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Cognitive Engagement and Cognitive Aging: Is Openness Protective?

Emily Schoenhofen Sharp,
University of Southern California, Department of Psychology

Chandra A. Reynolds,
University of California, Riverside, Department of Psychology

Nancy L. Pedersen, and
University of Southern California and, Department of Medical Epidemiology and Biostatistics, Karolinska Institutet

Margaret Gatz
University of Southern California and, Department of Medical Epidemiology and Biostatics, Department of Psychology, Karolinska Institutet

Abstract

The purpose of this study was to examine whether openness to experience is related to longitudinal change in cognitive performance across advancing age. Participants were 857 individuals from the Swedish Adoption/Twin Study of Aging (SATSA). Factors for 5 cognitive domains were created including: verbal ability, spatial ability, memory, processing speed, and a global score, "g". Latent growth curve models were used to assess level and longitudinal trajectories of cognitive performance. It was hypothesized that individuals who endorsed higher levels of openness would have higher cognitive test scores and lesser rates of cognitive decline. As predicted, higher openness to experience was associated with significantly higher performance across all cognitive tests for both males and females even after adjusting for education, cardiovascular disease and activities of daily living. Openness, however, was not predictive of differences in the trajectories of cognitive performance over age.

Keywords

aging; cognitive engagement; cognitive decline; openness to experience; personality

Research has suggested that an active engagement with life via cognitive, social and lesiure activities is associated with a decreased risk for dementia (Crowe, Andel, Pedersen, Johansson, & Gatz, 2003; Newson, & Kemps, 2005; Wang, Karp, Winblad, & Fratiglioni, 2002; Wang et al., 2006; Wilson et al., 2002; Wilson et al., 2003a). Overall, there has been support for the hypothesis that active engagement is associated with a reduced risk for cognitive decline and

Correspondence concerning this article should be addressed to Emily Schoenhofen Sharp, University of Southern California, Department of Psychology, 3620 McClintock Avenue, Los Angeles, CA 90089-1061. schoenho@usc.edu.

dementia (see Hertzog, Kramer, Wilson, & Lindenberger, 2009; Fratiglioni, Paillard-Borg, & Winblad, 2004).

A substantial body of research underscores the connection between measures of cognitive functioning in adulthood with cognitive functioning in old age. For example, individuals with higher levels of intellectual capacity and/or more years of education have been found to have a reduced risk for cognitive impairment and dementia compared to individuals without these cognitive advantages (Albert et al., 1995; Christensen et al., 1999; Gatz et al., 2001; Katzman, 1993; Leibovici, Ritchie, Ledesert, & Touchon, 1996). In addition, intellectual complexity of occupation has also been found to be a protective factor against cognitive impairment and Alzheimer's disease (Stern, 1995; Andel et al., 2005; Andel, Kareholt, Parker, Thorslund, & Gatz, 2007). In particular, higher complexity of lifetime occupational work with people or data (but not work with things) has been associated with a reduced risk of Alzheimer's disease and all other dementias (Andel et al., 2005).

We extend these findings to predict that the personality facets associated with openness to experience will positively influence the maintenance of higher cognitive functioning via a predisposition to ponder ideas, think creatively, and to actively engage in or seek out cognitively stimulating activities across the life span. We suggest that this predisposition may be protective against declines in cognitive functioning in later life. Thus, we theorize that openness may share a unique relationship with cognitive functioning that is important to the current aging literature.

In this study, we examined the relationship between the personality trait of openness to experience and cognitive functioning longitudinally. Open individuals are described as having an intrinsic wish for knowledge, curiosity, and the ability to assimilate novel ideas. In contrast, closed individuals are more rigid in their beliefs and less emotionally involved with experiences (Costa & McCrae, 1992a,b). Openness has been found to be correlated with cognitive ability and encompasses a basic receptivity to intellectual experience (Costa & McCrae, 1992a,b; McCrae, 1994). As such, openness may reflect a behavioral pathway by which cognitive engagement is associated with lower risk of cognitive decline or dementia.

Recent studies have highlighted the importance of personality as a predictor by demonstrating that personality has similar predictive influence to that of socioeconomic status and cognitive ability on life outcomes including mortality, occupational attainment and other important life events, including physical health (see Roberts, Kuncel, Shiner, Caspi, & Goldberg, 2007 for a review; Caspi, Roberts, & Shiner, 2005). Furthermore, researchers have specifically remarked that personality traits may be central to teasing apart age-related differences in cognitive performance (Hendrie et al., 2006; Schaie et al., 2004). We focus on the particular personality trait of openness to experience.

Limited research has investigated the relationship between personality and cognitive functioning in the second half of the life span and has largely focused on negative personality traits. For example, research findings from both cross-sectional and longitudinal designs suggests that individuals who endorse higher neuroticism perform more poorly on cognitive tasks (Jorm et al., 1993), and have an increased risk for cognitive impairment (Crowe et al., 2006) and Alzheimer's disease (Wilson et al., 2003b; 2005; 2006). Fewer studies have examined whether positive personality traits may be *protective* against cognitive aging and decline, although in a sample of men participating in the MacArthur Study of Successful Aging, higher self-efficacy was protective against losses in cognitive functioning (Seeman et al., 1996).

The relationship between openness to experience and cognitive performance has received some attention, although not necessarily focused on change over age. Some studies have demonstrated a significant relationship between openness and cognitive performance (Booth, Schinka, Brown, Mortimer, & Borenstein, 2006; Schaie et al., 2004), while other research has suggested inconsistencies in the relationship between openness and cognitive functioning (Baker & Bischel, 2006). Cross-sectional studies have suggested that openness affects the level of performance but is not related to age differences in cognitive performance (Hultsch, Hertzog, Small, & Dixon, 1999; Salthouse, 2006). In the Seattle Longitudinal Study, Schaie and colleagues (2004) found that openness was the NEO personality trait most substantially related to higher cognitive performance.

The maintenance of cognitive ability as an individual ages is at the heart of the “use it or lose it” hypothesis (Katzman, 1995). For a thorough and interesting review of and reply to this debate see Salthouse (2006; 2007) and Schooler (2007). The core question, as proposed by Salthouse, is whether protective factors such as education or cognitive training activities are associated with higher cognitive functioning *as well as* a slower rate of cognitive decline and by extension lower risk for dementia. The important distinction is the difference between maintaining a certain level of cognitive functioning, termed *preserved differentiation*, versus changing the rate of the trajectory of cognitive performance, termed *differential preservation* (Salthouse, 2006). Many studies have shown that protective factors (e.g. occupational complexity) are predictive of higher levels of cognitive performance; however, the rate of change, or decline in cognitive ability over time, has generally not been found to be significantly different for individuals with higher compared to lower levels of these protective factors (Salthouse, 2006).

In the SATSA sample, earlier investigations suggested small correlations (r =.14 to .20) between both internal locus of control and openness to experience with linear change across 10 years for select spatial and speed tests (Reynolds, Gatz, & Pedersen, 2002). However, the prior examination of openness to experience on cognitive change was limited in a number of respects. At that time, there were only three measurement occasions available. In addition, openness was not considered simultaneously in the multi-level models; rather, empirical Bayes estimates of linear slope from random effects regression models of the cognitive variables were correlated with openness scores. Furthermore, the growth model was assumed to be linear, only change over time (not age) was considered, only one member of each twin pair was selected for analysis, and the models were not adjusted for key covariates such as education.

As described below, we now have sufficient measurement occasions to consider nonlinear growth over age and rise above these previous limitations. Evaluations of change over age are better suited to answer the developmental question of longitudinal cognitive aging than evaluations of change based on time (McArdle, Ferrer-Caja, Hamagami, & Woodcock, 2002). Specifically, a model of change over time can lead to inadequate separation of within-individual variability and between-persons variability (See Singer & Willet, 2003). Even after adjusting for the time-based model with age of entry into the study, models based on age versus time are not equivalent (McArdle et al., 2002).

To our knowledge, no other study has investigated the longitudinal relationship between openness to experience and cognitive functioning over age using latent growth curve modeling. To examine this relationship, it was important to examine the longitudinal stability of openness. Some of the literature has suggested that mean openness to experience remains relatively stable across adulthood and into old age (Costa & McCrae, 1992a,b, 1997; Roepke, McAdams, Lindamer, Patterson, & Jeste, 2001; Terracciano, McCrae, Brant, & Costa, 2005). In contrast, other research has suggested decreases in mean scores over the second half of the lifespan (Pedersen & Reynolds, 1998; Roberts, Robins, Trzesniewski, & Caspi, 2003; Terracciano et al., 2005) and in addition to changes in mean scores, Pedersen and Reynolds (1998) noted an increase in intraindividual variability in openness with age. Within the construct of openness, however, Terracciano and colleagues (2005) found that, two trait facets, openness to ideas and openness to aesthetics, remained remarkably stable between age 30 and 90. This is an important finding as these facets best represent the intellectual, creative and cultural core of the openness construct.

A number of other factors may also influence the relationship between openness to experience and cognitive functioning. Low education has been found to be associated with increased risk of cognitive decline; whereas, higher education has been suggested to predict less decline in cognitive ability (for a review, see Hendrie et al., 2006). Activity level and health have also been associated with cognitive functioning. Disability, as indexed by activities of daily living (ADL), has been associated with slower processing speed (Christensen et al., 1994). Cardiovascular disease (CVD), as defined by heart disease and hypertension, has been associated with poorer cognitive functioning and increased risk for cognitive decline (see Hendrie et al., 2006). We therefore include education, activities of daily living, and cardiovascular disease in the longitudinal models to evaluate their impact on the relationship between openness and cognitive functioning.

The purpose of the current study was to examine whether openness to experience is associated with cognitive performance in the second half of the lifespan and the trajectories of cognitive ability over a 20-year span assessed via longitudinal models of change. Two hypotheses were tested: (1) that the personality trait of openness would be associated with level of cognitive performance, and (2) that openness would be associated with the rate of cognitive change longitudinally. The latter hypothesis represents a test of whether openness is protective against cognitive decline, and more specifically, with regard for Salthouse's (2006) argument, whether the relationship between openness and cognitive performance is best described as *perserved differentiation* or *differential preservation*. It was expected that higher openness would be associated with better performances on across each cognitive domain and slower rates of decline in cognitive performance over time. Lastly we explored the longitudinal stability of openness using a univariate dual score change model to verify the appropriateness of using baseline openness as a predictor of cognitive change given the wide range of baseline ages of the sample.

Method

Participants

The sample was comprised of individuals from the Swedish Adoption/Twin Study of Aging (SATSA). SATSA data collection began in 1984 and continues to collect longitudinal follow-ups approximately every 3 years. The population of individuals in SATSA came from the Swedish Twin Registry, which was found to be representative of the larger Swedish population on a variety of environmental and sociological variables (Cederlof, Friberg, & Lundman, 1977). Details of the SATSA questionnaire and cognitive assessments are described in Pedersen et al. (1991) and Finkel and Pedersen (2004).

857 individuals (59% female) who had both an openness score and at least one cognitive measurement were included in the current study. It is important to note that the current study treated twins as individuals and genetic influences were not estimated. To avoid biases associated with using both individuals from a twin pair, the models were adjusted to account for the correlation between twins (see the statistical method section).

SATSA data included individuals who were eventually diagnosed with dementia (N=78). Research has suggested that personality may be affected by dementia (Balsis, Carpenter, & Storandt, 2005). To address this possibility, if an individual was diagnosed with dementia within three years of completing the openness measure they were excluded from analysis. Two individuals were dropped from analysis on this basis. However, if an individual's onset of dementia occurred after having completed the openness measure and participated in at least one cognitive testing then that individual was retained in the analysis. Thus, for the 9% of the sample that became demented, the personality questionnaire always preceded dementia onset by three or more years.

Measures

Personality—Openness to experience was measured by a six-item scale developed by factor analysis (see Bergeman et al., 1993) from the widely used and validated NEO-PI (Costa & McCrae, 1985). This scale tapped the intellectual component as well as openness to new experiences (e.g. pondering ideas, taking up hobbies, exploring new foods). Items were scored in the traditional fashion of the NEO based on a 5-point likert scale ranging from *strongly disagree* to *strongly agree*. Items were summed to create a total openness score.

The present study also evaluated the pattern of openness to experience longitudinally. The openness measurement was collected by mailed questionnaire. There are five waves of questionnaire data. The first questionnaire (Q1) was sent out in 1984, Q2 was sent out in 1987, Q3 was sent in 1990, Q4 in 1993, and Q5 in 2003. The number of participants completing an openness measurement at each wave was 680, 741, 692, 672, and 428, respectively. The openness measure was consistent across all waves of data collection. 74% of individuals had an openness score at Q1. For those individuals whose first openness measurement was at a later wave, their openness score came from the first Q they completed prior to their first cognitive testing. Data collection dates and descriptive statistics for the five openness measurement occasions are presented in Table 1.

Cognition—There are five waves of cognitive data. The cognitive testing was conducted during in-person-testing (IPT) sessions. The IPTs were administered every three years beginning two years after the first questionnaire was sent out. To be included in an IPT assessment, a twin pair had to have responded to the first Q and be above 50 years of age. The first wave of IPT (IPT1) was conducted beginning in1986, with subsequent waves at 3 year intervals. All individuals participating in each wave were contacted for the subsequent wave with the addition of any twin pair who turned 50 years of age. Due to a gap in funding, IPT4 became a telephone interview and is not included in the present analysis. Thus, there are 5 waves of cognitive data. Table 2 shows the dates of data collection, Ns and ages of participants at each measurement occasion (IPT).

The original IPT cognitive battery included 13 cognitive measures designed to assess four domains of cognitive functioning: verbal, spatial, memory, processing speed, and a global functioning index, termed “g” (Nesselroade, Pedersen, McClearn, Plomin, & Bergeman, 1988). Principal components analysis was used to identify latent factors from the individual tests within each domain. Reliabilities for the individual tests ranged from .82 to .96 (see Pedersen et al., 1992). Verbal abilities were assessed by the Information subtest, Synonyms, and Analogies. Spatial abilities were comprised of Figure Logic, Block Design, and Card Rotations. The memory factor included Digit Span (Forward plus Backward), Thurstone Picture Memory task, and Names and Faces (immediate and delayed). Processing speed was indexed by Symbol Digit and Figure Identification. To create component scores with consistent definitions across waves, the cognitive measures were standardized relative to the respective means and variances at IPT1. The loadings from principal components analyses conducted at IPT1 were used to construct the verbal, spatial, and memory factors. All components were transformed into t-scores prior to analysis. The two measures of speed were combined into a speed factor using equal weighting. Loadings for the verbal, spatial, and speed components ranged from .78 to .92 and internal consistency was .85, .78, and. 82 respectively. The memory loadings ranged from .64 to .78, and internal consistency was .60. The more diverse loadings for memory were attributable to including measures tapping short-term, long-term, and picture memory within one factor. The global factor, “g”, was created using individuals' scores on the first principal component of the 13 cognitive tests. Comparisons of the factor structure of the cognitive tests have been conducted previously and indicate that the factor structure did not vary systematically across age or time (Finkel, Reynolds, McArdle, & Pedersen, 2005).

Covariates—The main covariates for this study were education, activities of daily living and cardiovascular disease. Educational attainment was treated as a continuous variable ranging from 1 (elementary school) to 4 (university or higher). An activities of daily living (ADL) scale was included as part of the SATSA questionnaire (Pedersen & Harris, 1990). It was comprised of 14 yes-no items, where seven of the questions pertained to instrumental activities and another seven questions pertained to physical activities. A total score was summed across questions. ADL was treated as a continuous variable. The presence of cardiovascular disease (CVD) was assessed as part of a self-reported health questionnaire also part of SATSA. If an individual reported yes to any of the following: angina pectoris, high blood pressure, heart insufficiency, heart attack, claudication, phlebitis, circulation problems, thrombosis, stroke, tachycardia, a heart operation, or heart valve problem, then they were considered as having self-reported cardiovascular disease. A portion of this measure was made up of the Rose Questionnaire (Rose, McCartney, & Reid 1977). All covariates were centered on their mean.

Statistical Method

Latent Growth Curve Analysis of Cognition—The present study employed latent growth curve modeling to measure change in cognitive performance over time and to explore what proportion of that change could be attributed to openness to experience. Latent growth curve models measure and allow for comparisons of individual trajectories of decline as well as an average trajectory of decline across the entire sample.

Two factors or more can be defined based on longitudinal data: an *intercept*, the estimate of the typical score at a specific age or point in time, and a s*lope*, the systematic longitudinal variation around the intercept. If there is reason to consider nonlinerarity, a quadratic term (age-squared) can be defined to further characterize a trajectory. In such a case, longitudinal variation around the intercept would be due to a linear slope defined at the point of the intercept plus acceleration in the curve over age. Both linear and quadratic models were considered for all cognitive factors.

Latent growth curve models can also be evaluated in a random coefficients model (Bryk & Raudenbush, 1987). This technique allows for the use of both missing and non-sequential data points. Furthermore, data from individuals with only one measurement occasion can be included in the analysis to stabilize both mean and variance estimates (Finkel, Reynolds, McArdle, Gatz, & Pedersen, 2003; McArdle & Anderson, 1990; McArdle & Hamagami, 1992). Latent growth curve models allow for missing data by giving more weight to individuals with the most measurement occasions or time points.

We have evaluated power to detect a small effect of a predictor on growth parameters using Monte Carlo methods in the program MPlus (Muthen & Muthen, 2002). For linear models power is .85 with a sample of 400 to detect an effect on the linear slope, assuming five time points, missing data, and unequal measurement intervals. For quadratic models, power is .77 to detect an effect on the quadratic change with a sample of 800. Sample sizes in the present study exceeded the sample sizes tested in the power analyses.

A frequent concern of longitudinal studies is missing data and whether the patterns of missing data are ignorable or nonignorable. A full maximum-likelihood estimate (MLE) technique was used in the latent growth models. This technique aggregates all available data on any participant included in the analyses to estimate the model parameters. A basic statistical assumption of MLE is that the incomplete data points are missing at random (MAR). The MAR assumption is typically applied to incomplete longitudinal data (Little, 1995; McArdle et al., 2004). This assumption was applied to the data in this study. Because this sample was comprised of individuals who were twins, and twins are not independent of each other, models were adjusted to account for the correlation between twins (detailed further below).

Longitudinal change was defined by chronological age (and age-squared) rather than by time or measurement occasion (McArdle, Ferrer-Caja, Hamagami, & Woodcock, 2002). An interaction effect between openness and age (or age squared) would be indicative of a difference in the trajectory of a cognitive task (slope) due to differences in level of openness. Models can be expanded to investigate and control for the effects of covariates, such as education (Reynolds, Finkel, Gatz, & Pedersen, 2002). An example of a linear latent growth model, expanded to include openness to experience and a covariate, is presented in Figure 1. Age was centered at 65 years. The mean age of 65 was selected because previous research had suggested that this was the age-point at which cognitive performance on most of the tasks began to decline (Finkel et al., 2003). Openness, education, ADL, and CVD were mean-centered. Males and females were modeled separately. Thus, the equations for the linear and nonlinear latent growth models are as follows:

Linear model:

$$COG_{ij}=\gamma_{00}+\gamma_{10}(Age_{ij}-65\Big)+\gamma_{01}OPEN_i+\gamma_{11}\Big(OPEN_i(\mathrm{Age}_{\mathrm{ij}}-65)\Big)+\zeta_{0\mathrm{i}}+\zeta_{1\mathrm{i}}(Age_{ij}-65\Big)+\varepsilon_{\mathrm{ij}} \quad [1a]$$

where COG_{ij} represents a cognitive factor score (e.g., Verbal) for the ith individual at time point j; $OPEN_i$ represents the ith individual's Openness score (centered at its mean at IPT1); AGE_{ij} is the ith individuals age at timepoint j; γ_{00} reflects the average intercept at age 65 and average Openness score; γ_{10} represents the linear rate of change at the average Openness score; ζ_{0i} and ζ_{1i} reflect the ith individuals deviations from the average intercept and slope respectively, and ε_{ij} reflects the deviation of the ith individual's score at time point j from their expected linear trajectory.

Quadratic model:

$$\begin{aligned}COG_{ij}\quad &=\gamma_{00}+\gamma_{10}(Age_{ij}-65\Big)+\gamma_{20}(Age_{ij}-65)^2+\\&\gamma_{01}OPEN_i+\gamma_{11}(OPEN_i(AGE_{ij}-65))+\gamma_{21}(OPEN_i(Age_{ij}-65)^2)+\\&\zeta_{0\mathrm{i}}+\zeta_{1\mathrm{i}}(Age_{ij}-65)+\zeta_{21}(Age_{ij}-65)^2+\varepsilon_{\mathrm{ij}}\end{aligned} \quad [1b]$$

where COG_{ij} represents a cognitive factor score (e.g., Verbal) for the ith individual at time point j; $OPEN_i$ represents the ith individual's Openness score (centered at its mean at IPT1); AGE_{ij} is the ith individuals age at timepoint j; γ_{00} reflects the average intercept at age 65 and average Openness score; γ_{10} represents the linear rate of change at age 65 and at the average Openness score; γ_{20} represents the quadratic rate of change at the average Openness score; ζ_{0i}, ζ_{1i} and ζ_{2i} reflect the ith individuals deviations from the average intercept, slope, and quadratic parameters respectively, and ε_{ij} reflects the deviation of the ith individual's score at time point j from their expected linear trajectory.

PROC MIXED (SAS Institute 9.0, 2000) was used to fit the latent growth curve models. A stepwise procedure was adopted to evaluate longitudinal trajectories. First, initial growth curves were fit to establish linear or nonlinear age trends for each cognitive task at the mean-centered age of 65. Next, mean-centered openness was added to the model, followed by terms for mean-centered education, ADL, and CVD. We then added two-way interaction terms for linear and nonlinear age with openness to the model. The final model of interest for each cognitive task included all terms, allowing for a more thorough evaluation of both hypotheses 1 and 2. Males and females were modeled separately. Hypotheses were evaluated by comparing deviances of nested models using the difference chi-square test with the degrees of freedom equal to the difference in the number of parameters of the two nested models. The current analyses focused on individual performance, making it necessary to eliminate any bias resulting from inclusion of twins. In SAS Proc Mixed, pair dependency was accounted for by specifying random effects of growth parameters within and between twin pairs.

Univariate longitudinal analysis - Openness—To examine the stability of openness scores during the years of cognitive testing, a univariate dual change score model was used to examine age changes in openness to experience independently of cognition. This type of model has been discussed elsewhere in detail (see Finkel et al., 2005; McArdle, 2001; McArdle & Hamagami, 2003; McArdle et al., 2004). Models were fit to males and females separately using full-information methods in Mplus 5.2 (Muthen & Muthen, 2009) to maximize the use of the data from all participants. In general, a growth model based on latent difference scores was fit where change from one age to the next is described in terms of static linear changes (α) occurring additively across age as well as proportional change (β) that accumulates across age, i.e. the difference in cognitive performance between adjacent ages is proportional to the previous score. Error variance is fixed to be equal at each age. The change in openness can be thus described as:

$$\Delta OPEN=\alpha_{\text{open}}+\beta_{\text{open}}OPEN[\mathrm{t}-1] \qquad [2]$$

The values of α and β are constant across age. In the full model, α is fixed to 1 while the value of β is estimated based on the shape of the trajectory over time (e.g. nonlinear). In addition, the mean intercept and slope as well as individual variation around the intercept and slope (and their covariance) are estimated. Thus, the time series for openness is described by eight parameters: mean intercept, mean slope, intercept deviation, slope deviation, intercept-slope correlation, error deviation, and the change parameters (α and β).

Bivariate longitudinal analysis – Openness and Cognition—Where the univariate dual change score model was supported for openness, we then extended the model to the bivariate case to explore the dynamic relationship between change in openness and change in cognitive factors. In addition to the constant and proportional change parameters (α and β), a coupling mechanism (γ) across the openness and cognitive traits was estimated, where change in trait openness depends on the previous value of cognitive performance (e.g., memory), and *visa-versa*. The differences in openness and cognitive performance can thus be described in terms of their respective static and proportional change processes within trait (α and β and that driven by the values of the other trait ($\gamma_{\text{cog,open}}$ and $\gamma_{\text{open,cog}}$):

$$\Delta OPEN=\alpha_{\text{open}}+\beta_{\text{open}}OPEN\mathrm{t}-1]+\gamma_{\text{cog,open}}COG[\mathrm{t}-1] \qquad [3a]$$

$$\Delta COG=\alpha_{cog}+\beta_{x}COG[t-1]+\gamma_{open,cog}OPEN[t-1] \quad [3b]$$

As in the univariate model, the parameters α and β, as well as the coupling parameters (γ's) are assumed to be constant. To test whether there is coupling between openness and cognitive performance across age we evaluated the significance of the γ parameters by fitting the full model and then dropping each γ in turn.

Model fit was indicated by deviance statistics, i.e., -2 times the log-likelihood fit (-2LL). In MPLUS, pair dependency was accounted for by specifying pair number as the clustering unit. This necessitated the use of maximum likelihood estimation with robust standard errors (MLR) given the non-independence of the twins. Thus, we computed difference chi-square tests according to the loglikelihood values and scaling correction factors obtained with the MLR estimator (see http://www.statmodel.com/chidiff.shtml).

Results

Openness to experience was normally distributed across the sample and ranged from a lowest score possible of 6 to the highest score possible of 30. The mean for baseline openness for males was 17.67 (std = 3.93) and was 17.87 (std =4.25) for females. Descriptive statistics for longitudinal openness scores by sex are presented in Table 1. Dates of cognitive measurement occasions (IPTs), means, standard deviations, and range for age by sex are listed in Table 2. Correlations with study covariates are given in Table 3. As expected, openness was positively correlated with education. Sex, ADL and CVD were not correlated with scores on openness to experience. The pattern of correlations was similar when examined separately for males and females, with the exception that openness was not significantly correlated with baseline age. We examined the correlation between openness and cognitive data across measurement occasions and found that openness was significantly positively correlated at all measurement occasions for both males and females within each cognitive domain (see Table 4). The median correlation was .40 for males and .26 for females. Overall, the correlations were strongest for the global cognitive composite "g" and weakest for the speed factor. This notable difference in correlations between openness and cognitive factors lead us to model males and females separately.

Latent Growth Curve Analyses

Results for the latent growth curve models are summarized in Tables 5 and 6. There was significant linear change with age on all cognitive factors with the exception of verbal abilities in women where no significant linear change was identified, and significant acceleration (age-squared) for all cognitive factors. Supporting hypothesis 1, significant average performance effects (intercept) were found for openness to experience across all cognitive domains while controlling for education, ADL and CVD. Specifically, individuals endorsing higher openness evidenced a better performance in all cognitive domains at the centering age of 65. In contrast, tests of hypothesis 2 indicated that openness was not associated with change over age in cognitive factor scores. There were no significant interactions between age (linear or nonlinear) and openness for males or females. The models were rerun without the 78 incident dementia cases and the results did not change.

Figures 3-7 illustrate the trajectories of cognitive performance over time as predicted by openness. The trajectories based on the growth model estimates for intercept, linear and quadratic slopes illustrate the interaction of age and openness. To give a visual representation of the data, two groups are graphed: High openness refers to openness scores 1 standard deviation above the mean and Low openness refers to openness scores 1 standard deviation below the mean.

Univariate longitudinal analysis - Openness

To examine the stability of openness over time, a univariate dual change score model (DCSM) was fit separately for males and females. This analysis allowed us to examine the shape of the trajectory of openness across time. Two models were compared: a full model that estimated both static and proportional change (β), and a reduced model wherein the proportional change effect β was set to zero to test the significance of accumulating nonlinear change over time. Parameter estimates (and standard errors), fit statistics and results of the reduced model are presented in Table 7. Nonlinear change was examined by testing the significance of the proportional change parameter, β. This was done by comparing the full model to a reduced model in which β was set to zero. For females only, removing the β from the model resulted in a significant reduction in model fit ($p < .0001$), substantiating proportional (nonlinear) change over time.

Overall, for females, the univariate model suggested very little change in openness scores until after age 75. After age 75, the model indicated an accelerating decline in openness scores. For males, the results from the univariate model suggested that openness scores were stable over time. The model did not identify nonlinear ($p > .07$) or linear change ($p > .23$). Figure 8 presents the average trajectories for males and females given the full model estimates.

Bivariate longitudinal analysis – Openness and Cognition

Because dynamic change was identified in the univariate models of openness for females, a bivariate DCSM was fit to explore the temporal coupling of openness and cognitive factor scores, in other words, to examine whether openness or cognitive performance was driving the relationship. We hypothesized that openness was the leading indicator of age changes in cognitive performance across the five cognitive domains: spatial, speed, verbal, memory, and “g”. However, the full model was not estimable for openness with any of the cognitive factors (i.e., did not converge). We next explored the dynamic models choosing one twin at random to reduce the complexity of the estimation but again the full model was not estimable. Given these results, we explored reduced unilateral models of coupling from openness predicting subsequent change in cognition or cognition predicting subsequent change in openness. These reduced models were in general not estimable.

The failure in fitting the bivariate DCSM models may be due to the fact that the measurement of openness and cognition were not concurrently measured; openness was measured at questionnaire (Q) waves while cognition was measured in in-person (IPT) sessions, generally 18 months apart. A more likely factor is that accelerating change occurs on average 10 years later for openness (for females) than for cognition in the SATSA sample: 75 versus 65 years, respectively (e.g., Finkel et al., 2003).

Discussion

This study examined whether openness to experience was protective of cognitive functioning across advancing age. Openness to experience, as predicted, was associated with cognitive performance. Individuals who endorsed higher levels of openness performed significantly better across all cognitive domains and this advantage was maintained over time. The pattern of effect for openness was similar for both males and females, although stronger for males, even when adjusting for education, ADL and CVD. These findings support previous literature on the relationship between openness to experience and cognitive performance (Baker & Bischel, 2006; Booth et al., 2006; Schaie et al., 2004).

A possible mechanism to explain the relationship between openness and cognition is the cognitive reserve hypothesis (Stern, 2003; 2006), i.e. individuals with higher openness are more actively engaged in cognitively-enriching activities, and these activities are protective of level of cognitive performance. This hypothesis is in agreement with the definition of openness as an intrinsic cognitive receptivity and the enjoyment of experiencing and thinking about novel ideas (McCrae, 1994). Furthermore, the protective nature of cognitive engagement in relation to cognitive aging has been demonstrated in a number of recent studies (see Hertzog et al., 2009; Fratiglioni et al., 2004). However, contrary to the hypothesis that openness would protect against cognitive decline, individuals endorsing higher levels of openness did not have an advantage in terms of the rate of decline compared to individuals lower on openness. For the most part, there was no relationship between openness and change over time.

In relation to Salthouse's (2006) description of *preserved differentiation* versus *differential preservation*, the results of this study support the *preserved differentiation* explanation. Openness was found to be predictive of significantly higher performance across all cognitive domains (level), but openness was not predictive of a slower rate of decline in cognitive abilities over time (slope). Thus, it can be argued that the effects of openness on the intercept (at age 65) proffered some protection because individuals with higher levels of openness had higher cognitive performance at 65 years (i.e. lifting up the entire trajectory) even though the rate of loss was not mitigated by openness.

Strengths and Limitations

Although openness to experience is presented as a personality trait, it is possible that openness may largely be a reflection of intellectual ability. The trait of openness has also been termed “need for intellect”, “intelligence”, and “culture” by researchers because of the curiosity component and high correlation with cognitive functioning (McCrae, 1994). The present study also found a strong positive correlation between openness and education for the entire sample (and within sex). Swedish individuals from the birth cohorts included in this study often only had access to the required elementary education (approximately 6 years). Because education is a poor proxy for intellectual stimulation after the conclusion of formal education, more open individuals may have had a distinct advantage stemming from an intrinsic motivation for cognitive stimulation and life-long learning.

One possible methodological explanation for the lack of relationship between openness and change over time is that there was only one measurement point for openness, raising the potential for loss of predictive power over time. However, the correlations between baseline openness and each cognitive domain at the five measurement occasions did not suggest a clear pattern of change over time; instead a moderate correlation was consistent across time (see Table 4). To further address the potential for a dynamic relationship between openness and cognitive performance, we analyzed univariate and bivariate dual change score models. Results of the univariate model identified dynamic change for females (only after age 75), while openness was found to be stable with no linear or nonlinear change for males. Results of the exploratory bivariate models were less clear. The lack of convergence in the bivariate models suggests that change may not be occurring concurrently. This may be due in part to the lack of concurrent measurement but more likely to differences in the age when change occurs for openness versus cognition. Previous studies of cognition in this sample have suggested that changes in cognition occur at approximately age 65 (e.g., Finkel et al, 2003), whereas change in openness is only identified in females after age 75 and not at all for males. Altogether, these circumstances support the use of baseline openness as a predictor of longitudinal cognitive performance.

One possible reason for not finding an effect of openness on change in cognition may be due to the reliability of the slope estimate. The reliability of the slope is related to the number of measurement points (Byrk & Raudenbush, 1992). In pervious studies of cognition with five measurement occasions, we have been able to demonstrate change and individual variation in change. If the effect of openness on change in cognition over time had been sufficiently large, we believe it would have been detectable.

Another concern in longitudinal studies is participation and dropout. It is possible that individuals who dropped out of the study, regardless of reason, may have had personality traits that could have affected the results. However, Pedersen and Reynolds (1998) found no suggestion of an effect of attrition on mean openness.

Conclusion

This study extends previous, mostly cross-sectional studies that have suggested that individuals who participate in more social and cognitive stimulating activities may be protected against cognitive impairment (Wang et al., 2006) and cognitive decline (Barnes, Mendes de Leon, Wilson, Bienias, & Evans, 2004; Hultsch, Hertzog, Small, & Dixon, 1999; Newson & Kemps, 2005; Wilson et al., 2003a,b). The results of this current study suggest a notable and consistent finding of a positive relationship between openness to experience and cognitive performance in the second half of the life span. Even after adjusting for the effects of education, ADL and CVD, higher levels of openness provided a distinct and significant advantage across all cognitive domains for both men and women. Still, rates of change in cognitive performance did not suggest that level of openness is associated with a slower decline in cognitive performance. Thus, the superior performance level as predicted by openness was maintained across advancing age. It seems likely that individuals who endorse more openness may be more actively and cognitively engaged with life and this engagement bestows an advantage in cognitive functioning in later life.

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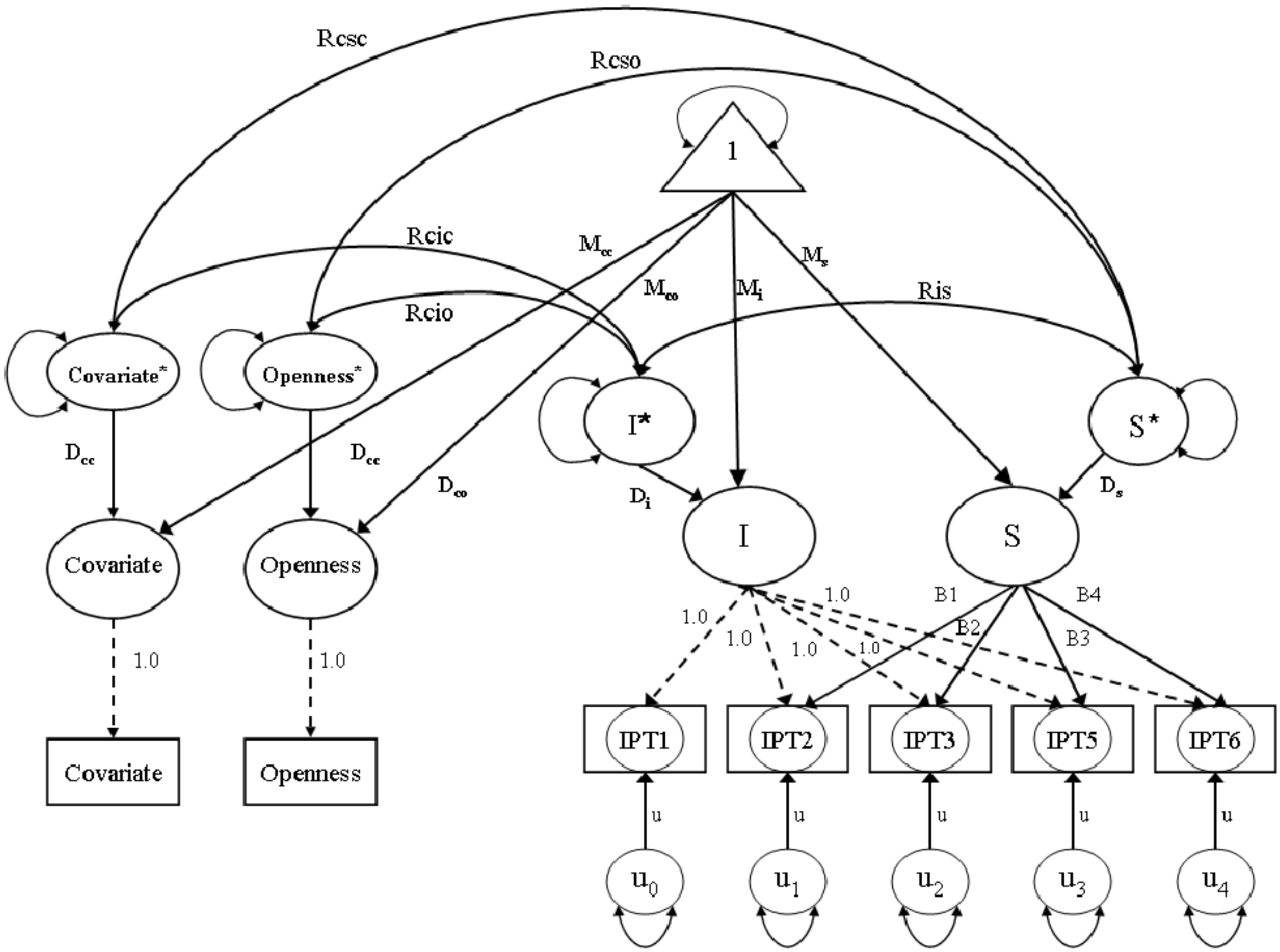


Figure 1.

Linear latent growth curve with covariate openness to experience and a control covariate. The squares represent observed, or measured, variables, whereas the circles denote latent variables; single-headed arrows represent regression coefficients, and double-headed arrows denote covariation. The triangle represents a unit constant that allows for the estimation of means; the circles within squares represent data that are potentially available for an individual participant at some but not necessarily all time points. r_{cso} = correlation between the slope and the covariate openness; r_{csc} = correlation between the slope and the control covariate; M_{co} = mean of the covariate openness; M_{cc} = mean of the control covariate; M_i = mean of the intercept; M_s = mean of the slope; r_{cio} = correlation between the intercept and openness; r_{cic} = correlation between the control covariate and the intercept; r_{is} = correlation between the slope and the intercept; Openness* = standardized score of the covariate openness; Covariate* = standardized score of the control variable; I* = standardized score for the intercept; S* = standardized score for the slope; D_{co} =deviation from the covariate openness mean; D_{cc} = deviation from the control covariate mean; D_i = deviation from the intercept; D_s = deviation from the slope; I = intercept; S = slope; B1-B4 = age basis coefficients; IPT1-IPT6 = cognition scores at each time point; u_0-u_4 = random components from the cognition scores; u = the constant deviation from the cognition scores (Adapted from Charles, Reynolds, & Gatz, 2001).

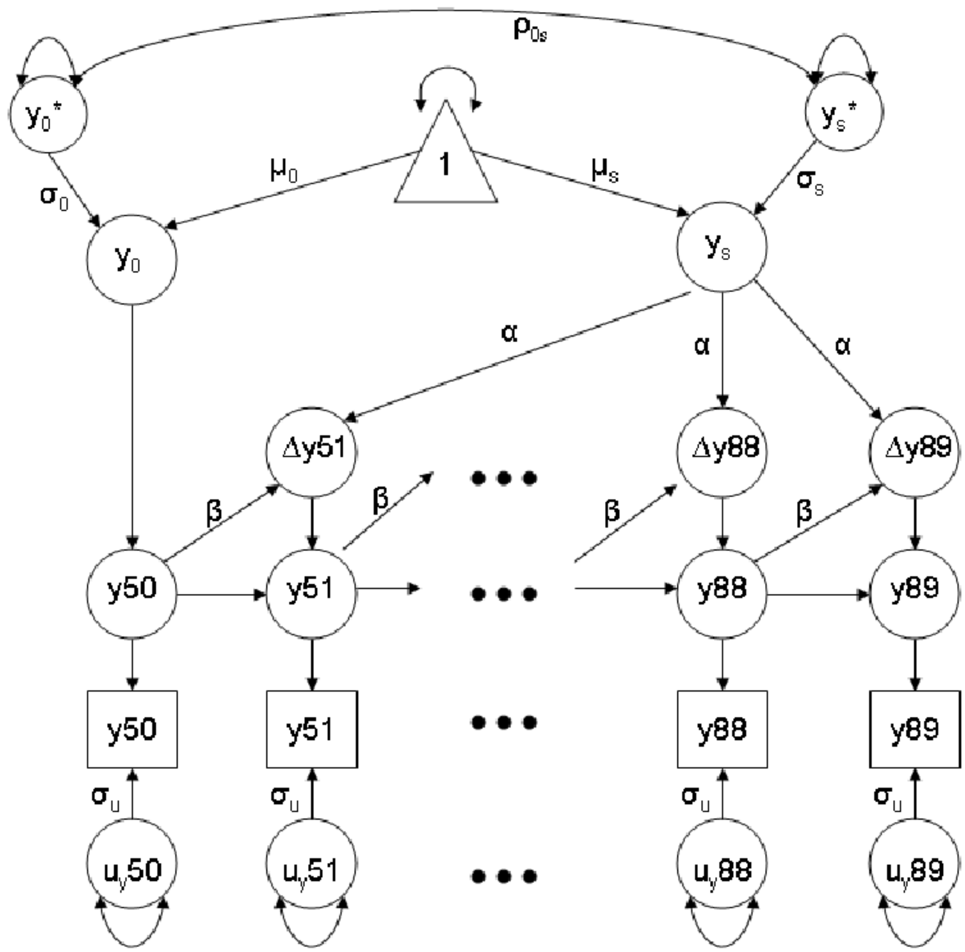
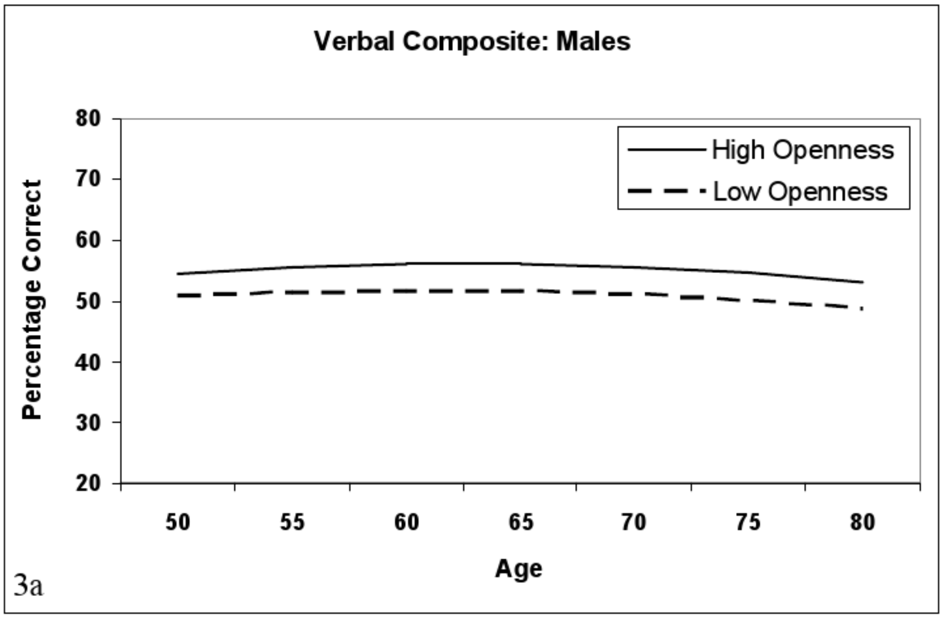


Figure 2.

Univariate dual change score model. Openness to experience is modeled independently (*Y*). Error variance (σ_u) is fixed to be constant at every age; α reflects constant change due to the slope factor y_s; β reflects proportional change. The model estimates a latent intercept (y_o) and slope (y_s), mean intercept (μ_o) and mean slope (μ_s), as well as variation around the mean intercept and slope (σ_o and σ_s). The y_o* and y_s* variables reflect the standardized scores of y_o and y_s. The ρ_{os} parameter is the correlation between initial score and rate of change.



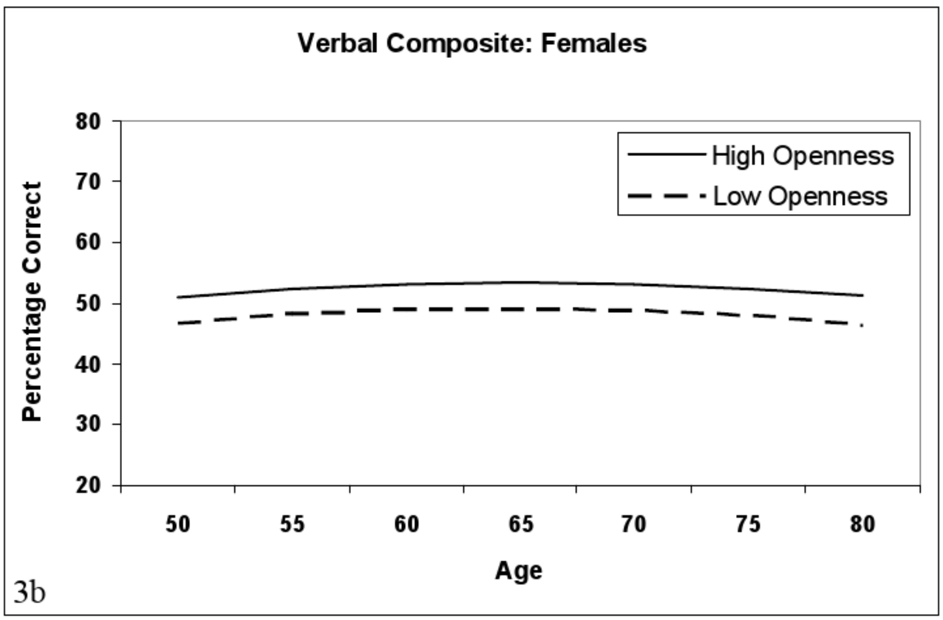


Figure 3.

Higher openness scores predicted better performance in the verbal domain for males (3a) and females (3b), controlling for education, ADLs, and CVD. *Note*. High Openness = 1 standard deviation above the mean, Low Openness = 1 standard deviation below the mean.

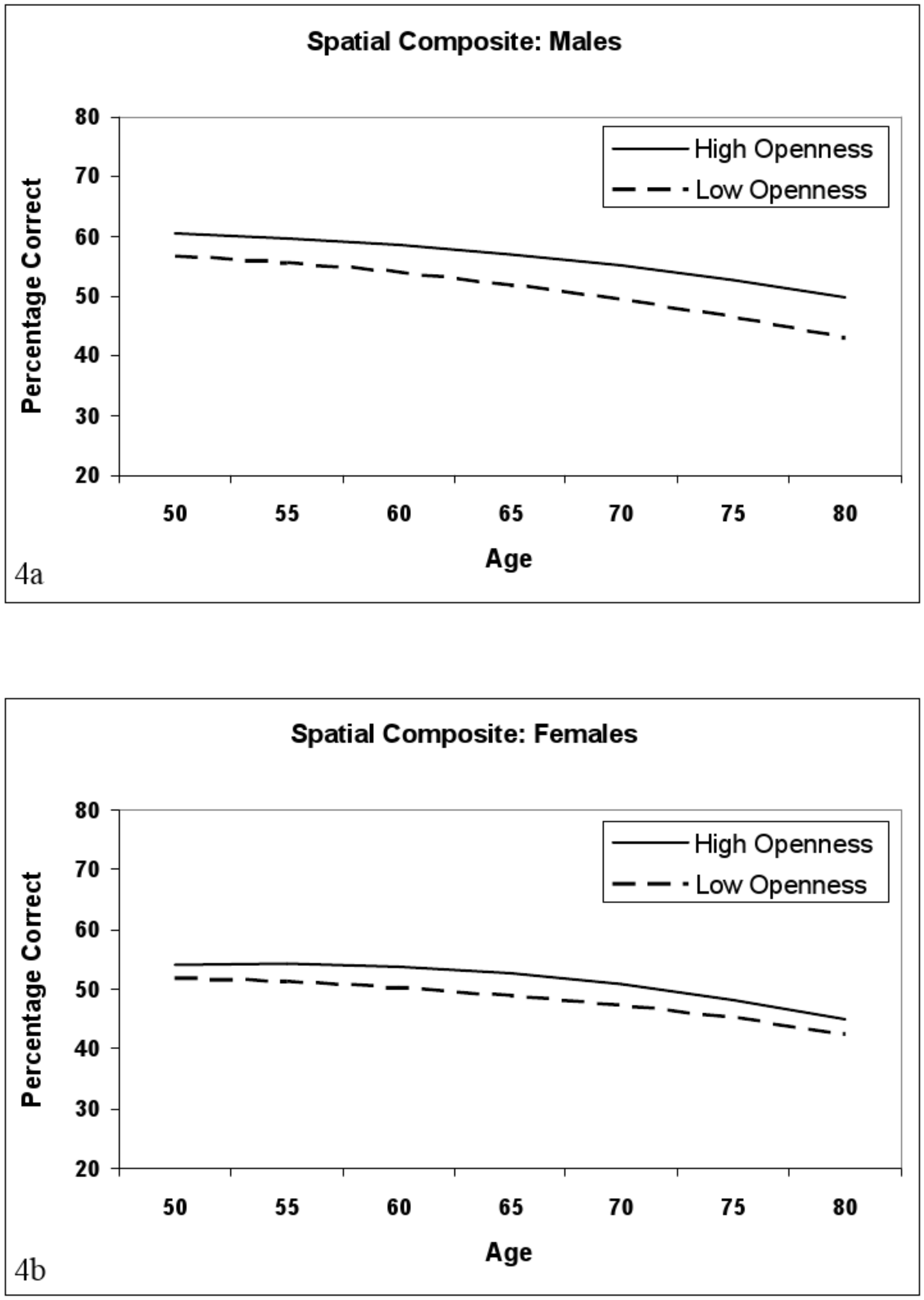


Figure 4.
Higher openness scores predicted better performance in the spatial domain for males (4a) and females (4b), controlling for education, ADLs, and CVD. *Note*. High Openness = 1 standard deviation above the mean, Low Openness = 1 standard deviation below the mean.

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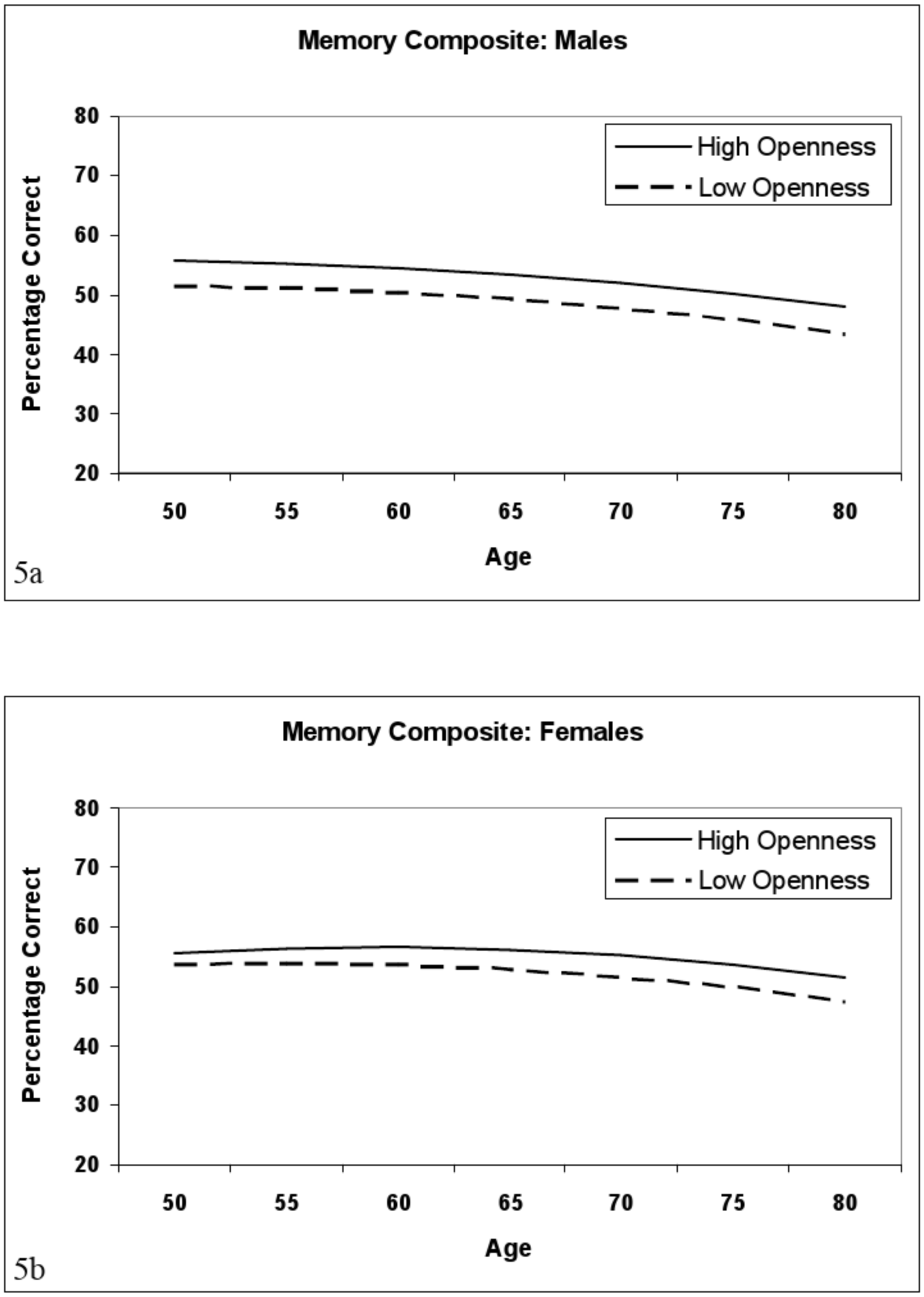


Figure 5.

Higher openness scores predicted better performance in the memory domain for males (5a) and females (5b), controlling for education, ADLs, and CVD. *Note*. High Openness = 1 standard deviation above the mean, Low Openness = 1 standard deviation below the mean.

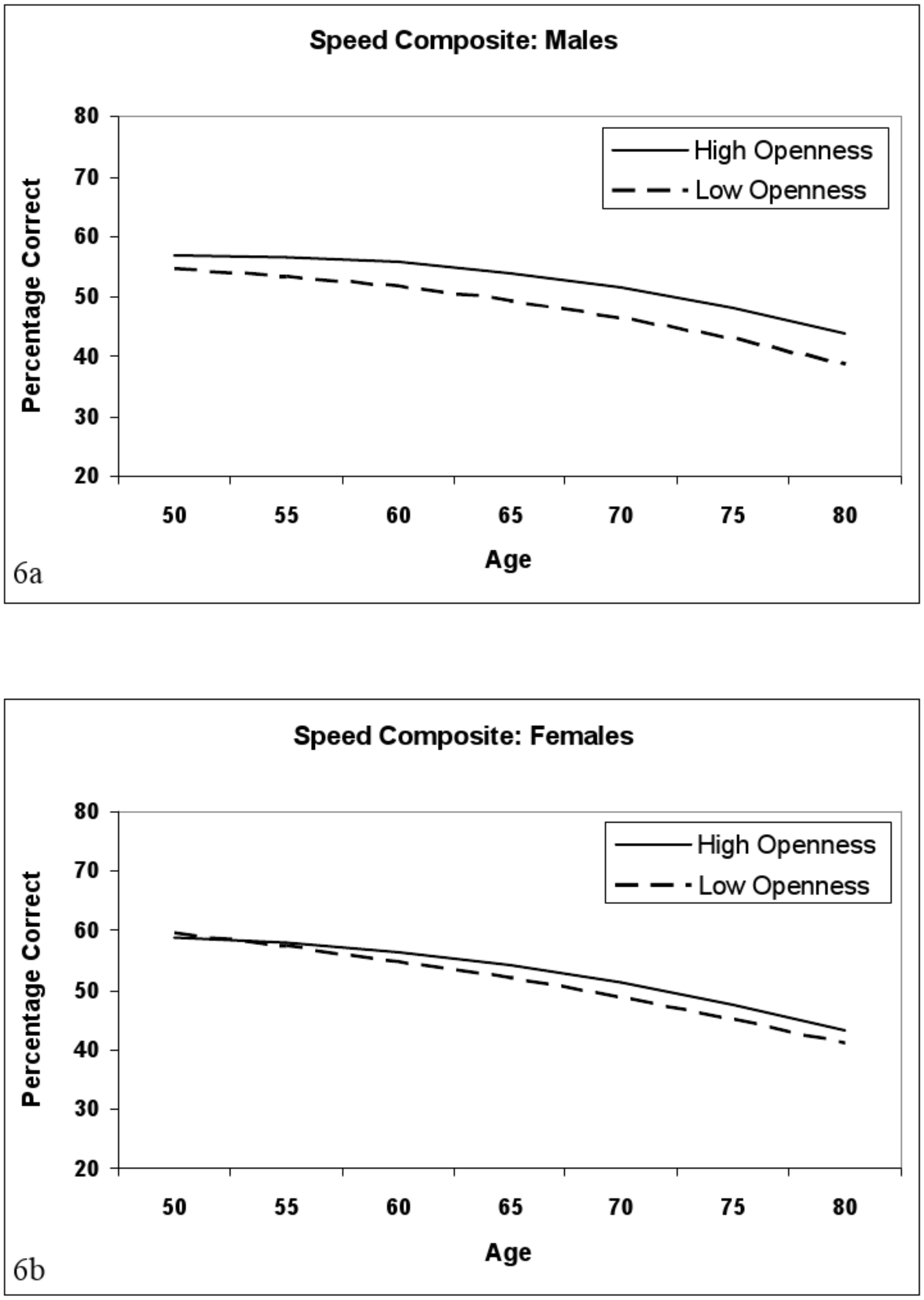
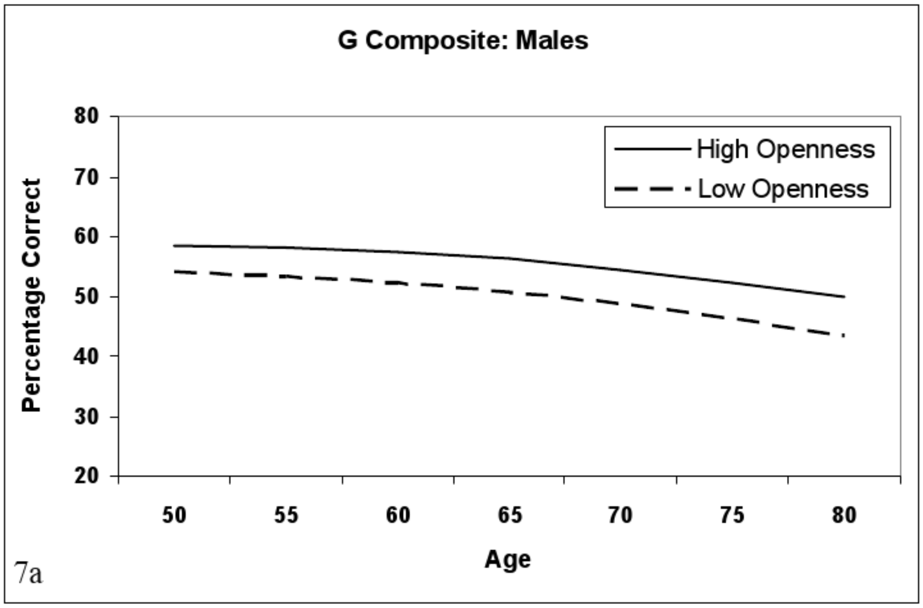


Figure 6.

Higher openness scores predicted better performance in the speed domain for males (6a) and females (6b), controlling for education, ADLs, and CVD. *Note*. High Openness = 1 standard deviation above the mean, Low Openness = 1 standard deviation below the mean.



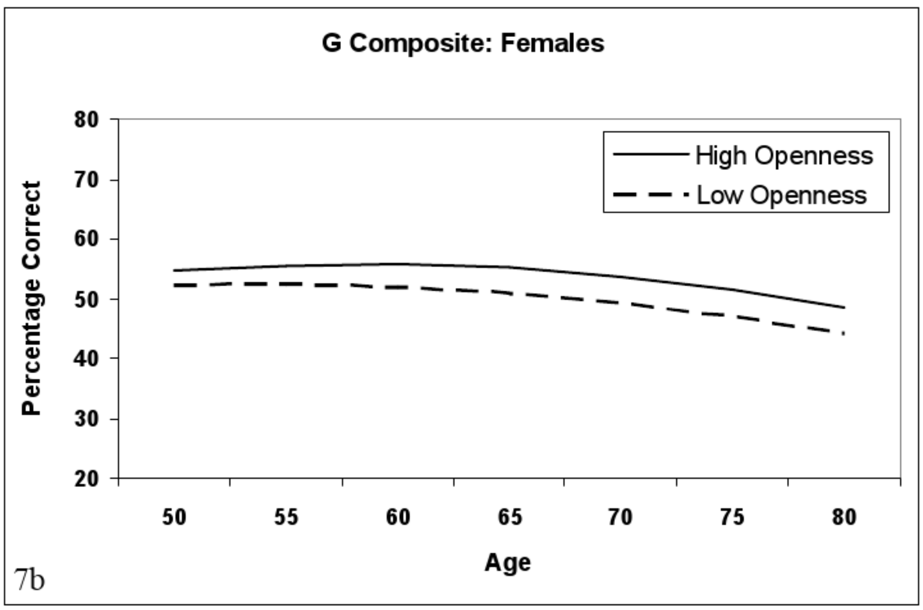


Figure 7.
Higher openness scores predicted better performance in global "g" performance for males (7a) and females (7b), controlling for education, ADLs, and CVD. *Note*. High Openness = 1 standard deviation above the mean, Low Openness = 1 standard deviation below the mean.

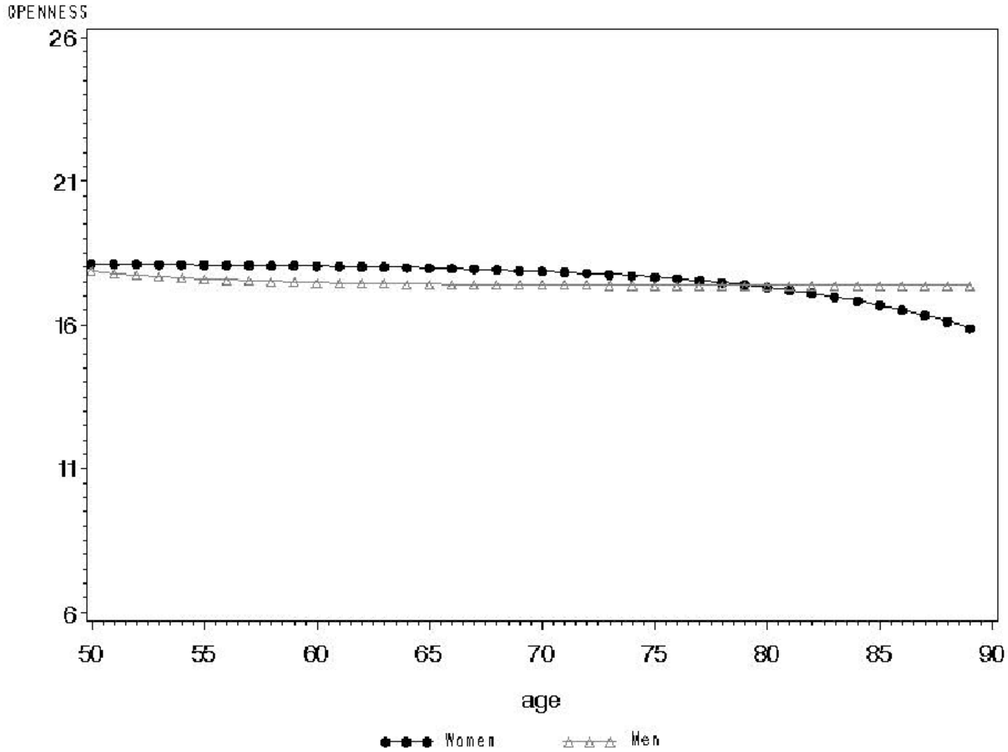


Figure 8.
Longitudinal openness trajectories by sex.

Table 1

Data Collection Dates, Mean Scores (Standard Deviations) and Range for Five Openness Measurement Occasions

	Openness Measurement Occasion				
	Q1 (1984)	**Q2 (1987)**	**Q3 (1990)**	**Q4 (1993)**	**Q5 (2003)**
N					
Males	290	307	277	278	168
Females	388	432	413	392	259
Mean					
Males	17.75 (3.83)	17.64 (3.93)	17.51 (4.11)	17.88 (3.86)	17.99 (4.06)
Females	18.05 (4.08)	17.96 (4.40)	18.08 (4.56)	17.73 (4.61)	18.03 (4.14)
Range					
Males	6-28	6-28	6-29	6-28	6-27
Females	6-30	7-30	6-30	6-30	6-30

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Table 2

Data Collection Dates, Mean Ages (Standard Deviations) and Age Range for Five Cognitive Measurement Occasions

	Cognitive Measurement Occasion				
	IPT1 (1986 – 1988)	**IPT2 (1989 – 1991)**	**IPT3 (1992 – 1994)**	**IPT5 (1999 – 2001)**	**IPT6 (2002 – 2004)**
N					
Males	232	239	232	208	176
Females	364	328	325	323	259
Mean					
Males	65.50 (6.78)	65.39 (8.14)	67.10 (8.33)	69.01 (9.20)	71.15 (8.83)
Females	66.61 (7.87)	67.05 (8.71)	69.87 (9.31)	71.59 (10.26)	73.01 (9.41)
Range					
Males	51-86	50-89	51-85	51-88	54-91
Females	50-88	50-91	50-94	51-96	54-95

Note: Data represents participants with a baseline openness measurement.

Table 3

Correlations between Openness and Education, Sex, Age, Activities of Daily Living (ADL), and Cardiovascular Disorder (CVD)

	Openness	Education	Sex	Age	ADL	CVD
Openness	1.00					
Education	0.27***	1.00				
Sex	0.02	-0.12**	1.00			
Age	-0.09*	-0.12**	0.09*	1.00		
ADL	0.06	0.07	-0.05	-0.17***	1.00	
CVD	-0.01	-0.07	0.005	0.28***	-0.09*	1.00

* $p<.05$,

** $p<.01$,

*** $p<.0001$

Table 4

Correlations between Openness and Cognitive Factors across Five Measurement Occasions

	Verbal		Spatial		Memory		Speed		g	
	Males	**Females**	**Males**	**Females**	**Males**	**Females**	**Males**	**Females**	**Males**	**Females**
IPT1	0.43	0.30	0.39	0.23	0.36	0.22	0.42	0.15	0.46	0.29
IPT2	0.39	0.29	0.41	0.26	0.29	0.24	0.40	0.15	0.44	0.31
IPT3	0.44	0.30	0.44	0.14	0.37	0.22	0.41	0.14	0.46	0.24
IPT5	0.53	0.40	0.41	0.26	0.35	0.29	0.47	0.16	0.43	0.34
IPT6	0.40	0.33	0.39	0.23	0.28	0.34	0.35	0.13	0.40	0.36

Note. IPT= in person testing. There is no cognitive data available for IPT4.

For all correlations, $p<0.05$

Table 5

Estimates and (Standard Errors) from Latent Growth Curve Models of Openness to Experience and Cognitive Performance for Males, controlling for Education, ADL, and CVD

Model Term	Verbal	Spatial	Memory	Speed	G
Intercept	53.922 (0.528)***	54.523 (0.615)***	51.351 (0.645)***	51.601 (0.536)***	53.426 (0.603)***
Age	-0.058 (0.027)*	-0.403 (0.029)***	-0.267 (0.040)***	-0.482 (0.028)***	-0.323 (0.024)***
Age squared	-0.019 (0.004)***	-0.018 (0.005)**	-0.016 (0.006)**	-0.028 (0.004)***	-0.018 (0.004)***
Openness	0.567 (0.119)***	0.647 (0.130)***	0.526 (0.129)***	0.594 (0.116)***	0.699 (0.117)***
Openness × Age	0.003 (0.006)	0.012 (0.007)	0.007 (0.009)	0.013 (0.007)	0.010 (0.006)
Openness × Age squared	-0.001 (0.001)	0.000 (0.001)	0.004 (0.001)	-0.001 (0.001)	-0.000 (0.001)

* $p<.05$,

** p<.001

*** $p<.0001$.

Table 6

Estimates and Standard Errors (SE) from Latent Growth Curve Models of Openness to Experience and Cognitive Performance for Females, controlling for Education, ADL, and CVD

Model Term	Verbal	Spatial	Memory	Speed	G
Intercept	51.260 (0.427)***	50.839 (0.489)***	54.506 (0.539)***	53.028 (0.456)***	53.013 (0.481)***
Age	-0.000 (0.023)	-0.307 (0.030)***	-0.176 (0.038)***	-0.568 (0.034)***	-0.237 (0.027)***
Age squared	-0.022 (0.003)***	-0.023 (0.004)***	-0.022 (0.005)***	-0.021 (0.005)***	-0.028 (0.004)***
Openness	0.490 (0.094)***	0.434 (0.101)***	0.388 (0.118)**	0.256 (0.096)*	0.495 (0.103)***
Openness × Age	0.002 (0.005)	0.001 (0.007)	0.008 (0.008)	0.011 (0.007)	0.008 (0.006)
Openness × Age squared	0.003 (0.000)	-0.001 (0.001)	-0.000 (0.001)	-0.001 (0.001)	-0.001 (0.001)

* *p*<.01,

** p<.001

*** *p*<.0001

Table 7

Intercept-slope correlation, ρso Estimates (Standard Errors) and Fit Statistics from the Univariate Dual Changes Score Model for Openness to Experience for Males and Females Separately

	Males		Females
Parameter and Fit	**Full**	**Best-Fitting**	**Full**
Constant change, α	1	1	1
Proportional change, β	-1.444 (0.058)	--	0.117 (0.035)
Mean intercept, μ_o	17.875 (0.478)	17.424 (0.201)	18.115 (0.223)
Mean slope, μ_s	2.501 (1.023)	--	-2.123 (0.628)
Intercept deviation, σ_o	9.844 (2.028)	9.143 (0.846)	12.556 (1.152)
Slope deviation, σ_s	0.198 (0.152)	--	0.172 (0.106
Intercept-slope correlation, ρ_{so}	1.147 (0.562)	--	-1.470 (0.477)
Error deviation, σ_u	4.211 (0.395)	4.360	4.704 (0.237)
Loglikelihood	-3998.476	-4001.894	-6033.436
# of parameters[1]	13	6	13
MLR scaling correlation factor	1.256	1.355	1.096

[1]Parameters not shown in the table include the regression weights associated with the covariates.