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Cognitive Functioning in Healthy Aging: The Role of Reserve and Lifestyle Factors Early in Life

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Purpose: According to the *reserve perspective* on cognitive aging, individuals are born with or can develop resources that help them resist normal and disease-related cognitive changes that occur in aging. The reserve perspective is becoming more sophisticated, but gaps in knowledge persist. In the present research, we considered three understudied questions about reserve: Is reserve primarily static (unchangeable) throughout the life course or dynamic (changeable, in terms of increases or decreases)? Can reserve be increased at any point in life, or are there optimal time periods—such as early life, midlife, or late life—to increase it? Does participation in different types of leisure and occupational activities in early life and midlife have different effects depending on specific domains of late-life cognitive functioning? Here we link early cognitive and activity data—gathered from archival sources—with cognitive data from older adults to examine these issues. ***Design and Methods:*** 349 participants, all mid-1940s graduates of the same high school, underwent telephone cognitive screening. All participants provided access to adolescent IQ scores; we determined activity levels from yearbooks. We used path analysis to evaluate the complex relationships between early life, midlife, and late-life variables. ***Results:*** Adolescent IQ had strong direct effects on global cognitive functioning, episodic memory, verbal fluency, and processing speed. Participants' high school mental activities had direct effects on verbal fluency, but physical and social activities did not predict any cognitive measure. Education had direct effects on global cognitive functioning, episodic memory, and, most strongly, processing speed, but other midlife factors (notably, occupational demands) were not significant predictors of late-life cognition. There were weak indirect effects of adolescent IQ on global cognitive functioning, episodic memory, and processing speed, working through high school mental activities and education. Verbal fluency, in contrast, was affected by adolescent IQ through links with high school mental activities, but not education. ***Implications:*** Our study suggests that reserve is dynamic, but it is most amenable to change in early life. We conclude that an active, engaged lifestyle, emphasizing mental activity and educational pursuits in early life, can have a positive impact on cognitive functioning in late life.

Key Words: Cognition, Reserve, IQ, Activity level

Over the past several decades, researchers have increasingly devoted themselves to studying risk and protective factors for cognitive functioning in aging. The central question has been why some individuals maintain good cognitive functioning as they age, whereas others experience cognitive decline. A large body of work has accumulated that describes some

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of the correlates of preserved and declining cognitive functioning in aging. Emerging from this empirical work—and now widely used to explain many findings in the cognitive gerontology literature—is the concept of *reserve* (Katzman, 1993; Satz, 1993; Stern, 2002). According to the reserve perspective, impairments in cognition become apparent only after a reserve (cognitive or neurological resources) is depleted to a certain threshold. Those individuals with less initial reserve are more likely to manifest clinical impairments because they have relatively fewer resources to sustain them in the face of normal and disease-related changes that accompany aging. In contrast, those with more initial reserve can function longer without manifesting clinical impairments because their supply of resources is greater.

Increasingly, researchers are refining their operational definitions of reserve, are using reserve to make predictions in studies, and are outlining with greater care the general and specific aspects of the reserve perspective. For example, authors have begun to discuss more explicitly the dynamic nature of reserve (Kliegel, Zimprich, & Rott, 2004; Richards, Hardy, & Wadsworth, 2003; Richards & Sacker, 2003; Wilson et al., 2005). That is, although the initial level of reserve may be determined by innate differences in resources at birth, or by differences in cognitive activity as the brain matures in childhood, there are processes in young adulthood, midlife, and late life that may also act to increase or decrease reserve (Kliegel et al.). Thus, the absolute level of reserve may change throughout the life course. This idea is consistent with several interrelated concepts that, in recent years, have emerged in the gerontology, aging, and neuroscience literatures. For example, the disuse perspective emphasizes that decreases in activity patterns result in atrophy of cognitive skills and processes (Salthouse, 1991). Mental activity, in contrast, in the form of educational activities, occupational demands, and mental leisure-time pursuits, increases these skills. The disuse perspective is commonly captured by the phrase, "use it or lose it," an idea that has been widely embraced by lay audiences. Neurologists and neuroscientists have long recognized the characteristic of the brain known as "plasticity" (Kramer, Bherer, Colcombe, Dong, & Greenough, 2004). Plasticity refers to the brain's ability to change and keep itself vital. Specifically, when a person is challenged, either by activities or environmental conditions, neurons form new dendritic branches and more synapses; these morphological changes enhance the brain and provide better capacities to resist insults from neurological conditions such as Alzheimer's disease (Kramer et al.). Several studies support the notion that reserve is dynamic, showing that early indicators of reserve (including childhood IQ, young adult IQ, or early education) predict mediating variables in midlife (such as intellectual activities or occupational status), which in turn predict adult cognitive functioning (assessed in terms of memory, global cognitive functioning, verbal, or visual ability; see, e.g., Arbuckle, Gold, Andres, Schwartzman, & Chaikelson, 1992; Kliegel et al., 2004; Richards et al., 2003; Richards & Sacker, 2003; Wilson et al., 2005). Importantly, however, although existing studies suggest that mediating effects of factors in midlife can be found, they also seem to indicate that these relationships are relatively weak, implying that *significant* changes in level of reserve cannot be easily made. More research is needed to confirm or refute this conclusion.

If reserve is truly dynamic, a closely related but unanswered question is whether there is an optimal time during the life course when one can intervene to modify one's level of reserve. If such an optimal time exists, identifying it would have practical value, because increasing reserve could delay the clinical manifestations of diseases such as Alzheimer's. Some research seems to indicate that reserve can be modified in adulthood and midlife. For example, in population-based studies of older adults, researchers have found that greater current involvement in mental, physical, and social leisure activities is associated with better memory and cognitive performance (Christensen & Mackinnon, 1994; Hultsch, Hammer, & Small, 1993), and changes in adult activity levels have been linked to changes in memory and cognitive functioning in longitudinal analyses (Hultsch, Small, Hertzog, & Dixon, 1999; Mackinnon, Christensen, Hofer, Korten, & Jorm, 2003). Research examining the relationships between occupational demands and cognition has shown that individuals in occupations with greater mental demands—including frequent decision making, self-direction, and intellectual challenge—have better cognitive functioning, whereas those in occupations with lower mental demands have poorer cognitive functioning (Kohn & Schooler, 1978; Schooler & Mulatu, 2001).

However, evidence from a few recent studies that measured participation in activities and level of reserve throughout the life course seems to suggest that changing one's reserve level can better be accomplished *early in life*. In two different reports (Kliegel et al., 2004; Richards & Sacker, 2003), research teams examined associations of early reserve, midlife mediating variables, and adult lifestyle factors with adult cognitive functioning. Results showed strong direct effects of early-life factors (childhood IQ and early education) on late-life cognitive functioning, but effects of midlife factors such as occupation were not significant. Other studies show that early activities and IQ contribute to cognitive functioning in late life principally through associations with late-life activities and late-life IQ (Arbuckle et al., 1992; Wilson et al., 2005). Together, these studies support the important role (either direct or indirect) of early-life factors in late-life cognition.

Authors have suggested that different aspects of cognitive functioning might respond in different ways to different social influences throughout the life span (Richards & Deary, 2005; Wilson et al., 2005). For example, one might predict that education and leisure and occupational activities requiring mental engagement would be strong predictors of abilities reflecting the products of education and mental activity, such as measures of general knowledge, vocabulary, and verbal abilities. In contrast, physical activities might enhance cognition in late life because physical activity enhances cerebral blood flood and oxygenation, which might slow processes linked to biological aging (e.g., accumulation of amyloid deposits, neurofibrillary tangles, and cerebral infarctions, over time, in the brain; see Friedland, 1993). Thus, physical activities might more strongly influence abilities reflecting the extent or degree of biological aging, such as processing speed, working memory, and attention. The effects of social activities on different domains of cognitive functioning are more difficult to predict. Some researchers have suggested that social activities may provide protection through a psychoneuroimmunological mechanism (Kiecolt-Glaser, McGuire, Robles, & Glaser, 2002). For example, social support is known to buffer against stress, which could result in the decreased production of cortisol. Consistently lower cortisol levels have been associated with better episodic memory performance (Hibber, Yau, & Seckl, 2000), but strong links to other domains of cognitive functioning have not been established as readily. Thus, involvement in social activities may predict memory better than other domains of cognition; however, the magnitude of the relationship would be weaker than that between education and mental activities, where there is a more proximal link between the type of activity (education) and the cognitive outcome (memory).

Nevertheless on the basis of our review, we could identify no single empirical study that examined the impact of participating in different types of activities (mental, social, and physical) in early life and midlife on specific domains of cognitive functioning in late life. Studies either assessed different domains of cognitive functioning in adulthood but did not measure different activity patterns in early life or midlife, such as the studies by Richards and Sacker (2003) and Wilson and colleagues (2005), or they measured participation in different activities in midlife and only assessed a single domain of cognitive functioning in late life, such as the study by Richards and colleagues (2003). Specifically, in the report by Wilson and colleagues, early cognitive activity and available cognitive resources in the home (such as newspapers and magazines) more strongly predicted semantic memory than perceptual speed, episodic memory, working memory, and visuospatial skill. In the report by Richards and Sacker, a measure of childhood IQ strongly predicted a measure of accumulated knowledge (NART) and verbal memory assessed in late life, but childhood IQ only weakly predicted visual search ability. In the research reported by Richards and colleagues, a person's physical activities and spare-time activities (including both mental and social activities) at age 36 predicted verbal memory at age 43. Furthermore, physical activities predicted change in memory from ages 43 to 53, but spare-time activities did not. Finally, Aartsen, Smits, van Tilburg, Knipscheer, and Deeg (2002) studied the lagged effects of three types of activities (social, experiential, and developmental) on several domains of cognitive functioning (memory, learning, fluid intelligence, processing speed, and global cognitive functioning) in a sample of older adults with a mean age of 69 years at a baseline assessment. None of the activities in which respondents participated at baseline had effects on any domain of cognitive functioning assessed 6 years later. However, faster processing speed at baseline was shown to predict greater involvement in developmental activities 6 years later. These studies clearly show that there is a need for research that examines associations of mental, social, and physical activities in early life and midlife with different domains of cognitive functioning in late life.

Thus, although a few studies have specifically addressed some relevant gaps in our ability to model the reserve process, further work is needed. In the present study, our goals were as follows: (a) to examine in more detail the nature of reserve by considering whether it is primarily dynamic or static; (b) to consider whether reserve can be increased throughout the life course, or whether there are specific periods during which attempts to modify reserve level should be made; and (c) to investigate whether participation in different types of activities in early life and midlife has different effects on cognitive aging, depending on the specific cognitive domain studied. Our study is an improvement over previous efforts, because we consider these questions in a single investigation; use strong measures of activity levels and engagement throughout life (high school extracurricular activities and occupational demands) that were directly assessed without reliance on proxy respondents; and have good control for extraneous variables because we recruited all participants from the same population (i.e., graduates of the same high school). On the basis of theory and results from previous research, we made the following hypotheses. First, early IQ will predict late-life cognitive functioning both directly and indirectly through midlife mediating variables, indicating that reserve is dynamic. Second, factors in early life will be stronger predictors of cognition in late life than will factors in midlife and beyond. Third, specific activities and pursuits in early life will predict some domains of late-life cognitive functioning more strongly than other domains (e.g., education and mental activities in high school will more

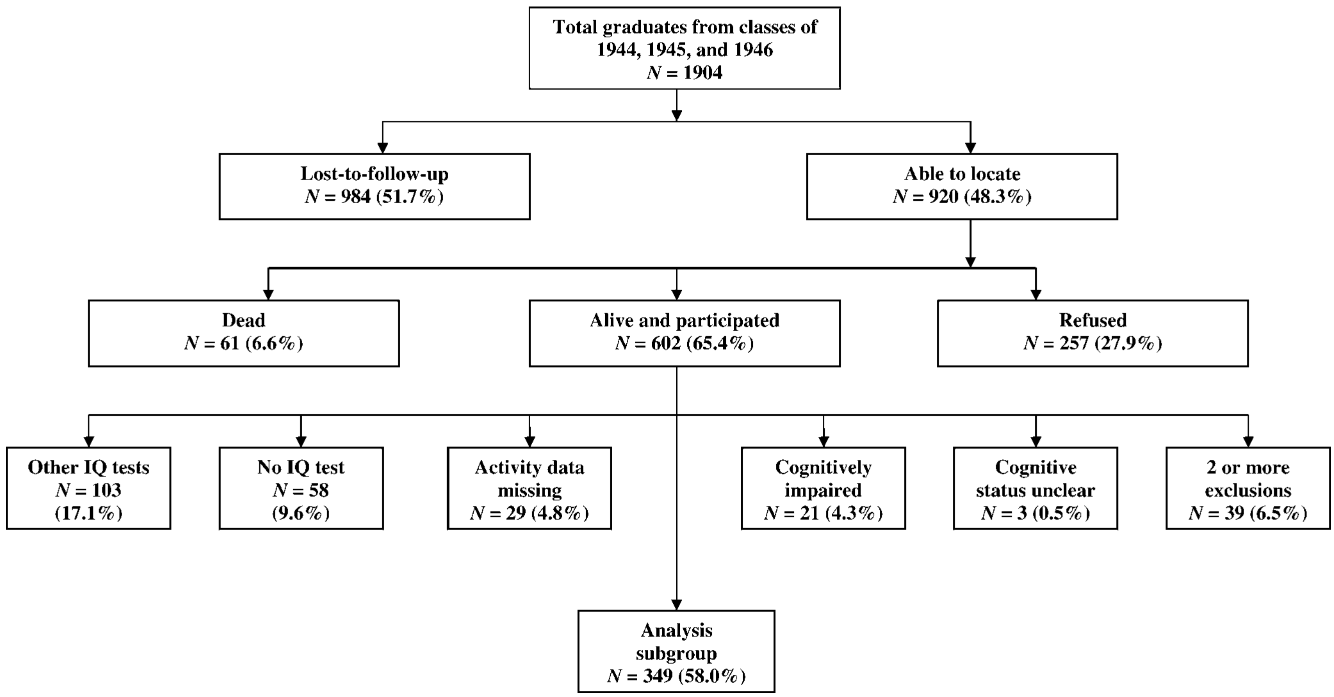

Figure 1. Flow diagram showing the sampling strategy.

strongly predict episodic memory, global cognition, and verbal fluency; physical activities will better predict processing speed; and social activities will predict each of the four domains of cognitive functioning, though less strongly).

Methods

This study is based on data from the Cleveland Longitudinal Aging Studies of Students, a retrospective cohort study of cognitive aging and dementia initiated in 2002 (Fritsch et al., 2005). This study uses archival data from high school records and yearbooks to provide previously documented information about the early cognitive abilities and activity levels of more than 600 mid-1940s graduates of the same high school. Researchers have evaluated the participants' cognitive status through telephone interviews. Preliminary accounts of the project have been reported elsewhere (Fritsch et al., 2005).

Participants

Study procedures associated with this project were reviewed and approved by the Institutional Review Board for Human Investigation of University Hospitals of Cleveland (IRB 09-01-52). Researchers drew participants in the Cleveland Longitudinal Aging Studies of Students from the population of students who graduated from Cleveland Heights High School (CHHS) in 1944, 1945, or 1946 (n = 1,904). CHHS is a public high school serving the cities of Cleveland Heights and University Heights, which are suburbs of Cleveland, OH. Today, residents of these cities are middle class, well educated, and ethnically diverse. In the 1940s, they were affluent and well educated, and nearly all residents were Caucasian.

In 2002, when the cognitive testing occurred, we were able to locate 920 potential participants by using addresses and phone numbers provided by the school's alumni association. We could not identify addresses and phone numbers for 984 individuals. Of those persons with addresses and telephone numbers available, 602 agreed to be interviewed (65.4% participation rate), 257 declined the screening (27.9% refusal rate), and 61 (6.6%) were determined to be deceased at the time of telephone screening.

The group reported on here consists of 349 individuals who participated in telephone screening; had IQ test scores from a specific IQ test, that is, the Otis Self-Administering Test of Mental Ability (Otis, 1928; see the subsequent discussion); and had activity data, had adult cognitive test scores, and scored as "normal" (i.e., not cognitively impaired). We excluded from the sample those potential participants who were tested with different IQ tests (n = 103), who did not have IQ data reported (n = 58), who were missing activity data (n = 29), or who had cognitive impairment (n = 21), as determined in follow-up interviews with proxy respondents (Fritsch et al., 2005). We also excluded 3 other individuals, whose cognitive status was questionable. We excluded 39 individuals for two or more of the aforementioned reasons. The sampling strategy is shown in Figure 1.

The mean age of participants in the analysis subset was 74.8 (SD = 1.0), the mean years of education completed was 15.9 (SD = 2.4), and 57.6% of the subset were women. Nearly all of the research volunteers were Caucasian (99.7%). We compared the analysis subset of 349 to the larger group of 602 who were alive and participated in telephone screening. The groups were not different in terms of education level ($p > .05$). However, the analysis subset of 349 was younger (M = 74.8; SD = 1.0) than the larger group of 620 (M = 75.6; SD = 1.0; $p < .001$); the subgroup of 349 had a higher grade point average (M = 2.5; SD = 0.7) than the larger group (M = 2.3; SD = 0.7; $p < .05$); and the proportion of women was higher in the subgroup of 349 (62.4%) than in the larger group (37.6%; $p < .05$). The differences in age and grade point average, although significant, were likely due to high power associated with the large sample sizes.

Procedure

Each of the potential participants first received two personalized letters, one from the Principal Investigator explaining the nature of the research and inviting participation, and one from the Associate Superintendent of Educational Services of CHHS acknowledging their cooperation and urging people to consider becoming involved. Potential participants were also informed about the study through an article that outlined the research and its aims, published in their high school alumni association newsletter prior to the start of the study. The correspondence and newsletter article indicated our plan to test participants' memory and cognitive functioning over the telephone, and to later request permission to access their high school records.

Measures

Cognitive Assessment.—We evaluated participants' global cognitive functioning with the Modified Telephone Interview for Cognitive Status (TICS-m; Welsh, Breitner, & Magruder-Habib, 1993). This instrument was developed as a telephone version of the Mini-Mental State Examination (MMSE) (Folstein, Folstein, & McHugh, 1975). The TICS-m tests functioning in several domains: concentration, orientation, memory, naming, comprehension, and abstraction. The TICS-m is reliable, with a high test–retest correlation over 18 months (r = .83; see Plassman, Newman, Welsh, Helms, & Breitner, 1994). The TICS-m correlates highly with the MMSE (r = .80), supporting its validity as a measure of global cognitive functioning (Welsh et al.).

We tested episodic memory with the Logical Memory A subtest of the Wechsler Memory Scale, Revised (Wechsler, 1987). This subtest requires the individual to remember a story, which is read by the examiner, and then repeat it back by the same wording. After a short delay, the respondent is asked to repeat the story again. The test has been validated for use over the telephone with individuals with Alzheimer's disease and with individuals without it (Debanne et al., 1997), and it is sensitive to mild impairments in memory (Peterson et al., 1999).

We assessed verbal fluency through "animal naming," in which respondents are asked to name as many animals as possible in 1 minute (Rosen, 1980). The test assesses verbal production and language, and it is sensitive to semantic retrieval deficits. Verbal fluency also assesses executive function and attention.

In the Timed Months of the Year Backwards Test (Ball, Bisher, & Birge, 1999), participants are asked to say the months of the year backward, starting with December. Response latencies are measured with a stopwatch. The test is a measure of central processing speed. It presumably taps constructs such as attention, executive function, and working memory. Reliability, assessed with a test–retest correlation obtained 1 week to 10 days later, is high, with r = .90. Construct validity is also high, when assessed through correlations between the Timed Months of the Year Backwards Test and measures of simple reaction time (r = .52) and choice reaction time (r = .51), and the Trails B subtest (r = –.45) (Ball et al.).

Adolescent IQ.—We asked participants who underwent telephone screening for written permission to access their high school records. We recorded scores from The Otis Self-Administering Test of Mental Ability (Otis, 1928) for a majority of students. The Otis was the first group IQ test developed for use outside the military. Otis test questions are an adaptation of Binet-type items into paper-and-pencil format (Beck, 1986). The test samples a broad range of cognitive abilities to produce a single score to measure "mental ability" (intelligence). Reliability coefficients of versions of the test are high, ranging from r = .921 to .948; correlations between versions of the Otis and school performance range from r = .55 to .57 (Otis). According to one early report, the correlation between the Otis and the Stanford–Binet is high, r = .76 (Miller, 1924). The Otis has a mean of 100 and a standard deviation of 12. The mean age when students were tested with the Otis was 15.1 years (SD = 0.7). The mean Otis score in the analysis sample was 113.2 (SD = 11.1).

High School Activity Level.—We determined the students' activity levels while they were in high school through an examination of their high school yearbooks. The types of activities in which students participated were diverse; they included academic clubs and organizations, athletics, performance activities, service activities and clubs, and organizations involving school involvement. As a group, students were involved in more than 150 different activities at the high school between 1944 and 1946.

We classified high school activities as mental, physical, or social to be consistent with other recent activity studies of older adults. We defined mental activities as academic clubs, any learning-focused club, honor societies associated with academics, theater groups, debate teams, government, and yearbook. We defined physical activities as athletic clubs including sports teams, dance clubs, honor groups associated with athletic performance, and cheerleading. Social activities were groups that gathered for fun and included clubs that provided service to the school.

We evaluated the reliability of the activity measures by having two of us (T. Fritsch and J. Larsen) independently categorize each activity as belonging to one of the three activity categories. We calculated kappa as a measure of interrater reliability, and we determined agreement to be excellent ($\kappa = 0.978$, $p < .001$). We later resolved disagreements through consensus discussion. We assessed the construct validity of the three measures in terms of correlations with adolescent IQ, education level, and gender. The mental activities measure was positively correlated with adolescent IQ ($r = .234$, $p < .002$) and education ($r = .240$, $p < .001$), and negatively with gender ($r = -.184$, $p = .001$; girls were more involved in mental activities than boys were). The physical activities measure was uncorrelated with adolescent IQ ($r = .032$, $p = .547$) but positively correlated with education ($r = .178$, $p = .001$) and gender ($r = .328$, $p < .001$; boys were more involved in physical activities than girls were). The social activities measure was uncorrelated with adolescent IQ ($r = -.014$, $p = .790$) and education ($r = .004$, $p = .942$), but it was negatively correlated with gender ($r = -.269$, $p < .001$; girls participated in more social activities than boys did).

Midlife Occupational Measures.—We assessed the mental, physical, and social demands of participants' longest held occupations by using methods reported previously (Smyth et al., 2004). Briefly, we derived occupational demand measures from 44 measures of worker functions and traits associated with various occupations. The measures were developed by the U.S. Department of Labor and assigned to over 12,000 occupations described in the fourth edition of the Department of Labor's *Dictionary of Occupations* (*DOT*). They are categorized into seven main groupings: complexity, training times, aptitude needs, comparative interests (e.g., abstract and creative activities vs concrete routine activities), temperamental attributes, physical demands, and environmental conditions.

We factor analyzed the measures of occupational demands to derive demands associated with jobs (Smyth et al., 2004). The analysis converged on four factors explaining 77.9% of the variance. These factors corresponded to conceptually distinct domains of occupational demands: mental, motor skill, physical, and social. We did not analyze motor demands in this study because our goal was to examine links between mental, physical, and social activities in high school with mental, physical, and social occupational demands in midlife. We standardized the scores to have a mean of zero and a standard deviation of one. We later recoded the scores to make higher values reflect higher occupational demands. Scores for the mental, physical, and social scales ranged from 0 to 4.34, 0 to 3.87, and 0 to 3.47, respectively.

We then matched each participant's longest held occupation to one of the *DOT* occupations, and we assigned the corresponding mental, physical, and social demands scores. Because our participants' occupations had been coded according to the 1980 U. S. Census occupation codes rather than the *DOT* occupation codes, we used a data set prepared by the Inter-university Consortium for Political and Social Research that links Census and *DOT* occupational codes to match our participants' occupations with *DOT* occupations.

Neither the *DOT* nor the 1980 Census occupations codes include a code for homemaker. Thus, we computed the mean of the respective mental, physical, and social demand scores for the following occupations listed in the 1980 Census occupations scheme: launderers and ironers; cooks, private household; housekeepers and butlers; child care workers, private household; and private household cleaners and servants (1980 Census occupation codes 403–407). The resulting means for the mental, physical, and social occupational demands of homemakers were 0.343, 1.918, and 1.407, respectively. The percentage of participants who identified themselves as a homemaker was low (6.0 %).

Parental Occupation.—We gathered data on parental occupation from the students' high school records. We then coded these data by using a modified U. S. Census occupation coding scheme, in which 0 = unskilled manual workers; 1 = operatives ("semi-skilled manual workers"); 2 = sales, clerical, craftsmen ("lower non-manual/upper manual"); and 3 = professional, technical, managerial ("upper non-manual"). We included this variable in the analyses to establish that any potential effect of lifestyle on cognition was not a spurious result of parental resources.

Time Periods in the Life Course.—Here we operationally define the broad time periods under consideration in this study. We define *early life* as the teen years and 20s, when most participants in our sample were pursuing their secondary (high school) and postsecondary education. Early-life data in this

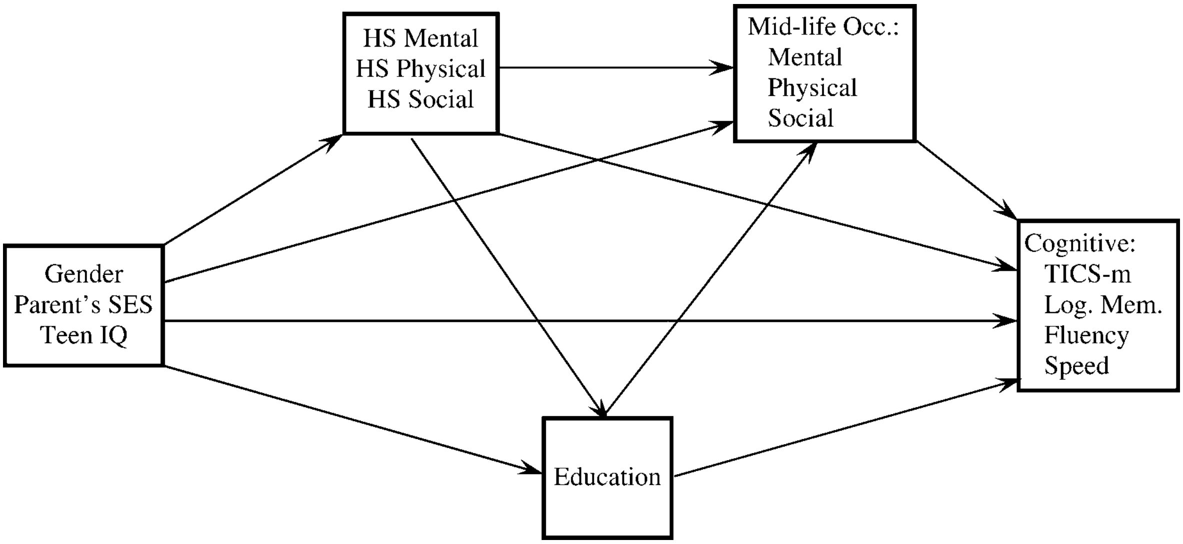

Figure 2. Hypothesized model showing relationships between early-life, midlife, and late-life variables. SES = socioeconomic status; HS = high school; Mid-life Occ. = midlife occupational demands; TICS-m = modified Telephone Interview for Cognitive Status; Log. Mem. = Logical Memory A subtest; Fluency = verbal fluency; Speed = central processing speed.

study include adolescent IQ measured at age 15; data representing students' involvement in extracurricular activities in high school; and overall education attainment level, ranging from 12 to 25 years in the subgroup we studied. We define *midlife* as the 30s, 40s, and 50s, when most of the participants in our study were active in the workforce. Midlife data in this study include measures of the mental, physical, and social demands of occupations, derived from participants' reports of their longest held occupation. Finally, we define *late life* as the 60s, 70, and 80s. Late-life data in this study include the telephone cognitive data we gathered from participants in 2002, when they had a mean age of approximately 75 years.

Analytic Strategy

We used path analysis (McClendon, 1994; Pedhazur, 1982), also known as structural equation modeling, to evaluate the hypothesized relationships among variables. Path analysis is a statistical technique for studying models of causal relationships among variables. The model specifies that some variables intervene between others in a causal sequence. Thus, one can estimate the magnitude of *direct* effects (i.e., those effects of an independent variable not mediated by other variables in the model) and *indirect* effects (i.e., those effects of an independent variable mediated by other variables in the model). Each variable in the model that is specified as being dependent on one or more other variables is regressed on all the variables that are specified as its causes. The magnitude of each direct effect is given by the respective standardized regression coefficients in the regression equations. Indirect effects can be calculated by multiplying the coefficients for two or more linked direct effects (McClendon; Pedhazur). We also calculated indirect effects, as well as total effects, by using the Alwin–Hauser method of hierarchical regression (Alwin & Hauser, 1975; McClendon). This method is a computationally efficient way of aggregating bundles of indirect effects. Total indirect effects (the sum of all indirect effects) and total effects (the sum of the direct effect and the total indirect effect) can also be easily calculated with this method.

We computed the regression coefficients for the causal model specified in Figure 2. We allowed the error terms for variables within a block (i.e., the high school activities block and the occupational demands block) to be correlated. We evaluated the path model by using AMOS 6 (Arbuckle, 2005). Gender was a dichotomous variable; parental occupation and education were ordinal; all other variables were interval or ratio. Because the model is saturated, there is a perfect fit and fit measures are not necessary.

We added the verbal fluency and processing speed measures to the research protocol several weeks after data collection had begun, resulting in smaller sample sizes for these tests. Thus, we ran two different sets of path analyses.

Results

Descriptive data for all measures collected in the study are given in Table 1. The standardized and unstandardized coefficients for the regression equations that we computed are shown in Table 2 for the sample with valid scores on the TICS-m and the Logical Memory subtest and in Table 3 for the sample with valid scores on the verbal fluency and

Table 1. Descriptive Statistics for Variables in the Study, Stratified by Data Set

Variable	TICS-m and LM Data Set (n = 349)		Fluency and Speed Data Set (n = 213)	
	M	(*SD*)	*M*	(*SD*)
Parental occupation	2.26	(0.73)	2.25	(0.71)
Proportion male	0.42	(0.49)	0.44	(0.50)
Otis IQ score	113.16	(11.12)	113.47	(11.00)
HS mental activities per year	2.35	(2.12)	2.31	(2.14)
HS physical activities per year	1.16	(1.17)	1.15	(1.17)
HS social activities per year	2.74	(1.77)	2.79	(1.85)
Education	1.87	(1.00)	1.84	(1.01)
Mental occupational demands	2.39	(0.85)	2.37	(0.85)
Physical occupational demands	2.92	(0.58)	2.91	(0.60)
Social occupational demands	2.22	(0.86)	2.19	(0.87)
TICS-m	36.67	(3.30)	—	—
LM	9.43	(3.34)	—	—
Fluency	—	—	17.45	(5.05)
Speed	—	—	13.14	(4.54)

Notes: TICS-m = Modified Telephone Interview for Cognitive Status; LM = Logical Memory A Subtest, Wechsler Memory Battery; HS = high school; Fluency = verbal fluency ("animal naming"); Speed = central processing speed (Timed Months of the Year Backwards Test). For parental occupation, 0 = unskilled manual workers; 1 = operatives ("semi-skilled manual workers"); 2 = sales, clerical, craftsmen ("lower non-manual/upper manual"); and 3 = professional, technical, managerial ("upper non-manual"). For education, 0 = 12 years; 1 = 13–15 years; 2 = 16 years; and 3 = 17 or more.

the central processing speed tests. We computed hierarchical regression equations for the cognitive outcome variables—resulting in four equations each—to get the coefficients needed to calculate direct, indirect, and total effects by the Alwin–Hauser method. The coefficients in the fourth equation for each cognitive variable, and those in the single equation for each of the other variables, represent direct effects of the antecedent variables. To simplify discussion of these results, we focus on variables most directly related to evaluation of aspects of the reserve perspective that were of interest to us, as outlined earlier.

We first examined the effects of adolescent IQ. There were direct effects of adolescent IQ on high school mental activities, education, and each of the four adult cognitive measures. Students with higher teen IQ participated in more mental activities while in high school; had higher educational attainment levels; and performed better on adult measures of global cognitive functioning, episodic memory, processing speed, and verbal fluency.

Next, we examined the effects of high school activities variables. High school mental activities had direct effects on education and on verbal fluency. Students who participated in more mental activities in high school attained more education, and later they had better verbal fluency scores as older adults. High school physical and social activities were not associated with any of the adult cognitive measures.

Turning to education, we see direct effects on several variables. Those individuals with more education had occupations with more mental and social demands. Education also had direct effects on global cognitive functioning, episodic memory, and processing speed. Individuals with more education performed better than those with less education on each of these measures.

Interestingly, there were *not* direct effects of midlife occupational demands on any of the adult cognitive variables. Because previous studies have reported a link between occupational demands and cognition (Kohn & Schooler, 1978; Schooler & Mulatu, 2001), this finding may, at first blush, seem surprising. The failure to find an effect of occupational demands could be due to the dependence of both occupational demands and cognition on the antecedent variables. To test this possibility, we ran several exploratory regression analyses, in which each cognitive measure was regressed on only the occupational demands measures (parental occupation, gender, adolescent IQ, high school activities, and education were excluded from these models). We found that midlife mental occupational demands were significant predictors of verbal fluency (β = .216, t = 2.889, p = .004) and processing speed (β = –.169, t = –2.239, p = .026). Other occupational demands were not significantly associated with the cognitive measures. These results indicate that the associations of mental occupational demands with verbal fluency and processing speed were spurious products of their common dependence on the antecedent variables, particularly IQ and high school mental activities in the case of verbal fluency, and IQ and education in the case of processing speed.

We examined *indirect* effects to evaluate whether reserve is relatively more static or dynamic. To simplify discussion of these results, we again emphasize paths most directly related to the evaluation of aspects of the reserve perspective in which we were

Table 2. Standardized and (Unstandardized) Regression Coefficients in Models With TICS-m and LM as Outcome Measures ($n = 349$)

	HS Mental	HS Physical	HS Social	Education	Occ. Mental	Occ. Physical	Occ. Social	TICS-m	TICS-m	TICS-m	TICS-m	LM	LM	LM	LM
Parental Occupation	.001 (.002)	−.014 (−.022)	.092 (.224)	.133** (.181)	.057 (.066)	.100 (.079)	.084 (.099)	.053 (.241)	.049 (.221)	.025 (.112)	.023 (.106)	.072 (.330)	.071 (.324)	.046 (.210)	.046 (.209)
Gender	−.242*** (−1.038)	.334*** (.791)	−.267*** (−.955)	.242*** (.487)	.293*** (.501)	−.001 (−.001)	−.145* (−.252)	−.157** (−1.044)	−.135* (−.901)	−.179** (−1.193)	−.175** (−1.164)	−.221*** (−1.488)	−.202*** (−1.362)	−.247*** (−1.670)	−.262*** (−1.768)
IQ	.283*** (.054)	−.033 (−.003)	.019 (.003)	.277*** (.025)	.013 (.001)	.059 (.003)	−.056 (−.004)	.287*** (.085)	.251*** (.074)	.200*** (.059)	.201*** (.059)	.321*** (.096)	.298*** (.090)	.246*** (.074)	.244*** (.073)
HS Mental				.209*** (.098)	−.020 (−.008)	−.101 (−.028)	.001 (.004)		.132* (.206)	.095 (.147)	.095 (.148)		.081 (.127)	.042 (.065)	.042 (.066)
HS Physical				.086 (.073)	−.018 (−.013)	.096 (.047)	−.031 (−.023)		.080 (.224)	.064 (.180)	.063 (.178)		.014 (.041)	−.002 (−.005)	−.001 (−.004)
HS Social				−.011 (−.006)	.038 (.018)	.029 (.009)	.086 (.042)		.060 (.112)	.062 (.116)	.061 (.114)		.014 (.027)	.016 (.031)	.017 (.032)
Education					.467*** (.396)	.073 (.042)	.332*** (.287)			.181** (.600)	.181** (.599)			.189*** (.632)	.178** (.595)
Occ. Mental											−.009 (−.036)				.039 (.155)
Occ. Physical											.010 (.056)				−.004 (−.022)
Occ. Social											.012 (.045)				−.021 (−.080)
R^2	.111	.109	.082	.267	.387	.045	.130	.099	.127	.151	.151	.140	.147	.173	.174

Notes: HS Mental = high school mental activities; HS Physical = high school physical activities; HS Social = high school social activities. For Education, 0 = 12 years; 1 = 13–15 years; 2 = 16 years; and 3 = 17 or more. Occ. Mental = mental occupational demands; Occ. Physical = physical occupational demands; Occ. Social = social occupational demands. TICS-m = Modified Telephone Interview for Cognitive Status; LM = Logical Memory Subtest, Wechsler Memory Battery. For parental occupation, 0 = unskilled manual workers; 1 = operatives ("semi-skilled manual workers"); 2 = sales, clerical, craftsmen ("lower non-manual/upper manual"); and 3 = professional, technical, managerial ("upper non-manual"). For Gender, 0 = female and 1 = male For error-term correlations, $r_{(\text{HS Mental, HS Physical})} = -.047$; $r_{(\text{HS Mental, HS Social})} = .166$; $r_{(\text{HS Physical, HS Social})} = .271$; $r_{(\text{Occ. Mental, Occ. Physical})} = .293$; $r_{(\text{Occ. Mental, Occ. Social})} = .064$; $r_{(\text{Occ. Physical, Occ. Social})} = .088$. $^{*}p \leq .05$; $^{**}p \leq .01$; $^{***}p \leq .001$

Table 3. Standardized and (Unstandardized) Regression Coefficients in Models With Fluency and Speed as Outcome Measures ($n = 213$)

	HS Mental	HS Physical	HS Social	Education	Occ. Mental	Occ. Physical	Occ. Social	Fluency	Fluency	Fluency	Fluency	Speed	Speed	Speed	Speed
Parental Occupation	.029	−.016	.092	.134*	.040	.139*	.161*	.008	.008	−.007	.006	.066	.073	.097	.082
	(.088)	(−.026)	(.238)	(.189)	(.048)	(.118)	(.195)	(.053)	(.059)	(−.050)	(.040)	(.422)	(.463)	(.616)	(.519)
Gender	−.241***	.315***	−.332***	.300***	.303***	−.013	−.108	.083	.084*	.049	.025	−.136*	−.154*	−.100	−.114***
	(−1.038)	(.744)	(−1.237)	(.608)	(.518)	(−.016)	(−.190)	(.839)	(.851)	(.501)	(.253)	(−1.247)	(−1.410)	(−.917)	(−1.042)
IQ	.242***	−.031	.060	.274***	.016	−.009	−.048	.341***	.295***	.264***	.259***	−.304***	−.287***	−.238***	−.237***
	(.047)	(−.003)	(.010)	(.025)	(.001)	(−.001)	(−.004)	(.156)	(.135)	(.121)	(.119)	(−.125)	(−.119)	(−.098)	(−.098)
HS Mental				.218***	−.030	−.146	.088		.216**	.191**	.195**		−.059	−.020	−.016
				(.102)	(−.012)	(−.041)	(.036)		(.507)	(.448)	(.460)		(−.125)	(−.042)	(−.033)
HS Physical				.067	−.027	.062	−.003		.098	.090	.093		−.052	−.040	−.041
				(.058)	(−.019)	(.032)	(−.002)		(.420)	(.386)	(.398)		(−.202)	(−.156)	(−.159)
HS Social				.040	.096	.106	.052		−.060	−.065	−.064		−.061	−.053	−.066
				(.022)	(.044)	(.034)	(.024)		(−.164)	(−.176)	(−.173)		(−.148)	(−.131)	(−.162)
Education					.433***	.159*	.323***			.115	.119**			−.179*	−.227**
					(.366)	(.096)	(.279)			(.557)	(.598)			(−.810)	(−1.024)
Occ. Mental											.053				.062
											(.315)				(.332)
Occ. Physical											−.022				.043
											(.183)				(.319)
Occ. Social											−.074				.043
											(−.427)				(.223)
R^2	.101	.098	.123	.284	.354	.077	.169	.134	.177	.186	.192	.123	.134	.157	.165

Notes: HS Mental = high school mental activities; HS Physical = high school physical activities; HS Social = high school social activities. For Education, 0 = 12 years; 1 = 13–15 years; 2 = 16 years; and 3 = 17 or more. Occ. Mental = mental occupational demands; Occ. Physical = physical occupational demands; Occ. Social = social occupational demands. Fluency = verbal fluency ("animal naming"). Speed = central processing speed (Timed Months of the Year Backwards Test). For parental occupation (socioeconomic status), 0 = unskilled manual workers; 1 = operatives ("semi-skilled manual workers"); 2 = sales, clerical, craftsmen ("lower non-manual/upper manual"); and 3 = professional, technical, managerial ("upper non-manual"). For Gender, 0 = female and 1 = male. Error-term correlations: $r_{(\text{HS Mental, HS Physical})} = -.097$; $r_{(\text{HS Mental, HS Social})} = .155$; $r_{(\text{HS Physical, HS Social})} = .301$; $r_{(\text{Occ. Mental, Occ. Physical})} = .380$; $r_{(\text{Occ. Mental, Occ. Social})} = .131$; $r_{(\text{Occ. Physical, Occ. Social})} = .111$. $^{*}p \leq .05$; $^{**}p \leq .01$; $^{***}p \leq .001$

Table 4. Decomposition of Effects of IQ and Mental Activities on Types of Cognitive Functioning

Variable		Type of Effect					
Dependent	Independent	Total	Indirect Through Activities	Indirect Through Education	Indirect Through Occupation	Total Indirect	Direct
TICS-m	IQ	.287	.036	.051	−.001	.086	.201
	Mental Act.	.132	—	.037	.000	.037	.095
LM	IQ	.321	.023	.052	.002	.077	.244
	Mental Act.	.081	—	.039	.000	.039	.042
Verbal Fluency	IQ	.341	.046	.031	.005	.082	.259
	Mental Act.	.216	—	.025	−.004	.021	.195
Speed	IQ	−.304	−.017	−.049	−.001	−.067	−.237
	Mental Act.	−.059	—	−.039	−.004	−.043	−.016

Notes: TICS-m = Modified Telephone Interview for Cognitive Status; LM = Logical Memory Subtest, Wechsler Memory Battery; Act. = activity.

interested. However, the coefficients for all indirect pathways omitted from consideration here can be obtained from Tables 2 and 3.

The significant path coefficients seen in Tables 2 and 3 suggest that there were indirect effects of IQ on three of the adult cognitive measures (the TICS-m, the Logical Memory subtest, and the processing speed test), working through high school mental activities first and then through education, as represented by this compound path: Adolescent IQ → High School Mental Activities → Education → Cognition. Individuals with higher adolescent IQ were involved in more mental extracurricular activities in high school; went on to attain more education; and subsequently performed better on measures of global cognitive functioning, episodic memory, and processing speed. These indirect effects, which can be computed by multiplying the coefficients along the preceding compound path, were .011, .011, and –.012, respectively. There were also possible indirect effects of IQ on the same cognitive variables, working through education only (IQ → Education → Cognition). The coefficients associated with these indirect effects were .050, .049, and –.062, respectively. Table 3 shows that there was an indirect effect of IQ on verbal fluency working through high school mental activities, but not education (IQ → Mental Activities → Fluency). The coefficient for this indirect effect was .047. Finally, high school mental activities had an indirect effect through education on verbal fluency (IQ → Education → Fluency). This indirect effect was .026. Thus, although mediation was suggested in the models we studied, the relative strengths of these indirect effects were low.

Table 4 shows selected indirect effects and total effects that were computed by the Alwin–Hauser method, as well as direct effects. The total indirect effect of IQ on global cognitive functioning (TICS-m) equals .086, which is an aggregate of the indirect effects flowing through all three high school activities, through education, and through all three occupational demands. The indirect effects through occupational demands are essentially zero, however. Thus, the total indirect effect of IQ is almost entirely mediated by high school activities and education. Most of the indirect effect through activities is through mental activities, which can be inferred by the relatively small standardized regression coefficients for the paths from IQ to physical and social activities and for the paths from physical and social activities to education and the TICS-m, compared with the coefficients for mental activities (Table 2).

In summing up the effect of IQ on the TICS-m score, we see that most of the total effect is direct (70%) and only 30% is indirect. This aggregate indirect effect is almost entirely through high school activities and education. The total indirect effect is the dynamic aspect of reserve, and it indicates that there is some augmentation of reserve in high school and college, if attended, but almost none in midlife occupational demands. The indirect effects of IQ on the other three types of cognitive functioning, relative to the total effect, are even smaller. The indirect effect of IQ as a percentage of the total effect is 24% for logical memory, 24% for verbal fluency, and 22% for processing speed.

The total effects of high school mental activities on cognitive functioning are smaller than those of IQ (Table 4), and only those for TICS-m scores and verbal fluency are significant. The indirect effects of mental activities on TICS-m scores and fluency are small relative to the total effects (28% for TICS-m scores and 10% for fluency), as was the case for IQ's indirect effects.

Discussion

The reserve hypothesis is frequently invoked by cognitive gerontologists to explain aspects of continuity and change in cognitive functioning as we age. Formulations of the reserve hypothesis are becoming increasingly sophisticated (e.g., Richards & Deary, 2005; Stern, 2002), but more work is needed to specify when and how reserve might affect cognition. In the present research, we considered three relatively understudied aspects of the reserve perspective: (a) whether reserve is primarily static throughout the life course, or whether it is dynamic and can be increased; (b) whether increases in reserve can be accomplished at any point in life, or whether there are optimal time periods when it is best to try to intervene to increase level of reserve; and (c) whether participation in different types of activities early in life (mental, physical, and social) has different effects on different domains of cognitive functioning later in life. Our research adds to knowledge about each of these issues.

Our results seem to confirm findings from a few other studies (Arbuckle et al., 1992; Kliegel et al., 2004; Richards et al., 2003; Richards & Sacker, 2003; Wilson et al., 2005) that suggest that reserve is dynamic and can be changed (i.e., increased) to a degree. Empirically, this was demonstrated in our path analyses by showing that there were *indirect* effects of IQ on measures of cognitive functioning in late life working through intervening variables. The path models indicated that teen IQ influenced global cognitive functioning, episodic memory, and processing speed through associations with high school mental activities and education. Verbal fluency, in contrast, was affected by adolescent IQ through links with high school mental activities, but not education. The direct effects of IQ on cognitive outcome measures were relatively strong, with standardized regression coefficients ranging in absolute values from .201 to .259. Only the direct effects of education on occupational mental demands were stronger, with coefficients of .467 and .433 in the two models we studied. Importantly, though, the mediation we observed in this study was weak, with standardized coefficients ranging from .050. to −.062 for the specific indirect paths previously described. When all indirect effects of IQ are summed, the indirect effects appear stronger. However, relative to the direct effects, the indirect effects of IQ on cognitive functioning were small, ranging from 22% to 30% of the total effect. This indicates that, although small changes in reserve can be made, *large* increases are not as easily accomplished.

Interesting was the fact that changes in level of reserve, though slight, only occurred *early* during the life course. We observed small mediated effects of IQ on cognitive outcomes through high school mental activities and education. These pursuits typically occur in the first two decades of life, suggesting that modification of reserve level may best be made at that time. Recent neuroimaging data suggest that the adolescent brain functions in qualitatively different ways than the adult brain. In tasks requiring executive functions (planning, organizing, and decision making), adolescents use more prefrontal cortex resources, whereas adults use brain areas that are more widely distributed across the cortex when completing the same task (Schweinsburg, Nagel, & Tapert, 2005). This indicates less efficient processing in teens than in adults. Pruning and myelination of brain cells, which are critical features of maturation, occur in adolescence and through the early 20s (Luna & Sweeney, 2004). These features of the adolescent brain indicate that growth is occurring and offer opportunities for modification by experiential factors. However, because the magnitude of mediation observed in our study was quite small, we do not wish to overstate these claims.

The finding that reserve can be modified somewhat early in life, but not in midlife or late life, seems to contradict recent studies showing that mental activity in midlife and beyond protects against cognitive decline and dementia (e.g., Friedland et al., 2001; Richards et al., 2003). Furthermore, previous studies have suggested that individuals in occupations with greater mental demands have better cognitive functioning than do those in occupations with lower mental demands (Kohn & Schooler, 1978; Schooler & Mulatu, 2001). Thus, it was surprising that, in the present study, significant associations were not detected between our midlife measures (mental, physical, and social occupational demands) and our measures of adult cognitive functioning. However, exploratory analyses, in which the cognitive measures were regressed on the occupational demands measures (but not the antecedent measures), seemed to suggest that the association between mental occupational demands and cognitive outcomes is a spurious product of their common dependence on the antecedent variables. For example, education causes higher mental demands and it also causes higher cognitive outcomes, so mental demands and cognitive outcomes become correlated because they share a common cause, that is, education. Of course, there are several antecedent variables that are common causes of occupational demands and cognitive outcomes. In future studies of occupational demands and cognition, researchers should consider these findings when interpreting results. Further, it will be important, when evaluating the possibility of critical periods for increasing reserve, to conduct studies that include high-quality measures of activities and exposures *at various points throughout the life course.* Comparing results from different studies—for example, one that measures midlife exposures, and another that measures early-life exposures—is insufficient to rule out spurious relationships and determine with certainty when it is best to try to intervene to increase reserve.

A further interest in this research was the potential to observe that different domains of cognitive functioning might respond in different ways to specific social influences throughout the life span. We hypothesized, for example, that leisure and mental occupational activities and education would be significant predictors of abilities reflecting the products of education and mental activity, such as measures of general knowledge, vocabulary, and verbal abilities. Supporting the prediction, we found that greater participation in high school mental activities was a significant predictor of verbal fluency ($\beta = .195$), independent of education and occupation. Also supporting the prediction was the finding that education was a significant predictor of global cognitive functioning ($\beta = .181$) and episodic memory ($\beta = .178$). Such findings are generally consistent with the concept known as *learning generalization* (Miller, Slomczynski, & Kohn, 1987). Learning generalization refers to the process by which knowledge and skills learned in one situation are generalized or transferred to other situations. The concept is consistent with the transfer of training hypothesis from psychological learning theory, which suggests that the more similar the training task is to a new task, the greater the amount of transfer.

However, in our study, the learning generalization interpretation breaks down somewhat when one considers whether the skills obtained through *specific activities* generalized to cognition in *specific domains*. In this research, we found an association between education and processing speed, which was stronger ($\beta = -.237$) than the reported associations of mental activity and education with other cognitive domains. Processing speed is believed to reflect the effects of biological aging rather than education and mental experiences throughout the life course. Thus, we expected education and early mental activities to have little or no effect on processing speed. In addition, participation in social and physical activities in high school, and jobs with greater mental, social, and physical demands, were not significant predictors of any of the cognitive outcomes. Interestingly, in their work, which considered the lagged effects of participation in classes of activities and domains of cognitive functioning, Aartsen and colleagues (2002) found that information-processing speed affected developmental activity (intellectual and creative work). Other associations between activities and cognition were not significant in this study. The link between speed and intellectual activity that Aartsen and colleagues reported is intriguing, given our finding that education was a strong predictor of speed. The relationships between activities in early life and midlife and outcomes in old age need further investigation. Findings to date do not match what would be predicted on the basis of current reasoning and theory.

Although it was not our primary interest in this study, we documented interesting effects of gender on several cognitive measures. Specifically, women outperformed men on measures of global cognitive functioning, episodic memory, and processing speed, but gender differences in verbal fluency were not observed. These findings are generally consistent with other investigations (Herlitz, Nilsson, & Bäckman, 1997; Meinz & Salthouse, 1998; Welsh et al., 1994), although some studies have shown that the gender gap in some cognitive measures is decreasing in more recent age cohorts (Hyde & Linn, 1988). Our study offers insight into possible mechanisms of the gender differences. As with teen IQ, gender may affect cognitive functioning in aging through links with high school mental activities and education.

Our study is consistent with findings from other recent investigations showing that exposure to complex stimulus environments is associated with better cognitive functioning in healthy aging. Generally speaking, two hypotheses have been offered to explain the nature of these types associations (Hultsch et al., 1999). The first suggests that participation in stimulating activities serves as a protection against cognitive decline in aging. This view is closely related to the well-known ''use it or lose it'' scenario and the concept of cognitive reserve (Friedland, 1993; Stern; 2002; Swaab, 1991). The other hypothesis suggests that high-ability individuals are more apt to lead more active and intellectually engaged lives, which helps maintain good cognitive functioning until a later time when normal age- and disease-related processes limit participation. These hypotheses are not mutually exclusive. Unfortunately, we do not have the data to compare them.

Study Strengths

Our study is unique for several reasons. High school records provided actual test scores reflecting early intelligence. Some other studies have relied on *estimates* of IQ based on verbal ability and demographic-based statistical models, but these approaches have limitations. High school yearbooks provided relatively objective data—free from the problem of recall errors and biases—about the types of activities in which respondents participated as young adults. Such data are rarely available. Furthermore, because these activities reflected students' interests, in combination with IQ data, they tend to support the idea that high-ability individuals seek out mentally stimulating activities, which may help to preserve cognitive functioning. We also have a solid measure of the mental, physical, and social demands of occupations, whereas previous work has generally considered occupational demands to be indexed by socioeconomic status, using rough ordinal categories.

Limitations

Ours was a convenience sample. On average, participants were healthy, had good function, were highly educated, and were intelligent. Nearly all were Caucasian. However, despite the restricted variance associated with some variables (e.g., IQ and education), we were able to detect associations that were statistically significant. A *failure* to find significant associations would have caused concern because the restriction in variance could result in the failure to detect a true effect (a Type II error). This, however, was not the case, decreasing our concerns about the effects of sampling biases.

We were unable to locate a large percentage of the total group of students who graduated in the years 1944, 1945, and 1946. Presumably, many of these individuals were deceased when our telephone screening occurred in 2002. Because the processes we are studying are very likely linked to the some of the processes associated with mortality, our sample could be considered to be a selective one—one that should not be used to generalize about the effects of early experiences on health-related functioning, including measures of cognition. However, if death is linked to the processes we are studying, we would argue that this implies that those who are less engaged or mentally active early in life would be more likely to have died prior to our survey, and also that they would have had lower adult cognitive performance scores prior to their death. If so, we would have a biased sample of early engagement (the extent of this bias would depend on the mortality rate of our population); that is, the sample would have a restricted range of engagement, which could lead to an underestimate of the standard error of the regression slope. The downwardly biased standard error could lead to a failure to reject the null hypothesis that there is no relationship between early engagement and cognitive functioning. However, because we found the regression slopes to be significant, that is not an issue.

In addition, there may be biasing effects associated with the fact that more men than women may have left high school because of World War II. As we mentioned, 57.6% were women and 42.4% were men in our analysis subset of 349 participants. These values are similar to those reported in the 2000 U.S. Census for the City of Cleveland Heights. In this population, among those individuals who were age 65 and older, 60.8% were female and 39.2% were male (U.S. Census, 2000). Thus, attrition by men in our analysis subgroup, as a result of the war or for other reasons, was relatively low and probably did not have biasing effects on our analyses.

We acknowledge that sociocultural factors associated with the specific cohorts we studied may limit the generalizability of our findings to subsequent cohorts. Among those individuals who were teenagers in the World War II years, social factors such as gender discrimination and class barriers may have limited full participation in high school activities, education, and mentally complex jobs. Our data specifically show that girls were more involved in mental activities than boys in high school, but attained less education overall and had less mentally complex jobs than men. Overall, those from lower socioeconomic categories had less education.

In the years following World War II, various formal efforts were made to remove or ameliorate the effects of some of these social barriers. Federal financial aid programs such as the GI Bill and the National Defense Education Act were offered to increase educational attainment (Schaie, Willis, & Pennak, 2005). Following the Women's Movement of the 1950's, women's involvement in the workforce increased, and opportunities for women to pursue occupations demanding greater mental complexity opened up. Title 9, enacted in 1972, mandated that girls and women were to have the same access to sports activities as boys and men. Some of these efforts were successful. Census data indicate steadily increasing educational attainment since the 1940s (U.S. Census Bureau, 2001); women's participation in higher prestige occupations, demanding more mental complexity, also increased (CNN/Money, 2004); and research suggests that, today, high school girls actively pursue all types of extracurricular activities, although boys still participate more in sports (Eccles, Barber, Stone, & Hunt, 2003).

We expect that education and participation in mental activities will have similar effects for men and women. Thus with women's access to education and mentally challenging activities and occupations becoming more like men's, we would expect the differences in cognitive functioning between older men and women, which we observed in this study, to decrease somewhat in the future. There are some data that indicate that gender differences in some domains of cognitive functioning (e.g., verbal ability) are decreasing with time (Hyde & Linn, 1988). It should be noted, however, that some gender differences, such as the use of different memory strategies by men and women, depending on their adolescent IQ (Fritsch, Larsen, & Smyth, in press), might be expected to remain.

Impact on Theory and Policy

The view that maintaining an active, engaged lifestyle can buffer against cognitive decline in aging has received empirical support in previous research, and practitioners and researchers often recommend pursuing activities that ''exercise the mind.'' Among lay audiences, the scenario of use it or lose it has worked its way into the public consciousness and popular literature, and it is widely accepted as valid (see, e.g., MSNBC, 2006).

Implied in this philosophy is the idea that, through mental, physical, or social activity, level of reserve is subject to considerable modification, and that this dynamic feature can be exploited throughout the life course. Some authors also report that mental, physical, and social activities each have independent effects on cognition, and perhaps different effects on different domains of cognitive functioning (e.g., Richards & Deary, 2005; Wilson et al., 2005).

However, data from our study call for modifications in these (often implied) aspects of the reserve hypothesis. First, although reserve may have some dynamic features, our data suggest that dramatic changes in reserve are difficult to make. Further, our data indicate that attempts to make even these small changes are better made in the early decades of life rather than in the later ones. This may be related to the plasticity of the brain, as well as physical changes and growth occurring in the early decades of life. Long-term studies using neuroimaging techniques may be required to validate this conclusion. Further, in this study, participation in mental activities and education seemed to provide protective effects against cognitive decline, whereas participation in social and physical activities provided little protection. Participation in mental activities and education seemed to impact speed of processing to the greatest degree, an unanticipated finding.

We are not arguing against the development of programs offering mental stimulation for older adults. These are emerging at a grass-roots level in terms of memory clubs, brain fitness groups, book clubs, discussion groups, and the like. However, the role of early experiences in influencing adult cognitive functioning should be considered. Likewise, although social clubs and athletic activities in high school may well provide benefits for the developing teen, our findings suggest that only those clubs and activities involving mental demands provide cognitive protection later in life. We therefore advocate that schools and communities continue to offer their young constituents a variety of mentally demanding activities and educational opportunities.

We also suggest that the growing evidence regarding our ability to influence brain reserve receive wider consideration by government officials seeking to set a course to improve our nation's health. At present, although the federal government's Healthy People 2010 initiative (U.S. Department of Health and Human Services, 2000) to enhance life expectancy and quality of life of the U.S. population identifies physical activity as one of its 10 leading health indicators, no mention is made of activities with high mental demands. Concerns for mental health described in Healthy People 2010 are focused solely on reducing levels of mental illness, rather than including goals of maintaining or enhancing cognitive abilities. Although promoting high school graduation is a stated goal of Healthy People 2010, it is couched in terms of the welfare and survival of children, reducing behaviors associated with dropping out of school (e.g., substance abuse, delinquency, and unintended pregnancy), and increasing the likelihood that individuals will be able to obtain or understand health promotion and disease prevention information. Direct effects of educational achievement on cognitive health are not discussed. With the large and growing public health burden associated with degenerative dementia in the United States, it would seem that the time has come to begin considering how results from studies such as ours can begin to be taken into account in setting public health goals.

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