed in adulthood: Cross-sectional and longitudinal studies. Psychology and Aging 1939;4:443–453. [PubMed: 2619951]

Schaie, K.W. (1996). *Intellectual development in adulthood:* The Seattle Longitudinal Study. New York: Cambridge University Press.

Schaie KW. The impact of longitudinal studies on understanding development from young adulthood to old age. International Journal of Behavioral Development 2000a;24:267–275.

Schaie, K.W. (2000b). Living with gerontology. In J.E. Birren & J.J.F. Schroots (Eds.), *A history of geropsychology in autobiography* (pp. 233–248). Washington, DC: American Psychological Association.

Schaie, K.W. (2004). *Developmental influences on cognitive development: The Seattle Longitudinal Study.* New York: Oxford University Press.

Schaie, K.W., Caskie, G.I.L., Reveil, A.J., Willis, S.L., Kaszoiak, A.W., & Teri, L. (in press). Extending neuropsychological assessments into the primary ability factor space. *Aging, Neuropsychology and Cognition.*

Schaie KW, Dutta R, Willis SL. The relationship between rigidity-flexibility and cognitive abilities in adulthood. Psychology and Aging 1991;6:371–383. [PubMed: 1930754]

Schaie KW, Labouvie-Vief G. Generational versus ontogenetic components of change in adult cognitive behavior: A fourteen-year cross-sequential study. Developmental Psychology 1974;10:305–320.

Schaie KW, Maitland SB, Willis SL, Intrieri RL. Longitudinal invariance of adult psychometric ability factor structures across seven years. Psychology and Aging 1998;13:8–20. [PubMed: 9533186]

Schaie, K.W., & O'Hanlon, A.M. (1990). *The influence of social-environmental factors in the maintenance of adult intelligence.* In R. Sehmitz-Schertzer, A. Kruse, & E. Olbrich (Eds.), *Altern – Ein lebenslanger Prozess der sozialen Interabion [Aging – A lifelong process of social interaction]* (pp. 55–66). Darmstadt, Germany: Steinkopf Verlag.

Schaie, K.W., & Parham, I.A. (1975). *Examiner manual for the Test of Behavioral Rigidity* (2nd ed.). Palo Alto, CA: Consulting Psychologists Press.

Schaie, K.W., Plomin, R., Willis, S.L., Gruber-Baldini, A., & Dutta, R. (1992). Natural cohorts: Family similarity in adult cognition. In T. Sonderegger (Ed.), *Nebraska Symposium on Motivation, 1991* (Vol. 38, pp. 205–243). Lincoln, NE: University of Nebraska Press.

Schaie, K.W., Plomin, R., Willis, S.L., Gruber-Baldini, A.L., Dutta, R., & Bayen, U. (1993). Family similarity in adult intellectual development. In J.J.F. Schroots (Ed.), *Aging, health and competence: The next generation of longitudinal research* (pp. 183–198). Amsterdam: Elsevier.

Schaie KW, Strother CR. The cross-sequential study of age changes in cognitive behavior. Psychological Bulletin 1968;70:671–680. [PubMed: 5712311]

Schaie KW, Willis SL. Can intellectual decline in the elderly be reversed? Developmental Psychology 1986;22:223–232.

Schaie, K.W., & Willis, S.L. (1995). Perceived family environments across generations. In V.L. Bengtson, K.W. Schaie, & L. Burton (Eds.), *Societal impact on aging: Inter-generational perspectives* (pp. 174–209). New York: Springer Publishing Co.

Schaie KW, Willis SL, O'Hanlon AM. Perceived intellectual performance change over seven years. Journal of Gerontology: Psychological Sciences 1994;49:P108–P118.

Sliwinski M, Buschke H. Cross-sectional and longitudinal relationships among age, processing speed and memory. Psychology and Aging 1999;14:18–33. [PubMed: 10224629]

Soldsz S, Vaillant GE. Five personality traits and the life course: A 45-year longitudinal study. Journal of Research in Personality 1999;33:208–282.

Thurstone, L.L. (1938). *Primary mental abilities.* Chicago: University of Chicago Press.

Thurstone, L.L., & Thurstone, T.G. (1949). *Examiner Manual for the SRA Primary Mental Abilities Test* (Form AH 10–14). Chicago: Science Research Associate.

Thurstone, T.G. (1962). *Examiner Manual for the SRA Primary Mental Abilities Test* (Rev. ed.). Chicago: Science Research Associates.

Tucker LR. Relations of factor score estimates to their use. Psychometrika 1971;36:427–436.

U.S. Public Health Service. (1968). *Eighth revision of the international classification of diseases, adapted for use in the Untied States.* Public Health Service Publication No. 1693. Washington: Government Printing Office.

Willis, S.L. (1989). *Cohort differences in cognitive aging: A sample case.* In K.W. Schaie & C. Schooler (Eds.), *Social structure and aging: Psychological processes* (pp. 94–112). Hillsdale, NJ: Erlbaum.

Willis, S.L. (1992). *Examiner manual for the Everyday Problems Test (EPT).* The Pennsylvania State University, University, Park, PA. Unpublished manuscript.

Willis, S.L. (1996). Everyday problem solving. In J.E. Birren & K.W. Schaie (Eds.), *Handbook of the psychology of aging* (4th ed., pp. 287–307). San Diego, CA: Academic Press.

Willis, S.L., & Schaie, K.W. (1983). *The Alphanumeric Rotation Test.* The Pennsylvania State University, Unpublished manuscript.

Willis, S.L., & Schaie, K.W. (1986a). *Practical intelligence in later adulthood.* In R.J. Sternberg & R.K. Wagner (Eds.), *Practical Intelligence: Origins of competence in the everyday world* (pp. 236–226). New York: Cambridge University Press.

Willis SL, Schaie KW. Training the elderly on the ability factors of spatial orientation and inductive reasoning. Psychology and Aging 1986b;1:239–247. [PubMed: 3267404]

Willis SL, Schaie KW. Gender differences in spatial ability in old age: Longitudinal and intervention findings. Sex Roles 1988;18:189–203.

Willis. S.L., & Schaie, K.W. (1994). *Cognitive training in the normal elderly*. In F. Forette, Y. Christen, & F. Boiler (Eds.), *Plasticité cérébrate et stimulation cognitive [Cerebral plasticity and cognitive stimulation]* (pp. 91–113). Paris: Fondation Nationale de Gérontologie.

Zelinski EM, Gilewski MJ, Schaie KW. Three-year longitudinal memory assessment in older adults: Little change in performance. Psychology and Aging 1993;8:176–186. [PubMed: 8323722]

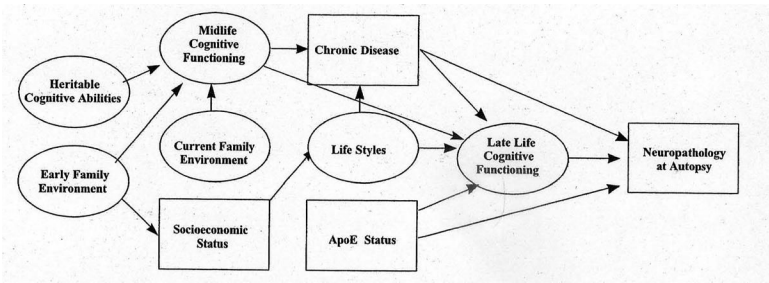
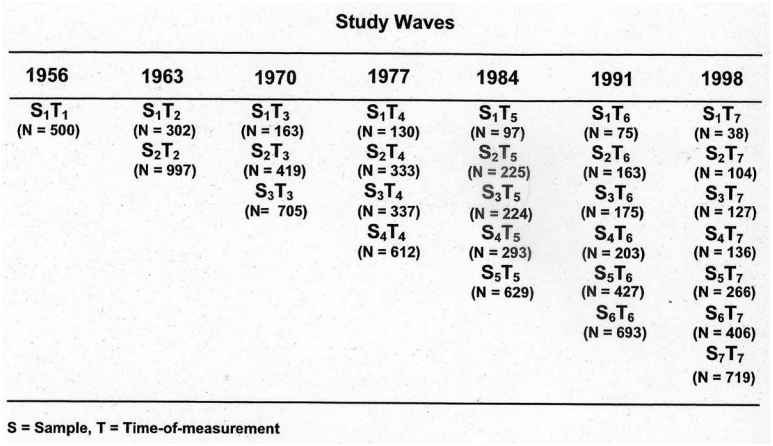


Fig. 1.
Conceptual model for the Seattle Longitudinal Study (from Schaie, 200la).



Fig, 2.
Basic Design of the Seattle Longitudinal Study (SLS).

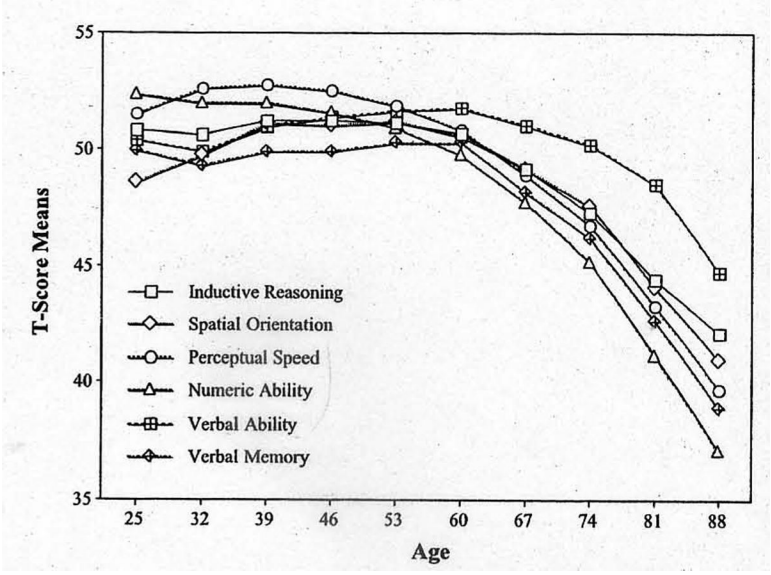


Fig. 3.
Longitudinal estimates of within participant age changes on the latent ability constructs (from 7-year longitudinal data).

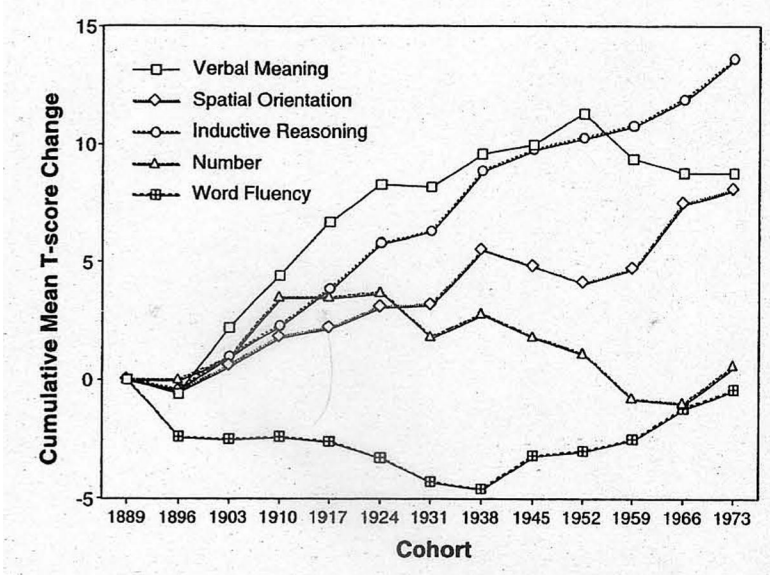


Fig. 4.
Cross-sectional differences on five ability measures for cohorts born from 1889 to 1973.

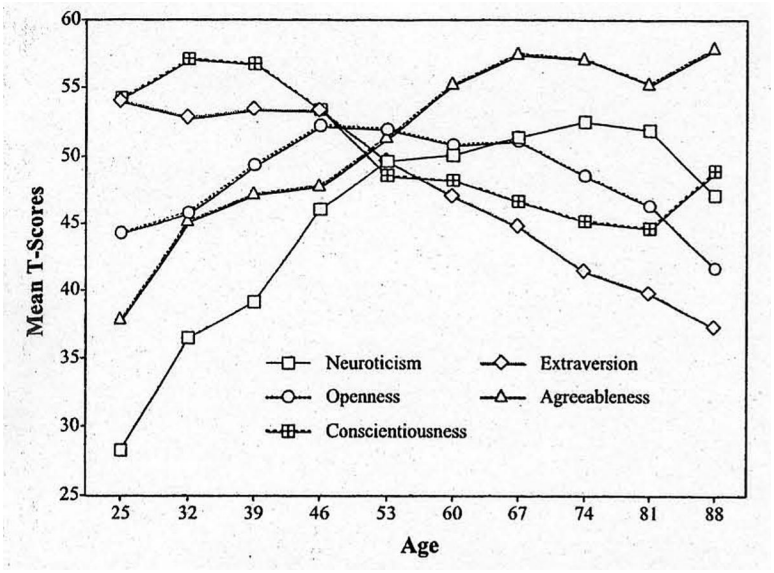


Fig. 5.
Longitudinal estimates of within participant age changes on the NEO scales (from predicted 7-year longitudinal data).

Table 1

Psychometric Intelligence Measurement Battery.

Primary ability	Test	Source	Test-retest correlation
Inductive Reasoning	PMA Reasoning (1948)	Thurstone & Thurstone (1949)	.884
	ADEPT Letter Series (Form A)	Blieszner et al. (1981)	.839
	Word Series	Schaie (1985)	.852
	Number Series	Ekstrom et al. (1976)	.833
Spatial Orientation	PMA Space (1948)	Thurstone & Thurstone (1949)	.817
	Object Rotation	Schaie (1985)	.861
	Alphanumeric Rotation	Willis & Schaie (1983)	.820
	Cube Comparisons	Ekstrom et al. (1976)	.951
Numerical Ability	PMA Number (1948)	Thurstone & Thurstone (1949)	.875
	Addition (N-1)	Ekstrom et al. (1976)	.937
	Subtraction & Multiplication (N-3)	Ekstrom et al. (1976)	.943
Verbal Comprehension	PMA Verbal Meaning (1948)	Thurstone & Thurstone (1949)	.890
	ETS Vocabulary (V-2)	Ekstrom et al. (1976)	.928
	ETS Advanced Vocabulary (V-4)	Ekstrom et al. (1976)	.954
Perceptual Speed	Identical Pictures	Ekstrom et al. (1976)	.814
	Finding A's	Ekstrom et al. (1976)	.860
	Number Comparison	Ekstrom et al. (1976)	.865
Verbal Memory	Immediate Recall	Zelinski et al. (1993)	.820
	Delayed Recall	Zelinski et al. (1993)	.732
	PMA Word Fluency	Thurstone & Thurstone (1949)	.896

Table 2

Concurrent Correlations of Personality Factor Scores and NEO Scales (*N*= 1417).

	Neuroticism	Extraversion	Openness	Agreeableness	Conscientious
Affectothymia	.077**	.124***	.218***	.192***	.050
Superego Strength	.019	.038	.133***	.008	.253***
Threctia	.031	.172***	.228***	.234***	.146***
Premsia	.079**	.164***	.349***	.004	.215***
Untroubled Adequacy	.098***	.106**	.303***	.107***	.115***
Conservatism	.005	.079**	.356***	.028	122***
Group Dependency	.225***	.228***	.229***	.037	.157***
Low Self Esteem	.062*	.072**	.145***	.042	.504***
Honesty	.096**	.065**	.080**	.183***	.111***
Interest in Science	.106***	.078**	.258***	.105***	.025
Inflexibility	.395***	.288***	.176***	.123***	.150***
Political Concern	.098***	.106***	.208***	.103***	.002
Community Interest	.052	.065*	.022	.087*	.125***
R^2	.452***	441***	.539***	.385***	.588**

* $p < .05$;

** $p < .01$;

*** $p < .001$.

Table 3

Standardized Factor Loadings for the NEO on the 13 Personality Factors.

	Neuroticism	Extraversion	Openness	Agreeableness	Conscientious
Affectothymia	.293***	.141	.027	.057	.323***
Superego Strength	.455**	.380**	.157	.557***	.371***
Threctia	.087	.108	.134	.346***	.127*
Premsia	.198	.438***	.790***	.352***	.107
Untroubled Adequacy	.386**	429***	.199	.346*	.330**
Conservatism	.458**	.296*	.081	.193	.498***
Group Dependency	.090	.023	.065	.080	.089
Low Self Esteem	.072	.496***	.437***	.324***	.333***
Honesty	.010	.032	.061	.267***	.072
Interest in Science	.000	.066*	.038	.057	.003
Inflexibility	.463***	.197*	.276**	.131	.423***
Political Concern	.011	.014	.046	.045	−.007
Community Interest	.278**	.272**	.100	.284**	.264***

* $p < .05$;

** $p < .01$;

*** $p < .001$.

Table 4

Stability of the Personality Factor Scores.

Factor	7 years 1991–98 *N* = 1065	14 years 1984–98 *N* = 667	21 years 1977–98 *N* = 419	28 years 1970–98 *N* = 285	35 years 1963–98 *N* = 157
Affectothymia	.318	.334	.205	.318	.297
Superego Strength	.588	.482	.440	.368	.415
Threctia	.696	.574	.545	.556	.452
Premsia	.589	.499	.487	.524	.514
Untroubled Adequacy	.643	.595	.597	.534	.441
Conservatism	.689	.613	.566	.586	.391
Group Dependency	.708	.653	.673	.631.	.661
Low Self Esteem	.675	.626	.483	.480	.482
Honesty	.500	.386	.362	.288	.291
Interest in Science	.694	.694	.653	.680	.604
Inflexibility	.570	.585	.529	.508	.530
Political Concern	.441	.475	.377	.236	.376
Community Interest	.595	.555	.415	.317	.357

Note. All stability coefficients are statistically significant at $p < .01$.

Table 5

Concurrent Correlations of Personality Factor Scores and Cognitive Abilities.

Factor	Inductive Reasoning	Spatial Orientation	Perceptual Speed	Numeric Facility	Verbal Comprehension	Verbal Memory
Affectothymia	.169***	.098***	.179***	.067**	.228***	.128***
Superego Strength	.059*	.017	.054*	.002	.102***	.035
Threctia	.096***	.118***	.074**	.040	.009	.063**
Premsia	.235***	.192***	.198***	.068**	.108***	.154***
Untroubled Adequacy	.290***	.199***	.255***	.084**	.257***	.247***
Conservatism	.369***	.257***	.342***	.144***	.372***	.307***
Group Dependency	.216***	.076**	.216***	.228***	.299***	.174***
Low Self Esteem	.136***	.112***	.096***	.006	.137***	.091***
Honesty	.082**	.061*	.089***	.009	.024	.088**
Interest in Science	.090***	.120***	.087***	.010	.116***	.035
Inflexibility	.116***	.081***	.150***	.075**	.081***	.123***
Political Concern	.142***	.069**	.120***	.054*	.192***	.125***
Community Interest	120***	.143***	.140***	.024	.080***	.105***

* $p < .05$;

** $p < .01$;

*** $p < .001$.

Table 6

Concurrent OLS Regression of Personality Factor Scores on Cognitive Abilities.

Factor	Inductive Reasoning	Spatial Orientation	Perceptual Speed	Numeric Facility	Verbal Comprehension	Verbal Memory
Affectothymia	.041	.017	.072**	.015	.083***	.023
Superego Strength	.109***	.126***	.104***	.035	.024	.109***
Threctia	.038	.059*	.027	.034	.014	.027
Premsia	.092***	.088**	.054	.034	.045	.018
Untroubled Adequacy	.145***	.084**	.081**	.001	.082**	.114***
Conservatism	.253***	.177***	.242***	.119***	.294***	.225***
Group Dependency	.140***	.019	.143***	.206***	.210***	.108***
Low Self Esteem	.001	.010	.026	.036	.060*	.009
Honesty	.038	.019	.013	.009	.036	.053*
Interest in Science	.024	.083***	.056*	.052*	.042	.020
Inflexibility	.013	.013	.068**	.025	.031	.061*
Political Concern	.001	.022	.017	.009	.033	.011
Community Interest	.051*	.100***	.085***	.020	.154***	.050*
Multiple *R*	.443	.336	.422	.267	.491	.370
R^2	.196	.106	.178	.071	.241	.137

* $p < .05$;

** $p < .01$;

*** $p < .001$.

Table 7

Concurrent Correlations of NEO Scores and Cognitive Abilities.

Factor	Inductive Reasoning	Spatial Orientation	Perceptual Speed	Numeric Facility	Verbal Comprehension	Verbal Memory
Neuroticism	.025	.045	.004	.052	.067**	.001
Extraversion	.093***	.051	.150***	.101***	.012	.134***
Openness	.294***	.177***	.318***	.053	.355***	.316***
Agreeableness	.090***	.143***	.016	.000	.036	.042
Conscientiousness	.053	.022	.037	.090***	.082**	.037

* $p < .05$;

* $p < .01$;

*** $p < .001$.

Table 8

OLS Regressions of Cognitive Abilities on NEO Scores.

Factor	Inductive Reasoning	Spatial Orientation	Perceptual Speed	Numeric Facility	Verbal Comprehension	Verbal Memory
Neuroticism	.003	.027	.058	.005	.152***	.058
Extraversion	.005	.004	.03	.074*	.200**	.021
Openness	.300***	.187***	.310***	.024	.414***	.314***
Agreeableness	.096***	.144***	.028	.018	.001	.033
Conscientiousness	.036	.014	.057*	.073*	.098***	.030
Multiple *R*	.314	.234	.339	.123	.405	.347
R^2	.095	.055	.115	.015	.164	.120

* $p < .05$;

** $p < .01$;

*** $p < .001$.

Table 9

Predictive OLS Regression of Personality Factor Scores on Cognitive Abilities.

Factor	7 years 1991–98 *N* = 986	14 years 1984–98 *N* = 588	21 years 1977–98 *N* = 384	28 years 1970–98 *N* = 245	35 years 1963–98 *N* = 144
Inductive Reasoning 1998					
Affectothymia	.010	.047	.005	.020	.118
Superego Strength	.128***	.112**	.072	.067	.025
Threctia	.064*	.060	.013	.080	.010
Premsia	.059*	.062	.079	.182**	.133
Untroubled Adequacy	.164***	.191***	.138*	.075	.008
Conservatism	.217***	.116**	.106	.124	.037
Group Dependency	.140***	.193***	.243***	.197**	.298**
Low Self Esteem	.050	.012	.063	.063	.113
Honesty	.047	.020	.111*	.007	.022
Interest in Science	.019	.036	.022	.114	.028
Inflexibility	.004	.003	.037	.070	.006
Political Concern	.002	.034	.078	.065	.050
Community Interest	.082**	.075	.003	.079	.042
Multiple *R*	.443***	.399***	.383***	.359**	.342
R^2	.197	.159	.147	.129	.117
Spatial Orientation 1998					
Affectothymia	.022	.042	.089	.113	.109
Superego Strength	.150***	.076	.011	.084	.048
Threctia	.059	.085*	.035	.045	.213
Premsia	.078*	.096*	.070	.098	.144
Untroubled Adequacy	.082*	.037	.036	.007	.177
Conservatism	.215***	.109*	.001.	.019	.155
Group Dependency	.020	.080*	.106*	.102	.230**
Low Self Esteem	.037	.003	.022*	.011	.059
Honesty	.073*	.020	.130*	.026	.013
Interest in Science	.066*	.058	.078	.166*	.055
Inflexibility	.004	.052	.001	.092	.026
Political Concern	.039	.038	.113*	.045	.048
Community Interest	.091*	.124**	.029	.019	.180*
Multiple *R*	.360***	.287***	.258***	.279***	.358
R^2	.130	.083	.066	.078	.128
Perceptual Speed 1.998					
Affectothymia	.045	.001	.040	.027	.141.
Superego Strength	.098**	.093*	.057	.048	.004
Threctia	.057	.106**	.042	.118	.004
Premsia	.032	.057	.010	.149*	.090
Untroubled Adequacy	.146***	.146**	.079	.020	.073
Conservatism	.212***	.111*	.062	.167*	.066
Group Dependency	.124***	.181***	.210***	.194**	.323***
Low Self Esteem	.009	.028	.051	.023	.091
Honesty	.063*	.013	.098	.043	.032
Interest in Science	.008	.008	.047	.009	.049
Inflexibility	.040	.015	.032	.052	.126
Political Concern	.012	.033	.086	.058	.053
Community Interest	.074*	.122**	.111*	.011	.197*
Multiple *R*	.413***	.384***	.333***	.347**	.422**
R^2	.170	.147	.111	.120	.178

Factor	7 years 1991–98 $N = 986$	14 years 1984–98 $N = 588$	21 years 1977–98 $N = 384$	28 years 1970–98 $N = 245$	35 years 1963–98 $N = 144$
Numeric Facility 1998					
Affectothymia	.043	.027	.050	.000	.058
Superego Strength	.052	.026	.042	.029	.165
Threctia	.003	.062	.048	.098	.051
Premsia	.019	.017	.050	.153*	.031
Untroubled Adequacy	.082*	.060	.069	.071	.033
Conservatism	.081*	.023	.019	.043	.048
Group Dependency	.177***	.203***	.146**	.169**	.200*
Low Self Esteem	.020	.035	.083	.109	.206*
Honesty	.006	.016	.030	.029	.054
Interest in Science	.062*	.069	.136**	.060	.064
Inflexibility	.007	.011	.018	.027	.163
Political Concern	.021	.036	.060	.023	.061
Community Interest	.064	.047	.068	.059	.065
Multiple R	.255***	.257***	.250*	.297***	.386
R^2	.065	.066	.063	.088	.149
Verbal Comprehension 1998					
Affectothymia	.033	.01.8	.197***	.158**	.176
Superego Strength	.001	.034	.008	.108	.028
Threctia	.007	.047	.023	.039	.038
Premsia	.007	.057	.078	.025	.043
Untroubled Adequacy	.141***	.174**	.152**	.210***	.067
Conservatism	.294***	.247***	.206***	.261***	.152
Group Dependency	.211***	.307***	.303***	.271***	.305***
Low Self Esteem	.057	.019	.052	.092	.048
Honesty	.063*	.009	.066	.000	.055
Interest in Science	.054*	.082*	.075	.052	.041
Inflexibility	.077**	.057	.01.5	.060	.049
Political Concern	.079**	.010	.016	.081	.115
Community Interest	.087**	.080*	.131**	.141**	.008
Multiple R	.517***	.509***	.536***	.609***	.453**
R^2	.267	.260	.287	.371	.205
Verbal Memory 1998					
Affectothymia	.024	.031.	.091	.002	.040
Superego Strength	.128***	.119**	.112*	.030	.032
Threctia	.020	.049	.088	.156*	.063
Premsia	.040	.015	.040	.215**	.083
Untroubled Adequacy	.137***	.165***	.112	.092	.103
Conservatism	.109.**	.120**	.129*	.147*	.143
Group Dependency	.155***	.136***	.130**	.120	.179
Low Self Esteem	.016	.049	.040	.052	.067
Honesty	.056	.024	.083	.047	.071
Interest in Science	.009	.007	.01.8	.105	.037
Inflexibility	.028	.063	.007	.066	.123
Political Concern	.033*	.054*	.001	.076	.023
Community Interest	.073***	.054***	.021.	.052	.000
Multiple R	.346***	.351***	.323***	.382***	.336
R^2	.120	.123	.104	.146	.113

* $p < .05$;

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** $p < .01$;

*** $p < .001$.