Correlates and Predictors of Intellectual Performance and Intellectual Change in Older Adults. Sherry L. Willis, Manfred Diehl, Ann L. Gruber-Baldini, Michael Marsiske, & Sarah Haessler. Department of Human Development and Family Studies, The Pennsylvania State University, University Park, PA 16802.

In the present study, correlates and predictors of longitudinal change in psychometric ability performance were examined in 102 Pennsylvania older adults (mean age = 76.9 years). Subjects were first tested in 1979, and retested in 1986. Mean educational level was 12.1 years. Longitudinal predictors of 1986 ability level and of 1979-86 ability change were examined for four intellectual dimensions: Fluid Reasoning (Gf), Crystallized Knowledge (Gc), Perceptual Speed (Ps), and Memory Span (Ms). Predictors of 1986 level and 1979-86 change were examined for five domains: Personal, Perceived Health and Drug Use, Intellectual Control Beliefs, Social Support, and 1979 ability performance. Multiple regression and path analysis models were conducted to examine these predictors.

Significant longitudinal predictors of 1986 ability level varied across the four abilities. For all four abilities, education, health, and prescription drug use were significant predictors. Prior 1979 ability level was also a significant predictor of 1986 performance, and suppressed the direct effects of 1979 educational level and perceived health. The direct effect of prescription drug use on 1986 ability level remained when 1979 ability performance was added as a predictor.

Significant predictors of cognitive change (1979-1986) included prior cognitive performance, prescription drug use, and perceived health.

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Correlates and Predictors of Intellectual Performance and Intellectual Change in Older Adults

The body of knowledge on adult intellectual development has grown tremendously over the course of the last three decades (see Botwinick, 1977; Labouvie-Vief, 1985; Schaie, 1990). In particular, longitudinal studies of intellectual development during adulthood have documented that different intellectual abilities show different developmental trajectories across the adult life-span (Schaie, 1979), and that these trajectories differ for individuals from different birth cohorts (see Schaie, 1983). Thus, longitudinal studies have resulted in the acceptance of the notion that intellectual development during adulthood is multidirectional and can be conceptualized as a dynamic interplay between growth and decline (see Baltes, 1987). In addition, it has been shown that adults' performance on psychometric ability measures can be successfully modified via cognitive training programs (Willis, 1985).

However, despite the tremendous amount of research focusing on adult intellectual development, relatively little is known about the factors that affect growth, stability, or decline in intellectual functioning during adulthood (see Schaie, 1990). The antecedents of intellectual aging studied so far include health status, personality variables such as self-efficacy or rigidity/flexibility, and environmental factors such as complex workplaces.

Health Status Predictors

Many studies have investigated the impact of health status upon cognitive functioning. Researchers have investigated the impact of global health measures, specific disease categories, and prescription drug effects. Measures of general intelligence and of general health have both been found to decline with age (Field, Schaie, & Leino, 1989). Studies using global health status measures have varied in their findings. Klonoff and Kennedy (1966) found evidence of lower performance

Making matters even more complicated, Light (1980) found that certain medications prescribed to hypertensives (resperine, methyldopa, and clonidine) lead to impairment on a number of measures; the effects of other drugs for hypertension (propranol and other beta-blocking agents) have been negligible. Perlmutter et al. (1987) have also noted the impairing effects of sedatives (i.e., diazepam) on memory performance.

Personality Predictors

Lachman and Leff (1989) investigated the relationship between personal control beliefs and intellectual functioning in an elderly sample over a 5-year period. They found that control beliefs did not predict changes in intellectual functioning. However, changes in intellectual control beliefs were predicted by fluid intelligence.

Environmental Predictors

Environmental or social structural variables that have been associated with maintenance of intellectual functioning during adulthood include demographic variables such as high levels of education, occupational status, and income (see Schaie, 1990). Schooler (1987) has provided evidence that high workplace complexity and exposure to stimulating environments contribute to a high level of cognitive functioning during adulthood.

The present study had three objectives. The first objective was the examination of longitudinal predictors of performance on four second-order psychometric abilities (Fluid Reasoning, Crystallized Knowledge, Memory Span, and Perceptual Speed). The predictors included variables from four domains: personal characteristics (age, education), health and prescription drug use behaviors, intellectual control beliefs, and prior intellectual functioning.

The second objective was the examination of the same set of predictors on intellectual changes over a 7-year period. The third involved the examination of concurrent correlates of intellectual functioning. Additional variables included in the latter analyses focused on the older adults' affective conditions (morale and depression) and the social support they perceived as being available to them from the most important members in their social network.

Method

Subjects

The sample comprised 102 white community-dwelling older adults (16 males, 86 females) from rural, central Pennsylvania. All subjects had participated in the first phase of the ADEPT study in 1979 and were retested in 1986. The mean age of the sample in 1986 was 76.9 years (Range = 69-93; $\underline{SD}$ = 5.74), with no significant gender difference in age. Mean educational level was 12.08 years (Range = 6-22; $\underline{SD}$ = 3.25); men had a significantly higher level of education ($\underline{M}$ =13.56 years) than women ($\underline{M}$ = 11.80; $\underline{t}[100] = 4.08$, $\underline{p} < .05$). The average annual income was $9,200 (Range = $1,000-$28,000). The majority of the sample were widowed (55%), while 36% were married and 9% were single or divorced. Subjects rated their health as good, and reported themselves as being moderately happy.

Sample attrition. In 1979 a total of 237 subjects (51 males, 186 females) had participated in the ADEPT study. Of the 135 participants who did not return in 1986, 38.5% were deceased; 27.4% were ill or had sensory problems that prohibited their continued participation; 5.9% were living in nursing homes; 16.3% had moved and could not be contacted; and 11.9% were not interested in continuing.

In 1979, returnees and dropouts did not differ significantly in age, educational level, self-rated vision or hearing, or in number of doctor visits during the previous year. However, significant differences between returnees and dropouts were found in self-reported health status ($p<.004$), with returnees rating themselves in better health. Significant differences between returnees and dropouts were found for 12 of the 17 ability measures, with returnees' scoring higher on all measures.

Procedure

Testing procedures in 1986 were very similar to those employed in 1979. Subjects were assessed in small groups of 3-12 persons by a young adult tester and a proctor. Individual testing was required for a few subjects, due to sensory limitations or transportation problems. The test battery was administered in two three-hour sessions with multiple rest breaks per session. The two testing sessions were usually held within a ten-day period. Tests were administered in an invariant order within each testing session. All testing was conducted in facilities in the communities (e.g., senior citizen center) where the subjects resided.

Measures

Ability battery. The same psychometric ability battery was administered in 1979 and 1986. The battery was developed within the fluid (Gf) and crystallized (Gc) model of intelligence (e.g., Cattell, 1971), and included multiple marker tests of four broad, second-order dimensions of intelligence: Fluid Reasoning (Gf), Crystallized Knowledge (Gc), Memory Span (Ms) and Perceptual Speed (Ps) (see Table 1). This four-factor ability structure was identified via confirmatory factor analyses in 1979 (Baltes et al, 1980). Longitudinal invariance of the factor structure from 1979 to 1986 was established (Willis & Jay, 1989a).

The primary abilities of Figural Relations (CFR) and Induction (I) were selected to represent Fluid Reasoning. The marker tests of these abllities require subjects to discern a pattern of relationships within an array of figures, letters and numbers. Crystallized Knowledge was represented by the primary abilities of

Experiential Evaluation (EMS) and Verbal Comprehension (V). The EMS measures required subjects to generate solutions to problems of a social nature. The verbal measures represented recognition vocabulary tests of varying difficulty level. Measures of Semantic Relations (CMR), which require subjects to select words to complete verbal analogies, marked both fluid and crystallized intelligence. Memory was represented by the primary mental ability of Memory Span (Ms); marker tests assessed the number of digits subjects could hold in memory, in forward and backward order. The dimension of Speed was represented by the primary ability of Perceptual Speed (Ps); measures assessed the speed with which subjects made simple visual discriminations.

Insert Table 1 about here

All but two of the measures were adapted versions of published psychometric ability tests. Adaptation of the measures took two forms: 1) enlargement of test stimuli to facilitate administration to elderly subjects, and 2) reduction of the number of test items to facilitate administration of the battery in two sessions. Reduction of test length was based on the alpha reliability of the full-length measure; all reduced test versions had reliabilities greater than .65. The ADEPT Figural Relations Test and the ADEPT Induction Test were developed during the 1979 phase (Blieszner, Willis, & Baltes, 1981; Willis, Blieszner & Baltes, 1981).

Intellectual control and self-efficacy beliefs measure. Intellectual control and self-efficacy were assessed by the Personality-in-Intellectual-Aging Contexts (PIC) inventory. The PIC was developed in the first ADEPT phase to measure older adults' beliefs and attributions regarding their own cognitive functioning (Lachman, 1983, 1986). The PIC has six scales. Three PIC Locus of Control scales (Internal, Chance, Powerful Others) assess evaluations of one's capabilities and attributions regarding control of intellectual competence. A PIC Achievement scale examines the perceived importance and meaning of intellectual competence. A PIC Anxiety Scale assesses affective reactions to intellectually demanding tasks; and a PIC Morale scale examines degree of perceived change in intellectual competence with age. Prior confirmatory factor analyses (Lachman, 1983; Willis & Jay, 1989b) identified two second-order factors: Intellectual Self-efficacy (PIC-SE), marked by the Internal control scale and Achievement; and Concern about Intellectual Aging (PIC-CA), marked by the Chance and Powerful Others control scales, and the Anxiety and Morale scales. Subjects' scores on these two second-order factors were included in the analyses reported here.

Health measures. Several self-report health measures were included in the study. In 1979, the health-related measures consisted of a self-report general health item (comparing to others their age), a self-report vision item, and a self-report hearing item. All three items were 6-point Likert scales ranging from "very good" to "very poor." In 1986, these measures were repeated, and several additional health related questions were asked. These additional measures included: (1) three 7-point items assessing self-perceived change on health, vision, and hearing since 1980 (1="much better" to 7="much worse"), (2) a single dichotomous item on hearing aid use, (3) two items assessing the number of hospital days and physician visits in the year prior to testing, and (4) a series of "functional health" items pertaining to several chronic conditions and the degree to which the conditions limited the participants involvement in everyday activities. The chronic conditions included: Gout, Asthma, Bronchitis, Cancer, Thyroid problems, Diabetes, Digestive problems, Urinary tract disorders, High Blood Pressure, Heart problems, Circulatory problems, Skin problems, Osteoporosis, and Nervousness.

An exploratory factor analyses was conducted on these health items in order to explore whether subjects' responses to the health items reflected some underlying

common factors allowing us to summarize the obtained information into more global health indices. The model was modified using maximum likelihood estimation in LISREL VI (Jöreskog &Sörbom, 1986). A three factor model fit the data well (X^2=532.88, df=302; X^2/df=1.76; GFI=.71; RMSR=.11). The first factor consisted of the general health items in 1979 and is referred to as Self-reported Health 1979. The second factor included the health change items and the 1986 hearing aid question. The second factor is referred to as Health Change. The third factor included the 1986 general health items, number of hospital days and physician visits, plus a number of the functional health questions (significant loadings were found for: Gout, Bronchitis, Digestive problems, High Blood Pressure, Heart, Circulatory problems, and Nervousness). This factor is referred to as Health 1986. Self-reported Health 1979 and Health 1986 had a correlation of .71 (p<.001), Self-reported Health 1979 and Health Change had a correlation of .24 (ns) , and Health Change and Health 1986 had a correlation of .55 (p<.001).

Prescription drug use. In addition to the self-reported health measures, in 1986 subjects were asked to bring the prescription drugs they were currently taking to the testing session. These drugs were coded according to the therapeutic category classification of the American Hospital Formulary Service (American Society of Hospital Pharmacists, 1985), and the number of drugs taken within each category was summed. Five therapeutic classifications were included in the current analyses: Cardiac drugs, Diuretics, Replacement solutions, Sedatives, and Eye, Ear, Nose, and Throat (EENT) preparations. These drugs were selected on the basis of significant and consistent bivariate correlations with the 1986 cognitive factors.

Life stress. Participants reported the three most important life events that had occurred during the five years prior to the second time of measurement. Subjects also reported the year in which each life event had occurred. A life stress score was assigned to each life event using the mean life change unit (LCU) from the Social

Readjustment Rating Scale (Holmes & Rahe, 1967). Assignment of LCUs to life events was performed by two independent raters who had been trained in rating the LCU associated with a wide array of life events. Agreement between raters was consistently high (r = .97).

In addition, each life event score was weighted by its approximate distance from the time of report and a total weighted life stress score was calculated by adding the weighted LCUs for all three events.

Morale. A person's morale was assessed using the Philadelphia Geriatric Center Morale Scale (PGC; Lawton, 1975). The PGC has 17 items that form three scales: Agitation, Attitude Toward Own Aging, and Loneliness. For the analyses reported in this paper, subjects' scores were summed into a total score for morale.

Depression. Participants' depressive symptoms were measured using the Zung Depression Scale (Zung, 1965). The Zung Depression Scale has 18 items and an individual's total score was used as an indication of depressive symptoms.

Social Support. Perceived Social Support was measured using Kahn and Antonucci's (1980) Social Support questionnaire. This questionnaire consists of two parts. In the first part, participants were asked to fill in the names or initials of those people who are most important in their lives, or who they felt closest to. Additional questions obtained demographic and frequency of contact information on the first two people named by the participant.

The second part of the questionnaire consists of 32 questions relating to the two most important people in the participants lives. Originally, these 32 questions had been designed to tap four distinct dimensions of social support: emotional support, resource support, reciprocity, and negativity. Confirmatory factor analyses using LISREL VI (Jöreskog &Sörbom, 1986) yielded an emotional support factor and a resource factor. However, these two factors were highly intercorrelated indicating that the instrument measures a general support factor rather than two distinct

dimensions of social support. Thus, scale scores for emotional support and resource support were added across the two most important network members into a total social support score.

Statistical analyses

The importance of longitudinal predictors of psychometric ability performance and longitudinal change in ability performance was assessed via path analysis (Duncan, 1975). The final path analysis models were derived following a two-step procedure: (1) Based on the pattern of correlations among the conceptually relevant variables, fully recursive models were specified. (2) Based on the results from the fully recursive models, reduced models were estimated retaining the statistically significant path. Ordinary least squares estimation was used to estimate the models (Duncan, 1975; Pedhazur, 1982). The importance of 1986 concurrent correlates of psychometric ability performance was assessed via multiple regression (Pedhazur, 1982).

Results

Results of our analyses are reported in three parts: (1) analyses pertaining to the longitudinal predictors of ability level in 1986; (2) analyses pertaining to the predictors of change in intellectual abilities from 1979 to 1986; and (3) analyses pertaining to the concurrent correlates of intellectual functioning in 1986.

Longitudinal predictors of ability performance

In a first step, four fully recursive models were estimated separately for each cognitive ability. These models contained all possible direct and mediated (indirect) effects of the exogenous variables on the endogenous variables. In a second step, reduced models were estimated retaining only the significant effects of the exogenous variables on the criterion variables. All models were first established without including the subjects' 1979 level of cognitive performance to identify the noncognitive predictors; then models were reestimated including both cognitive and noncognitive predictors.

The weighted event score, health change, and prescription drug categories were conceptualized as mediating variables of 1986 performance in these analyses (see Table 2 for the full path model predictors). Although these variables were measured in 1986, all are indexes of events which occurred prior to the 1986 testing. Results from these analyses are presented in Figures 1-4.

Insert Table 2 about here

Longitudinal Predictors of Fluid Reasoning. The only significant noncognitive predictors of 1986 performance on Gf were subjects' educational level in 1979 (P=.51) and perceived general health in 1979 (P=-.21; see Figure 1a). Subjects with higher education performed better on fluid reasoning measures and subjects reporting poorer health did less well on these measures. Self-reported health in 1979 had both a direct effect and an indirect effect (mediated via the number of prescribed cardiac drugs) on Gf. The indirect effect indicated that subjects in poorer health also took a larger number of cardiac drugs and scored lower on Gf.

Insert Figures 1a and 1b about here

Inclusion of subjects' initial performance level on the cognitive abilities changed the model in the following way: First, 1979 performance on Gf became the strongest predictor of 1986 performance level (P=.85). Subjects with higher scores in 1979 also performed higher in 1986. The previous direct effects of education and

self-reported health in 1979 became insignificant, whereas the indirect effect of health via the number of prescribed cardiac drugs persisted (see Figure 1b). None of the other cognitive abilities predicted performance on Gf.

Longitudinal Predictors of Crystallized Knowledge. The path analysis model for 1986 performance on Gc yielded similar results as for Gf (see Figure 2a). Again, the only two significant noncognitive predictors were educational level in 1979 (P=.54) and self-reported health in 1979 (P=-.23). Self-reported health had an indirect effect (via number of cardiac drugs) on Gc performance.

Insert Figures 2a and 2b about here

This model changed when subjects' initial cognitive performance on the different abilities was included in the analysis (see Figure 2b). The direct effects of educational level and self-reported health became insignificant, whereas the indirect effects of self-reported health on Gc persisted. In addition, 1979 performance on Gc (P=.67) and on Ms (P=-.17) emerged as significant predictors of 1986 Gc performance.

Longitudinal Predictors of Memory Span. The path analysis model for the 1986 Ms performance yielded somewhat different results (see Figures 3a). Three personal variables exerted direct effects on 1986 Ms performance: subjects' age at initial testing (P=-.20), educational level in 1979 (P=.22), and self-reported health in 1979 (P=-.28). Older subjects, less educated subjects, and subjects reporting poorer health in 1979 scored lower on Ms in 1986. In addition, the 1979 personality factor intellectual self-efficacy from the PIC inventory had a positive effect on 1986 Ms performance (P=.33), indicating that subjects who perceived themselves in 1979 as more in control of their intellectual functioning performed better on Ms in 1986. The indirect effects of self-reported health in 1979 via the number of prescribed cardiac conditions persisted in this model, too.

Insert Figures 3a and 3b about here

The inclusion of the 1979 cognitive abilities changed the path analysis model only slightly (see Figure 3b). The effect of educational level and the indirect effect of self-reported health became nonsignificant, while the direct effects of age, health, and intellectual self-efficacy remained statistically significant. The two 1979 ability predictors that showed significant relationships with 1986 Ms were the 1979 Ms performance (P=.18) and 1979 Gf performance (P=.42). Subjects with high scores on these two abilities in 1979 also achieved higher scores on Ms in 1986.

Longitudinal Predictors of Perceptual Speed. The path analysis models for 1986 Ps are shown in Figures 4a and 4b. Two personal variables emerged as significant predictors: educational level in 1979 (P=.33) and self-reported health in 1979 (P=-.23). However, in this model the effect of self-reported health was mediated by both the number of prescribed cardiac drugs (P=-.20) and the number of EENT drugs (P=.24). Since the EENT drug category contained primarily eye medications, this relationship can be interpreted in the following way: subjects using a greater number of eye medications performed better on tasks involving Ps.

Insert Figures 4a and 4b about here

Including the 1979 performance on the four cognitive abilities in the model yielded the following changes: First, the direct effects of educational level and self-reported health in 1979 became insignificant. Second, performance on Gf and Ps in 1979 showed positive relationships (P=.48 and P=.43, respectively) with Ps in 1986. Thus, individuals who scored higher on Gf and Ps in 1979 also scored higher on Ps in 1986.

Longitudinal predictors of ability change

Path analysis models were specified to assess the significant predictors of intraindividual change on the four cognitive ability factors over the 7-year period. The predictors included in the analyses were drawn from the personal and health domain, the personality domain, and the cognitive ability domain (see Table 2). The final path analysis models resulting from these analyses are shown in Figures 5-8.

Longitudinal Predictors of Change in Fluid Reasoning. The two significant predictors of change (1979-86) in Gf ability were self-reported health at 1979 testing and the 1979 personality factor Concern About Intellectual Aging from the PIC-inventory (see Figure 5).

Insert Figure 5 about here

The personality factor Concern About Intellectual Aging showed a positive relationship (P=.30) with change in Gf, indicating that subjects who were more concerned about the loss of decline of their intellectual ability showed positive change (growth) on Gf from 1979 to 1986. The effect of 1979 self-reported health was again mediated by the number of prescribed cardiac drugs (P=-.26). The path coefficients indicated that subjects who reported poorer health also took more cardiac drugs and showed negative change (decline) in Gf ability.

Longitudinal Predictors of Change in Crystallized Knowledge. Three variables emerged as significant predictors of change in Gc: subjects' age in 1979, self-reported health in 1979, and Ms performance at 1979 testing (see Figure 6).

Insert Figure 6 about here

Subjects older in 1979 showed negative change (decline) on Gc; the same was the case for subjects who scored higher on Ms in 1979. In this model the effect of self-reported health in 1979 was mediated by the number of diuretic drugs. Participants who reported poorer health were taking more diuretics which in turn were associated with negative change (decline) in Gc from 1979 to 1986.

Longitudinal Predictors of Change in Memory Span. Significant predictors of change in Ms performance were self-reported health in 1979, and 1979 performance in Gf and Ms (see Figure 7).

Insert Figure 7 about here

The effect of self-reported health in 1979 on change in Ms was mediated by the number of prescribed diuretic drugs (P=-.19). Subjects who perceived themselves being in poorer health in 1979 were taking a greater number of diuretics and showed negative change in Ms performance. Two cognitive abilities assessed at 1979 testing predicted change in Ms: subjects who scored higher on Gf in 1979 showed positive change on Ms (P=.39), and subjects who had performed high on Ms in 1979 showed negative change (P=-.62).

Longitudinal Predictors of Change in Perceptual Speed. The significant predictors of change in Ps were self-reported health in 1979, Gf performance in 1979, and Ps performance in 1979. In addition, the mediating variable assessing the life stress associated with life events exerted an independent positive effect on change in Ps during the 7-year period (see Figure 8).

Insert Figure 8 about here

In this model the effects of self-reported health in 1979 were mediated by two groups of prescription drugs: cardiac drugs (P=-.28) and EENT drugs (P=.23). Use of

more cardiac drugs was associated with negative change in Ps, whereas use of EENT drugs (primarily eye medications) was associated with positive change on Ps.

Performance on two cognitive abilities at initial testing also predicted change in Ps. Subjects who scored high on Gf in 1979 maintained their performance or showed positive change in Ps; whereas participants who scored high on Ps in 1979 showed negative change in this ability. Unexpectedly, individuals reporting a higher degree of life-event related stress also maintained their performance on Ps or showed positive change.

Concurrent correlates of 1986 ability level.

A model predicting each of the four 1986 ability levels was run using the 1986 variables as predictors. Predictors included: age in 1986, education in 1986, the 1986 general health factor, the health change factor, cardiac drug use, diuretic drug use, use of EENT preparations, PIC Intellectual Self Efficacy in 1986, PIC Concern About Aging in 1986, perceived social support in 1986, the Zung Depression Scale in 1986, and the PGC in 1986. Results for the final reduced models, after nonsignificant predictors were dropped, are reported in Table 3. The models predicted between 18% and 33% of the variance in the 1986 abilities.

Insert Table 3 about here

Significant predictors of Gf and Gc included: age, education, general health in 1984, health change, and PIC Concern About Intellectual Aging. Significant predictors of Ms included: education, PIC Concern About Intellectual Aging, and EENT preparations. Significant predictors of Ps included: age, education, general health in 1984, and EENT. Higher education was predictive of higher performance across all the abilities. People who were older, less healthy, reporting more health change (decline), and more concerned about intellectual aging performed less well on some of the 1986 abilities. People who took more eye, ear, nose and throat preparations performed better on the Ms and Ps abilities.

Discussion

The path analysis models estimated in this study provided an unexpectedly consistent picture with regard to the predictors of intellectual performance over a 7-year period. From the noncognitive domain, two main variables emerged as significant predictors of level of performance on the four psychometric abilities included in this study. These variables were educational level and perceived health status. Subjects with a higher educational level and better self-reported health status showed better performance on these cognitive abilities years later. Self-reported health status also affected cognitive performance via prescription drug use, in particular, the use of cardiac drugs and EENT drugs.

Although these results are consistent with findings reported from other studies (see Hertzog, Schaie, & Gribbin, 1978) there are at least two caveats worth considering. One caveat is that our study did not include an independent measure of cardiovascular disease, such as physicians' ratings or information from patient records. A second caveat is that in our drug use data we were not able to distinguish clearly between symptom-oriented drugs and disease-related drugs; although the latter seems to be more likely in an aged sample like the one investigated in the ADEPT project.

An interesting finding in our study was the fact that the effect of perceived health status on perceptual speed performance was mediated by the number of EENT prescription drugs, primarily eye medications. This relationship even persisted after cognitive variables were included in the model, and it may be indicative of health-related compensatory behavior of the aged individuals.

Two additional noncognitive variables were relevant in predicting performance

on memory span in 1986. These two variables were subjects' age in 1979 and the personality factor of Intellectual Self-Efficacy assessed with the PIC inventory. The latter result is consistent with Lachman's findings (Lachman, 1986; Lachman & Leff, 1989) suggesting that Intellectual Self-Efficacy is not related to performance on fluid or crystallized intelligence measures but to performance on measures assessing memory functioning and speed of processing information.

It needs to be addressed that the importance of the noncognitive predictors was relative compared to the effects of individuals' 1979 level of performance on the respective cognitive abilities. When these initial performance levels were entered into the models, the effects of educational level and self-reported health status failed to reach significance in three out of four models. This was primarily due to the fact that with the exception of memory span, the psychometric abilities are relatively stable and therefore show moderate to high autocorrelations across time.

It is also interesting to note that Fluid Reasoning in 1979 was the most important predictor for three out of four of the abilities. This indicates that fluid reasoning measures do not only tap aspects of fluid intelligence but also aspects of working memory and speed of information processing, a notion that has been emphasized by Horn (1978) in his work on adult intelligence development.

In terms of the predictors of intraindividual ability change, the picture changed somewhat. Self-perceived health status in 1979 was the only noncognitive variable that consistently emerged as a predictor of change on the four intellectual abilities. However, its effects were always mediated by individuals' drug use behavior, primarily the use of cardiac drugs for fluid reasoning and perceptual speed, diuretics for crystallized knowledge and memory span, and EENT drugs for perceptual speed. Although we do not know whether the number of prescribed drugs is a reliable and valid indicator of individuals' health conditions, this variable was predictive of negative change in intellectual performance in three out of four path models. The exception was the number of prescribed EENT drugs. Again, the number of drugs in this category seemed to be indicative of some compensatory behavior of the aged individuals; persons taking these drugs attain sensory correction, and consequently demonstrate less downward change.

The only control belief variable that emerged as a significant predictor of intellectual change was the personality factor Concern of Intellectual Aging from the PIC inventory. Subjects who scored high on this factor in 1979 showed positive change on Fluid Reasoning over the 7-year period. Two explanations seem to be plausible for this finding. First, subjects who expressed greater concern about their intellectual aging in 1979 may have been individuals who took steps to compensate for subjectively experienced ability loss. They may have accomplished this by involvement in daily mind exercises such as reading, solving crossword puzzles, or attending educational programs. A second possible explanation may be that higher functioning individuals are affectively more preoccupied with their intellectual aging and therefore voice concerns that are not really mirroring their actual level of performance. Further research is needed to explore these possibilities.

The abilities that were significantly related to intellectual change over the 7-year period were 1979 Memory Span, 1979 Fluid Reasoning, and 1979 Perceptual Speed. While high scores on 1979 Fluid Reasoning were associated with positive change on Memory Span and Perceptual Speed, the reverse was the case for 1979 Memory Span and 1979 Perceptual Speed. This may be due to the fact that individuals who scored high on Memory Span and Perceptual Speed in 1979 had more room left to decline on these abilities (i.e., regression to mean performance level) over the 7-year time span. An alternative explanation could also be that the subjects in our study dealt less with tasks in their daily lives that required the activation of speed and working memory, tasks that are often required in job-related settings. The disuse of these intellectual abilities, combined with the possible use of external aids, may have resulted in the negative change in

Memory Span and Perceptual Speed. Both explanations seem to be plausible and call for further research.

To summarize, our analyses helped to identify a set of predictors from four broad domains that were significant both in predicting longitudinal intellectual performance as wall as intraindividual change on four second-order ability factors over a 7-year period. The question of whether the importance of these predictors is maintained while subjects in the ADEPT project progress into old age will be pursued in future research.

References

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

Baltes, P. B. (1987). Theoretical perspectives of life-span developmental psychology: On the dynamics between growth and decline. Developmental Psychology, 23, 611-626.

Baltes, P. B., Cornelius, S. W., Spiro, A., Nesselroade, J. R., & Willis, S. L. (1980). Integration versus Differentiation of Fluid/Crystallized Intelligence in Old Age. Developmental Psychology, 16, 625-635.

Blieszner, R., Willis, S. L., & Baltes, P. B. (1981). Training Research in Aging on the Fluid Ability of Inductive Reasoning. Journal of Applied Developmental Psychology, 2, 247-265.

Botwinik, J. (1977). Intellectual abilities. In J. E. Birren & K. W. Schaie (Eds.), Handbook of the psychology of aging. (pp. 580-605). New York: Van Nostrand Reinhold.

Cattell, R. B. (1971). Abilities: Their Structure, Growth and Action. New York: Houghton Mifflin.

Cattell, R. B. & Cattell, A. K. S. (1957). Test of 'g': Culture Fair (Scale 2, Form A). Champaign, IL.: Institute for Personality and Ability Testing.

Cattell, R. B. & Cattell, A. K. S. (1961). Measuring Intelligence with the Culture-Fair Tests: Manual for Scales 2 and 3. Champaign, IL.: Institute for Personality and Ability Testing.

Cattell, R. B. & Cattell, A. K. S. (1963). Test of 'g': Culture Fair (Scale 3, Form A and Form B). Champaign, IL.: Institute for Personality and Ability Testing.

Costa, P. T., & Shock, N. W. (1980). New longitudinal data on the question of whether hypertension influences intellectual performance. In M. F. Elias & D. H. P. Streeten (Eds.), Hypertention and cognitive processes. Mount Desert, ME:

Beech Hill Enterprises, Inc.

Duncan, O, D. (1975). Introduction to structural equations models. New York: Academic Press.

Ekstrom, R. B., French, J. W., Harman, H., & Derman, D. (1976). Kit of Factor-Referenced Cognitive Tests, revised edition, Princeton, NJ: Educational Testing Service.

Field, D., Schaie, K. W., & Leino, E. V. (1988). Continuity in intellectual functioning: The role of self-reported health. Psychology and Aging, 3(4), 385-392.

Guilford, J. P. (1969a). Verbal Analogies Test. I. Beverly Hills, CA: Sheridan Psychological Services.

Guilford, J. P. (1969b). Word Matrix Test. Beverly Hills, CA: Sheridan Psychological Services.

Hertzog, C., Schaie, K. W., & Gribbin, K. (1978). Cardiovascular disease and changes in intellectual functioning from middle to old age. Journal of Gerontology, 33, 872-883.

Holmes, T.H., & Rahe, R. H. (1967). The Social Readjustment Rating Scale, Jounal of Psychosomatic Reasearch, 11, 213-218.

Horn, J. L. (1967). Social Situations--EP03A. Unpublished test, University of Denver, CO.

Horn, J.L. (1978). Human Ability Systems. In P. Baltes (Ed.), Life Span Development and Behavior (Vol. 1, pp. 211-256). New York: Academic Press.

Jöreskog, K. G., & Sörbom, D. (1986). LISREL VI--Analysis of Linear Structural Realtionships bt the Method of Maximum Likelihood (4th ed.). Mooresville, IN: Scientific Software, Inc.

Kahn, R.L., & Antonucci, T. C. (1980). Convoys over the life course: Attachment, roles and social support. In P. B. Baltes & O. G. Brim (Eds.) Lifespan development and behavior, (Vol. 3, pp. 383-405). New York: Academic Press.

Klonoff, H., & Kennedy, M. (1966). A comparative study of cognitive functioning in old age. Journal of Gerontology, 21, 239-243.

Labouvie-Vief, G. (1985). Intelligence and cognition. In J. E. Birren & K. W. Schaie (Eds.), Handbook of the psychology of aging. (2nd edition, pp. 500-530). New York: Van Nostrand Reinhold.

Lachman, M. E. (1983) . Perception of Intellectual Aging: Antecedent or Consequence of Intellectual Functioning? Developmental Psychology, 19, 482-498.

Lachman, M. E. (1986). Personal Control in Later Life: Stability, Change, and Cognitive Correlates (pp. 207-236). In M. M. Baltes & P. B. Baltes (Eds.), The Psychology of Control and Aging. Hillsdale, NJ: Erlbaum.

Lachman, M. E., & Leff, R. (1989). Perceived control and intellectual functioning in the elderly: A 5-year longitudinal study. Developmental Psychology, 25, 722-728.

Lawton, M. P. (1975). The Philadelphia Geriatric Center Morale Scale: A revision. Journal of Gerontology, 30, 85-89.

Light, K. C. (1980). Antihypertensive drugs and behavioral performance. In M. F. Elias & D. H. P. Streeten (Eds.), Hypertention and cognitive processes. Mount Desert, ME: Beech Hill Enterprises, Inc.

O'Sullivan, M. & Guilford, J. P. (1965). Social Translations. Form A. Beverly Hills, CA: Sheridan Psychological Services.

O'Sullivan, M., Guilford, J. P., & de Mille, R. (1965). Measurement of social intelligence. Technical Report No. 34. Los Angeles: University of Southern California, Psychology Laboratory.

Pedhazur, E.J. (1982). Multiple regression in behavioral research (2nd ed.) New York: Holt, Rinehard, and Winston.

Perlmutter, M., Adams, C., Berry, J., Kaplan, M., Person, D., & Verdonik, F. (1987). Aging and memory. In K. W. Schaie & C. Eisdorfer (Eds.) Annual Review of Gerontology and Geriatrics, Volume 7 (pp. 57-92). New York: Springer.

Plemons, J. K., Willis, S. L., & Baltes,P. B. (1978). Modifiability of Fluid Intelligence in Aging: A Short Term Longitudinal Training Approach. Journal of Gerontology, 33, 224-231.

Raven, J. C. (1962). Advanced Progressive Matrices, Set II, Revised edition. London: H. K. Lewis.

Schaie, K. W. (1979). The Primary Mental Abilities in adulthood: An exploration in the development of psychometric intelligence. In P. B. Baltes & O. G. Brim, Jr. (eds.), Life-span development and behavior (Vol. 2). New York: Academic Press.

Schaie, K. W., editor (1983). Longitudinal Studies of Adult Psychological Development. New York: Guilford.

Schaie, K. W. (1984). Midlife influences upon intellectual functioning in old age. International Journal of Behavioral Development, 7, 463-478.

Schaie, K. W. (1989). Late life potential and cohort differences im mental abilities. In M. Perlmutter (Ed.) Late life potential. Washington, DC: Gerontological Society of America.

Schaie, K. W. (1990). Intellectual development in adulthood. In J. E. Birren & K. W. Schaie (Eds.), Handbook of the psychology of aging. (3rd ed., pp. 291-309). San Diego, CA: Academic Press.

Schooler, C. (1987). Cognitive effects of complex environments during the life-span: A review and theory. In C. Schooler & K. W. Schaie (Eds.), Cognitive functioning and social structure over the life course. (pp. 24-49). Norwood, NJ: Ablex.

Spieth, W. (1964). Cardiovascular health status, age, and psychological performance. Journal of Gerontology, 19, 227-284.

Thurstone, T. G. (1962). Primary Mental Abilities for Grades 9-12, Revised edition. Chicago, IL: Science Research Associates.

Willis, S.L. (1985). Towards an educational psychology of the older adult learner: Intellectual and cognitive basis. In J. E. Birren & K. W. Schaie (Eds.), Handbook of the psychology of aging. (2nd ed., pp. 818-847). New York: Van Nostrand Reinhold.

Willis, S. L., Blieszner, R., & Baltes, P. B. (1981). Intellectual Training Research in Aging: Modification of Performance on the Fluid Ability of Figural Relations, Journal of Educational Psychology, 73, 41-50.

Willis, S. L. & Jay, G. M. (1989a). Structural Invariance of Cognitive Abilities from Young-Old to Old-Old Age. Unpublished manuscript, The Pennsylvania State University, University Park, PA.

Willis, S. L. & Jay, G. M.. (1989b). Lagged Relationships between Cognitive Abilities and Personality. Unpublished Manuscript. The Pennsylvania State University, University Park, PA.

Zung, W. (1965). A self-rating depression scale. Archives of General Psychiatry, 12, 63-70.

Table 1
The ADEPT Ability Battery: Second-Order Dimensions, First-Order Primary Mental Abilities and Marker Tests

General Dimension	Primary Ability	Test	Source
Gf	CFR	Culture Fair Test (Scale 2, Form A) and Power Matrices (scale 3, Form A, 1963 ed., and Form B, 1961 ed.)	Cattell & Cattell (1957, 1961, 1963)
	CFR	ADEPT Figural Relations Diagnostic Test (Form A)	Plemons, Willis, & Baltes (1978)
	CFR	Raven's Advanced Progressive Matrices (Set II)	Raven (1962)
Gf	I	ADEPT Induction Diagnostic Test (Form A)	Blieszner, Willis, & Baltes (1981)
	I	Induction Standard Test	Ekstrom, French, Harman & Derma (1976); Thurstone (1962)
Gf/Gc	CMR	Verbal Analogies I	Guilford (1969a)
	CMR	Word Matrix	Guilford (1969b)
Gc	EMS	Social Translations (Form A)	O'Sullivan & Guilford (1965); O'Sullivan, Guilford, & de Mille (1965)
	EMS	Social Situations	Horn (1967)
Gc	V	Verbal Meaning (9-12)	Thurstone (1962)
	V	Vocabulary (V-2, V-3, V-4)	Ekstrom, et al. (1976)
Ms	Ms	Visual Number Span	Ekstrom, et al. (1976)
	Ms	Auditory Number Span	After Ekstrom, et al.(1976)
	Ms	Auditory Number Span--Delayed Recall	After Ekstrom, et al (1976)
Ps	Ps	Finding A's	Ekstrom, et al. (1976)
	Ps	Number Comparisons	Ekstrom, et al. (1976)
	Ps	Identical Pictures	Ekstrom, et al. (1976)

Note: This table presents the hypothesized relationship among broad-second order dimensions, primary mental abilities, and specific marker tests, as expressed in the Gf/Gc theory of intelligence (e.g., Cattell, 1971). Hypothesized broad dimensions include fluid intelligence (Gf), crystallized intelligence (Gc), Memory (Ms) and Speed (Ps). Hypothesized primary mental abilities include Figural Relations (CFR), Induction (I), Verbal Comprehension (V), Experiential Evaluation (EMS), Semantic Relations (CMR), Memory Span (Ms) and Perceptual Speed (Ps).

General Model of Longitudinal Predictors

Exogenous variables

Personal Charcteristics, 1979
Age
Education

Health 1979
Perceived general health Composite:
- Self-rated health
- Vision
- Hearing

Intellectual Control Beliefs 1979
PIC-Self-Efficacy
PIC-Concern About Aging

Cognitive Abilities 1979
Fluid Reasoning (Gf)
Crystallized Knowledge (Gc)
Memory Span (Ms)
Perceptual Speed (Ps)

Mediating variables

Life Event Stress
Weighted Life Events (1980-86)

Health and Drug Use
Drugs: Cardiac Drugs
- Diuretics
- Sedatives
- Replacements
- EENT drugs

Perceived Health Change (1980-86)

Endogenous variables

Cognitive Abilities 1986:
Fluid Reasoning (Gf)
Crystallized Knowledge (Gc)
Memory Span (Ms)
Perceptual Speed (Ps)

OR

1979-1986 Ability Change:
Fluid Reasoning (Gf)
Crystallized Knowledge (Gc)
Memory Span (Ms)
Perceptual Speed (Ps)

Table 3

Concurrent Correlates of Intellectual Ability Level in 1986 (Reduced Model)

	Dependent Variables			
Predictors	Gf 1986	Gc 1986	Ms 1986	Ps 1986
Age in 1986	-.28***	-.22**	-.16	-.22**
Education 1986	.40***	.49***	.23*	.29***
Health Factor 1986	-.20**	-.20*	---	-.27***
Health Change 79-86	.20**	.17*	---	---
PIC CA 1986	-.28***	-.19*	-.35***	-.16
PGC 1986	---	---	.06	---
EENT	---	---	.18*	.24**
R^2	.578	.527	.331	.427

Note: n=102. Standardized regression weights reported.
***p<.001, **p<.01, *p<.05

Figure 1: LONGITUDINAL PREDICTORS OF FLUID REASONING

Figure 1a: Noncognitive Predictors of Fluid Reasoning

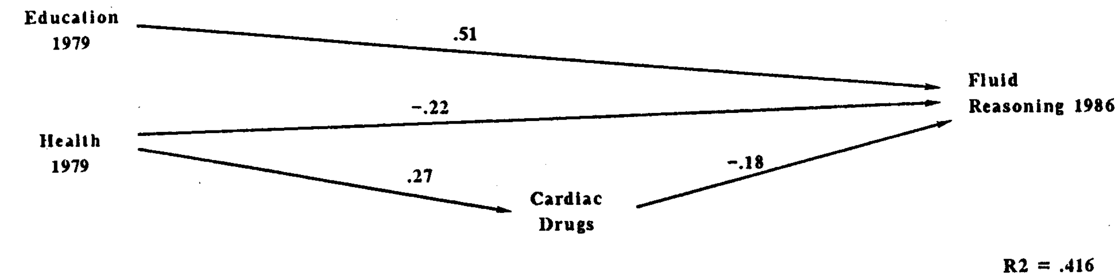

Figure 1b: Noncognitive and Cognitive Predictors of Fluid Reasoning

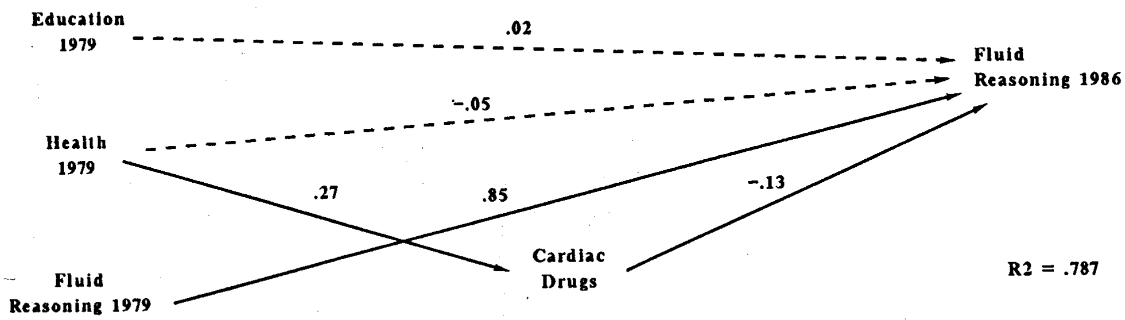

Figure 2: LONGITUDINAL PREDICTORS OF CRYSTALLIZED KNOWLEDGE

Figure 2a: Noncognitive Predictors of Crystallized Knowledge

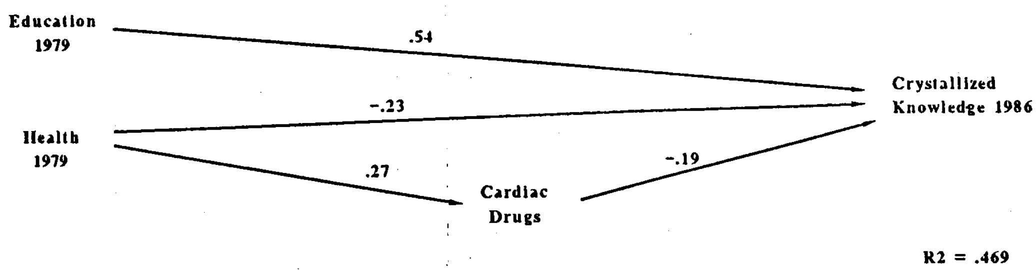

Figure 2b: Noncognitive and Cognitive Predictors of Crystallized Knowledge

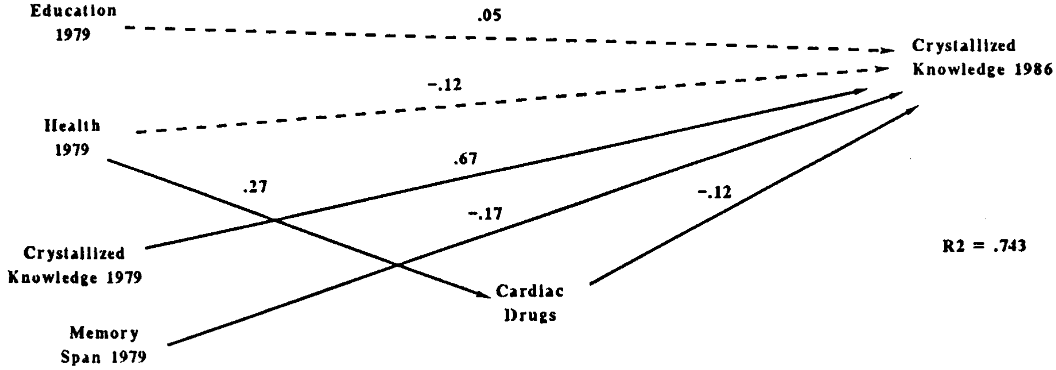

Figure 3: LONGITUDINAL PREDICTORS OF MEMORY SPAN

Figure 3a: Noncognitive Predictors of Memory Span

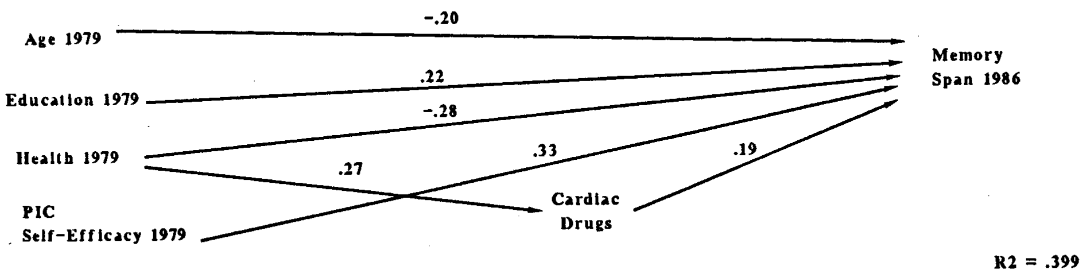

Figure 3b: Noncognitive and Cognitive Predictors of Memory Span

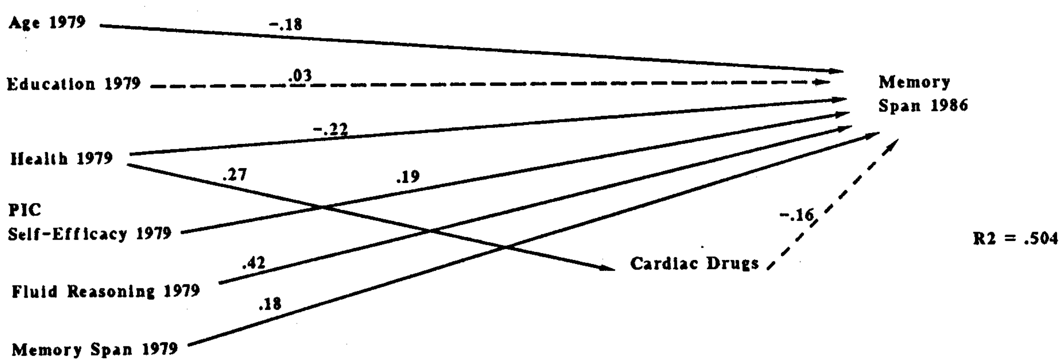

Figure 4: LONGITUDINAL PREDICTORS OF PERCEPTUAL SPEED

Figure 4a: Noncognitive Predictors of Perceptual Speed

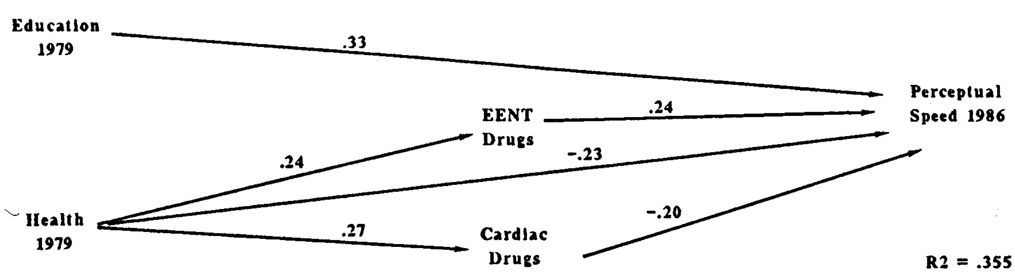

Figure 4b: Noncognitive and Cognitive Predictors of Perceptual Speed

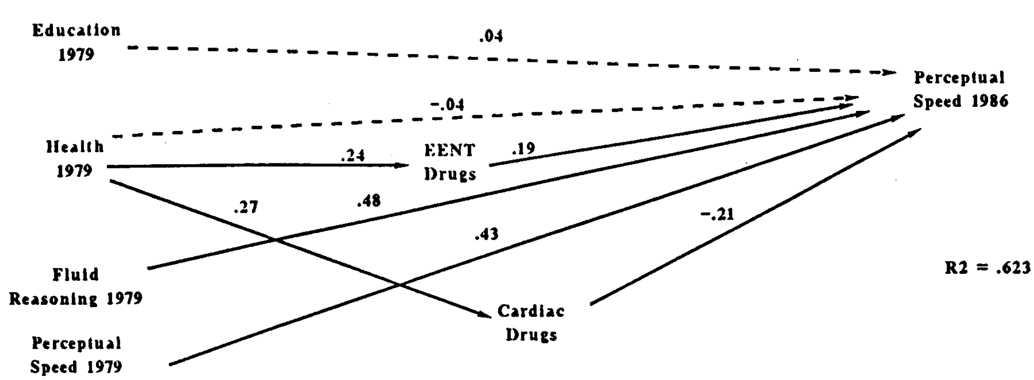

Figure 5: LONGITUDINAL PREDICTORS OF 1979-1986 CHANGE IN FLUID REASONING

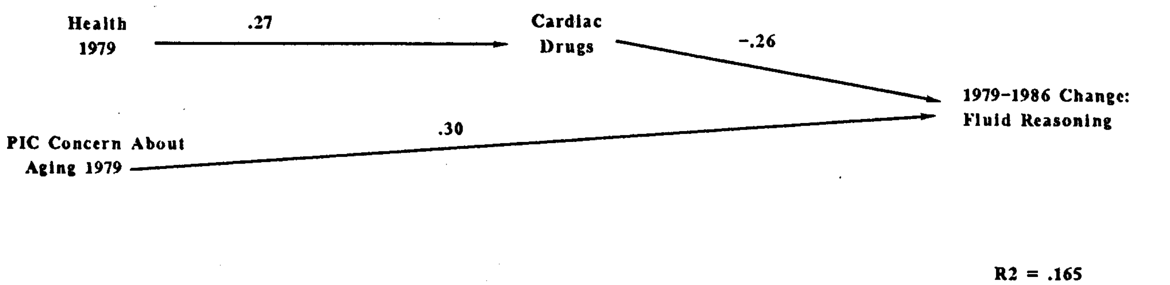

Figure 6: LONGITUDINAL PREDICTORS OF 1979-1986 CHANGE IN CRYSTALLIZED KNOWLEDGE

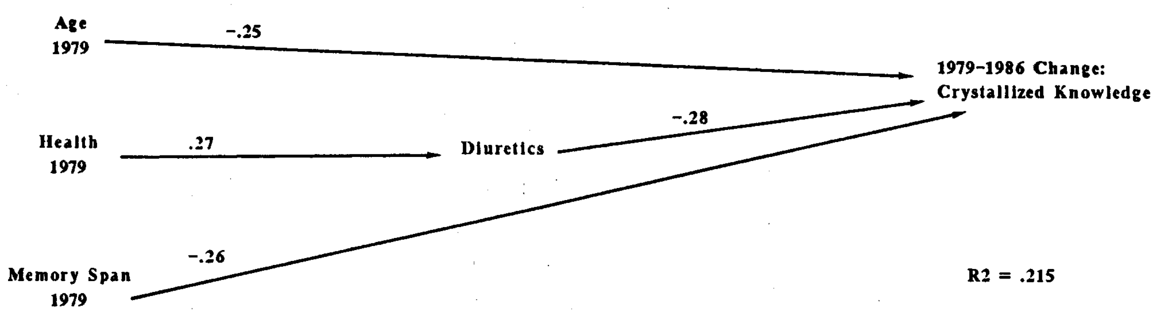

Figure 7: LONGITUDINAL PREDICTORS OF 1979-1986 CHANGE IN MEMORY SPAN

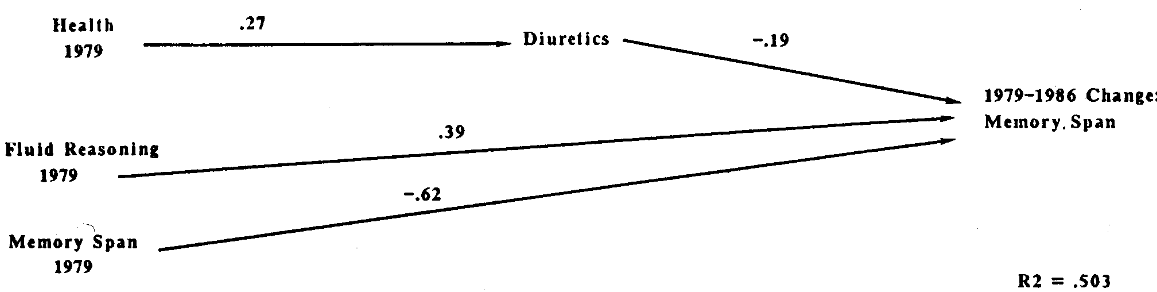

Figure 8: LONGITUDINAL PREDICTORS OF 1979-1986 CHANGE IN PERCEPTUAL SPEED