Published in final edited form as:
Neuropsychol Dev Cogn B Aging Neuropsychol Cogn. 2017 May ; 24(3): 321–332. doi: 10.1080/13825585.2016.1210079.

Grit in Adolescence Is Protective of Late-Life Cognition: Non-Cognitive Factors and Cognitive Reserve

Emma Rhodes, **Kathryn N. Devlin**, **Laurence Steinberg**, and **Tania Giovannetti**
Temple University Department of Psychology, 1701 N.13th St., Philadelphia, PA, 19122.

Abstract

Various psychological assets have been shown to protect against late-life cognitive impairment by promoting cognitive reserve. While factors such as educational attainment and IQ are well-established contributors to cognitive reserve, non-cognitive factors, such as grit, have not been studied in this regard. We examined the contribution of adolescent grit, indexed by high school class rank controlling for IQ, to late-life cognition and its decline among approximately 4,000 participants in the Wisconsin Longitudinal Study, a random sample of high school graduates followed from 1957 to 2011. Adolescent grit significantly predicted both immediate and delayed memory at ages 64 and 71, over and above the contribution of IQ. While the relative contributions of IQ and grit to immediate memory were comparable, grit was a stronger predictor of delayed memory. Cognitive reserve has non-cognitive, as well as cognitive, components.

Keywords

cognitive reserve; cognitive aging; non-cognitive factors; academic achievement; class rank; intelligence

Many older individuals with dementia do not demonstrate the degree of cognitive impairment that would be predicted on the basis of brain pathology. Inconsistency between the amount of brain pathology observed and clinical presentation in Alzheimer's disease (AD) has been explained by the concept of "cognitive reserve," which refers to an individual's capacity to withstand the effects of dementia pathology. Theories of cognitive reserve have sought to identify indicators of reserve to further clarify the source of the brain's buffer against aging, damage, and disease. Although premorbid IQ and educational attainment have been identified as useful proxy measures, the precise mechanisms of how psychological assets evident prior to late life confer cognitive reserve remain unclear. In addition, the relations among premorbid intelligence, academic achievement, and rate of cognitive decline are poorly understood.

Correspondence to: Tania Giovannetti.
Emma Rhodes, M.A. – emma.rhodes@temple.edu, 843-607-6777
Kathryn N Devlin, M.A. – kathryn.devlin@temple.edu, 610-742-2321
Laurence Steinberg, Ph.D. – lds@temple.edu, 215-204-7321
Tania Giovannetti, Ph.D. – tgio@temple.edu, 215-204-4296

No financial or other relationships exist that could be interpreted as a conflict of interest affecting this manuscript.

Models of cognitive reserve explain the relation between brain pathology and cognitive impairment as a function of the efficiency, capacity, and flexibility of cognitive processes and brain networks (Stern, 2002; Stern, 2009). Neuroanatomically, cognitive reserve is defined as the efficient use of brain networks and ability to flexibly recruit alternate networks to optimize cognitive performance in the face of brain aging and pathology. This neuroanatomic variability is thought to underlie the use of compensatory cognitive strategies, which bolster performance on tasks of neuropsychological and everyday functioning (Stern, 2002; Tucker & Stern, 2011). Cognitive reserve models predict that the rate of cognitive decline in late adulthood will be slower in those with greater reserve, as they are more capable of engaging compensatory strategies to circumvent neuroanatomical degradation. However, longitudinal investigations of cognitive reserve have not consistently shown steeper declines among individuals with low reserve, suggesting that cognitive reserve may explain only life-long differences in cognitive ability, rather than differential rates of age-associated cognitive decline (Andel, Vigen, Mack, Clark, & Gatz, 2006; Manly, Touradji, Tang, & Stern, 2003; Tucker-Drob, Johnson, & Jones, 2009).

Cognitive reserve is measured indirectly using proxy variables such as childhood IQ, educational attainment, and physical, social, and mental activity throughout the lifespan. In particular, educational attainment and IQ have been found to impart reserve above and beyond other proxy measures (see Stern, 2009 for a review). Although childhood IQ predicts later cognitive outcomes, cognitive reserve continues to develop into early adulthood, largely as a function of educational attainment (Richards & Sacker, 2003). Research on literacy in relation to cognitive decline highlights the importance of capturing alternative aspects of the educational experience as it relates to cognitive reserve. Indeed, Manly and colleagues (2003; 2005) have found literacy to be a more robust predictor than years of education of cognitive decline among African-Americans. Proposed mechanisms through which education facilitates reserve include protracted neuronal activation (Friedland, 1993; Swaab et al., 1998) and the enhancement of cognitive processes through increased knowledge stores (Salthouse, 2003).

Most research on cognitive reserve has used conventional measures of intellectual performance or educational attainment. Investigations into non-cognitive indicators of reserve have revealed significant contributions of personality factors to risk of dementia (Wilson et al., 2003; Wilson et al., 2005; Wilson et al. 2006; Wilson, Schneider, Arnold, Bienias, & Bennett, 2007). Specifically, conscientiousness has been identified as a personality trait associated with a reduction in risk for dementia and age-related declines in global cognition and memory (Wilson et al., 2007). However, no direct comparison of standard cognitive reserve measures to non-cognitive predictors of dementia or age-related cognitive decline exists, and the specific contributions of IQ, education, and non-cognitive factors to cognitive reserve remain unclear.

Given strong associations between personality and cognitive outcomes, it may be necessary to expand the theoretical model of cognitive reserve to include non-cognitive factors that may contribute to reserve via factors related to motivation, perseverance, task-oriented coping, and goal pursuit (Cohan, Jang, & Stein, 2006; Duckworth, Peterson, Matthews, & Kelly, 2007; Friborg, Barlaug, Martinussen, Rosenvinge, & Hjemdal, 2005; Simeon et al., 2007). Grit, or “perseverance and passion for long-term goals,” has been identified as a powerful predictor of success and achievement across a variety of contexts, including educational attainment and occupational success (Duckworth et al., 2007, p. 1087). Importantly, grit has been found to be a better predictor of success and achievement outcomes compared to IQ and conscientiousness (Duckworth & Gross, 2014). Individual characteristics such as grit may enhance the relation between IQ and reduced dementia risk, as the sustained application of intellectual resources may increase exposure to enriched developmental contexts known to impart reserve. One potential measure of grit is academic achievement (e.g., class rank), which may reflect a combination of intellectual capability and tenacious goal pursuit (Kautz & Zanoni, 2015).

The purpose of the present study was to explore the independent contributions of adolescent IQ and grit to late-life cognition. Presumably, two individuals with comparable IQ scores but different levels of achievement within the same school differ in ways other than sheer intelligence. Our measure of grit—high school class rank controlling for IQ—is similar to ones used by economists interested in non-cognitive contributors to success in life (e.g., Borghans, Duckworth, Heckman, & ter Weel, 2008; Kautz & Zanoni, 2015). We predicted that both IQ and grit would be independently associated with better cognition in late life, but that grit would demonstrate a stronger predictive effect given similar findings for adolescents and young adults in domains of educational and occupational success (Duckworth et al., 2007). Measures of immediate and delayed verbal recall were selected to evaluate late-life cognition based on previous literature demonstrating sensitivity to AD pathology and associations with non-cognitive factors assessed in adulthood, such as conscientiousness (Wilson et al., 2007; Wilson et al., 2005). We predicted that the relation between grit and late-life cognition would be significant for both immediate and delayed recall.

Method

Wisconsin Longitudinal Study

Data were obtained from the Wisconsin Longitudinal Study (WLS), a long-term study of a random sample of 10,317 individuals who graduated from Wisconsin high schools in 1957 (Hauser, Sewell, & Herd, 2012; Herd, Carr, & Roan, 2014). The WLS cohort is composed almost exclusively of white, non-Hispanic Americans, consistent with the demographics of Wisconsin in 1957 (Gibson & Jung, 2002; Herd et al., 2014). Survey data were collected in 1957, 1964, 1975, 1992, 2004, and 2011. Initial survey data included educational, career, social, family, health, and psychological variables, which have been supplemented by archival data, such as IQ scores from state records. Later follow-up surveys have collected additional information across a wide range of areas, including cognition. Data, documentation, publication lists, and additional materials are available from the Wisconsin Longitudinal Study, University of Wisconsin-Madison, 1180 Observatory Drive, Madison, Wisconsin 53706, http://www.ssc.wisc.edu/wlsresearch/.

Measures

Adolescent IQ—IQ was measured using the Henmon-Nelson Test of Mental Ability (Henmon, 1954), a 30-minute examination consisting of 90 multiple-choice questions that include word problems, number problems, and graphical representation problems. Henmon-Nelson raw scores have been shown to correlated strongly with standard intelligence measures, such as WAIS Full Scale IQ scores (Watson et al., 1992; Watson et al., 1981). Participants completed this test during high school, and scores were obtained from the Wisconsin State Testing Service. Most participants completed this test during their junior year; when junior year IQ scores were unavailable, freshman year scores were used. Age-normed values were expressed as standard scores with a mean of 100 and SD of 15. IQ scores and other characteristics of the sample are presented in Table 1.

Adolescent grit—Grit in adolescence was operationalized as high school class rank controlling for intelligence (Borghans, Golsteyn, Heckman, & Humphries, 2011; Kautz & Zanoni, 2015). Class rank was based on the mean of all grades earned throughout high school and adjusted for class size. Grades and class size were obtained from high school records. Percentile class rank for each participant was calculated as [100 − (class rank/class size × 100)], then converted to a standard score (mean = 100, SD = 15) based on the normal distribution, with higher values indicating better performance. For example, a participant whose grades ranked 30th in a class of 100 would rank at the 70th percentile and have a normalized class rank of 108.

Memory in late life—In 2004 and 2011, when participants were approximately 64 and 71 years of age, respectively, they were administered the Telephone Interview for Cognitive Status that included a word list memory task (Brandt, Spencer, & Folstein, 1988). Participants were asked to remember an orally presented ten-word list. The number of correct words recalled immediately and after a 12-minute delay constituted the immediate recall and delayed recall measures. Given our interest in the effects of aging and education on cognition, raw scores were used rather than normative scores that would correct for demographic factors such as age and education.

Statistical Analysis

Analyses were conducted using SPSS (IBM). Immediate and delayed recall measures were examined in separate multiple linear regression analyses. To examine the effect of grit on the level of late-life memory, high school class rank and adolescent IQ were entered as predictors of immediate or delayed recall at age 64 and of immediate or delayed recall at age 71. Finally, to examine the effect of grit on change in late-life memory, high school class rank and adolescent IQ were entered as predictors of immediate or delayed recall at age 71, controlling for immediate or delayed recall at age 64. IQ, class rank, and the memory measures were significantly correlated (see Table 2). However, values of the variance inflation factor fell between 1.54 and 1.56, well within acceptable limits, indicating that multicollinearity was not a concern when interpreting the results of the regression analyses.

The present sample consisted of a subset of 3,826 WLS participants with available data for all measures of interest. Of the 10,317 WLS respondents, 693 (7%) did not have data for class rank, 4,933 (48%) for immediate recall in 2004, 5,745 (56%) for delayed recall in 2004, 5,095 (49%) for immediate recall in 2011, and 5,751 (56%) for delayed recall in 2011. A total of 3,052 WLS respondents did not complete the 2004 interview due to death (n =

1287), loss to follow-up (n = 279), inability (n = 39), refusal (n = 956), request for data deletion after participation (n = 3), or administrative reasons (n = 38), or because their participation was not fielded for other reasons, predominantly nonparticipation in prior waves (n = 450). Of the 7,265 respondents who did participate the 2004 wave, 5,665 were randomly selected to complete the memory task, 281 of whom did not complete the immediate recall task due to refusal (n = 220) or administrative reasons (n = 61), and 543 of whom did not complete the delayed recall task due to refusal (n = 137), administrative reasons (n = 79), or completion of the interview over multiple sessions (n = 227).

A total of 4,349 WLS respondents did not complete the 2011 interview due to death (n = 1587), loss to follow-up since the 2004 wave (n = 104), inability (n = 21), refusal (n = 1091), request for data deletion after participation (n = 2), data loss (n = 1), or administrative reasons (n = 4), or because their participation was not fielded for other reasons, predominantly nonparticipation in prior waves (n = 1539). Of the 5,968 respondents who did participate the 2011 wave, 4,661 were randomly selected to complete the memory task, 52 of whom did not complete one or both portions of the memory task due to refusal (n = 17), administrative reasons (n = 11), or completion of the interview over multiple sessions (n = 2), or completion of the interview by a proxy respondent (n = 22). For more information on the WLS cohorts and data collection, see http://www.ssc.wisc.edu/wlsresearch/.

No respondents were missing data for adolescent IQ. Junior year IQ scores were available for 93% (n = 3562) of the present sample, while freshman year scores were used for the remainder (7%; n = 264); in a subset of the present sample who had both junior and freshman year scores available (n = 2476), scores were very strongly correlated ($r = .83$, $p < .001$). In comparison with the rest of the WLS sample, participants in the present sample were significantly more likely to be women (54% vs. 50%, $p < .001$), scored approximately 4 points higher (i.e., approximately 1/3 of a standard deviation) in adolescent IQ ($p = .019$) and class rank ($p = .018$), and recalled 0.1–0.3 additional words in each memory measure (age 64 immediate recall, $p = .003$, delayed recall, $p = .001$; age 71 immediate recall, $p = .009$, delayed recall, $p = .005$). Effect sizes for these differences ranged from trivial ($\eta^2_p = .001$ to .009 for memory) to small ($\eta^2_p = .02$ for IQ and class rank), however. Nevertheless, results should be interpreted with the caveat that data were not missing at random.

Results

Class Rank and IQ Predicting Immediate Recall

When examined simultaneously, higher high school class rank and higher adolescent IQ both predicted better immediate recall of a ten-word list at age 64, with rank a stronger predictor than IQ (Table 3). Each additional SD in rank was associated with 0.25 more words recalled, whereas each additional SD in IQ was associated with 0.19 more words recalled.

Higher class rank and higher IQ also both predicted better immediate recall at age 71, with IQ a stronger predictor than rank. Each additional SD in rank was associated with 0.21 more words recalled at age 71, while each additional SD in IQ was associated with 0.28 more words recalled.

Controlling for immediate recall at age 64, higher class rank and higher IQ both predicted better immediate recall at age 71, with IQ a stronger predictor of change in recall between these two ages than class rank. Each additional SD in rank was associated with a gain of 0.15 more words recalled, while each additional SD in IQ was associated with a gain of 0.24 more words recalled.

Class Rank and IQ Predicting Delayed Recall

When examined simultaneously, higher high school class rank, but not adolescent IQ, was associated with better delayed recall at age 64 (Table 4). Each additional SD in rank was associated with 0.33 more words recalled.

Higher class rank and higher IQ both predicted better delayed recall at age 71, with comparable effect sizes. Each additional SD in rank was associated with 0.27 more words recalled, while each additional SD in IQ was associated with 0.25 more words recalled.

Controlling for delayed recall at age 64, higher class rank and higher IQ were both associated with better delayed recall at age 71, with IQ a slightly stronger predictor of improvement than rank. Each additional SD in rank was associated with a gain of 0.18 more words recalled, while each additional SD in IQ was associated with a gain of 0.23 more words recalled.

Discussion

In a sample of over 3,000 older adults, we explored the relations between IQ and academic achievement in adolescence and late-life cognition. Both IQ and high school class rank were predictive of late-life cognition, such that individuals with higher IQ scores and class ranks performed better on tests of immediate and delayed verbal recall in later adulthood. IQ and class rank were both predictive of immediate recall; class rank was marginally more predictive of task performance at age 64 and IQ was marginally more predictive of performance at age 71. Class rank was the sole predictor of delayed recall performance at age 64; at age 71 both class rank and IQ predicted delayed recall performance.

These results suggest that grit, as measured by adolescent academic achievement adjusted for IQ, is a non-cognitive predictor of late-life cognitive functioning that is equally, if not more, significant than a standard, well-established measure of cognitive reserve. The identification of grit in adolescence as a trait with protective influence on late-life memory functioning underscores the utility of conceptualizing cognitive reserve as a multifactorial construct with non-cognitive indicators (Satz, Cole, Hardy, & Rassovsky, 2011). The stronger contribution of grit to the prediction of delayed recall at age 64, compared to immediate recall, highlights the potential role of non-cognitive factors in episodic memory, a sensitive indicator of pathological aging (Backman, Small, & Fratiglioni, 2001; Wilson, Bienias, Berry-Kravis, Evans, & Bennett, 2002). The finding that grit, but not IQ, is predictive of delayed recall performance at age 64, while both grit and IQ are predictive of delayed recall at age 71 and change over time suggests that traditional components of cognitive reserve (i.e. intellectual functioning) may become particularly important over time as age-related cognitive changes warrant the use of more cognitively demanding compensatory strategies.

Recent studies have found that conventional measures of cognitive reserve primarily reflect only mean differences in cognitive abilities, not differential rates of cognitive decline (Tucker-Drob et al., 2009; Zahodne et al., 2011). In the present study, however, adolescent IQ and grit predicted both the rate of cognitive decline as well as mean levels in cognitive performance. Our finding that high IQ in adolescence predicts attenuated cognitive decline in a nonclinical (i.e., community-based, non-treatment seeking) sample suggests that intelligence may have a greater impact on the rate of cognitive change than previously suspected. This could be due to the use of early measures of intelligence. Previous research has relied on education level of measures of intellectual functioning taken during mid- or late-life, which may be confounded by common cognitive difficulties observed in aging. Intellectual functioning measured during adolescence may be a more useful indicator of future decline, as it is less likely to be impacted by cognitive aging. Class rank was also predictive of reduced decline in immediate and delayed recall, suggesting that grit measured in adolescence has a protective influence on late-life cognitive change. This is consistent with active models of cognitive reserve, which posit that reserve mitigates cognitive decline by allowing individuals to cope more effectively with age-related changes in brain pathology (Stern, 2002). Although grit has been shown to increase with age, less is known about the role of grit in successful and cognitive aging (Duckworth & Quinn, 2009).

Our findings raise the question of precisely how grit and other non-cognitive factors measured in adolescence come to influence cognition in late life. One possibility concerns the ability to adapt to cognitive aging through the use of novel strategies, which may reflect the neural flexibility and compensation described by Stern (2002) as a component of cognitive reserve. Deliberate practice has been identified as a behavioral mechanism underlying the association between grit and achievement in younger samples (Duckworth & Quinn, 2009). Grittier older adults may engage in cognitive exercises more frequently or seek more difficult cognitive challenges that combat age-related cognitive decline. Grit has also been associated with the capacity to delay gratification, which may play a role in reducing common risk factors for late-life cognitive decline (i.e., smoking, substance abuse, cardiovascular disease; Robertson-Kraft & Duckworth, 2013). Personality factors may additionally contribute to the relation between grit and late-life cognition, as grit is positively associated with conscientiousness, a personality trait that has been associated with reduced cognitive decline in aging (Wilson et al., 2007). An alternative hypothesis is that grit enhances early academic success, which subsequently increases the likelihood of exposure to enriched developmental contexts that impart reserve. The relation documented in the present study between grit and late-life cognitive outcomes begs further exploration. Determining the mechanism of this effect has clinical implications, as interventions designed to increase grit in educational settings may also be effective in preventing age-related cognitive decline.

Previous research on educational attainment as a proxy for cognitive reserve has been limited by the skewed distribution of education level (Tucker-Drob et al., 2009; Zahodne, Stern, & Manly, 2015). Studies of IQ as a proxy measure for cognitive reserve have relied heavily on cross-sectional designs, which utilize IQ scores measured in late life (Alexander et al., 1997; Stern, Alexander, Prohovnik, & Mayeux, 1992; Stern et al., 1994). Our findings are enhanced by the use of longitudinal data to directly compare IQ and class rank measured in adolescence to cognitive performance measured in late life. Furthermore, our findings add to the literature by using continuous, domain-specific cognitive outcome variables. Much of the existing research on cognitive reserve has relied on dichotomous outcome variables and global measures of cognition (Scarmeas et al., 2001; Stern et al., 1994), which makes it hard to detect effects due to reduced statistical power compared to continuous, performance-based measures.

Despite these strengths, the present study is limited by a lack of information about rates of dementia in this sample. A measure of incident dementia would have allowed for the development of more clinically relevant conclusions. Additionally, the sample was limited in terms of ethnic diversity, with nearly all participants identifying as Caucasian. In light of previous findings on ethnic differences in predictors of late-life cognitive functioning within demographically diverse samples, it is critically important to expand the investigation of non-cognitive contributions to late-life cognition and dementia risk to include greater representation of racial and ethnic minorities (Manly, et al., 2003; Manly, et al., 2005). In comparison with the rest of the WLS sample, participants in the present study had better IQ scores and school performance in high school and better memory performance in late life, suggesting the possibility of attrition bias; although these differences were trivial to small and therefore may have limited practical significance, future investigations should include greater representation of persons with lower levels of IQ, achievement, and late-life cognitive abilities. Additionally, our measurement of grit is likely not devoid of cognitive influence, as the brief intelligence assessment may not have sufficiently captured all of the cognitive variance that explains academic rank. Further investigation combining comprehensive cognitive assessments, objective measures of achievement, and validated self-assessments (i.e., the Short Grit Scale [GRIT-S]) is warranted (Duckworth & Quinn, 2009).

The current study provides considerable evidence of the significant influence of non-cognitive factors across the lifespan for late-life cognitive performance. Our findings highlight the need to expand the theoretical models and measurement of cognitive reserve to include proxy variables that capture non-cognitive constructs, such as grit. We propose that these factors are as important as cognitive factors in explaining cognitive aging. However, further research is necessary to clarify the specific path through which cognitive functioning in late life is associated with cognitive and non-cognitive factors in adolescence. Additional longitudinal research on early predictors of cognitive functioning in healthy and pathological aging is needed to specify the causal components of these relations. Future research should also explore relations between concurrent grit and cognitive aging in older adults, as varying levels of grit over the lifespan may clarify the nature of this protective effect.

Acknowledgments

This research uses data from the Wisconsin Longitudinal Study (WLS) of the University of Wisconsin-Madison. Since 1992, data have been collected by the University of Wisconsin Survey Center. A public use file of data from the Wisconsin Longitudinal Study is available from the Wisconsin Longitudinal Study, University of Wisconsin-

Madison, 1180 Observatory Drive, Madison, Wisconsin 53706 and at http://www.ssc.wisc.edu/wlsresearch/data/. The opinions expressed herein are those of the authors.

Funding: The WLS has been supported principally by the National Institute on Aging under Grants AG-9775, AG-21079, AG-033285, and AG-041868, with additional support from the Vilas Estate Trust, the National Science Foundation, the Spencer Foundation, and the Graduate School of the University of Wisconsin-Madison. The present study was partially supported by a National Science Foundation Graduate Research Fellowship under Grant DGE-1144462.

References

Alexander GE, Furey ML, Grady CL, Pietrini P, Brady DR, Mentis MJ, Schapiro MB. Association of premorbid intellectual function with cerebral metabolism in Alzheimer's disease: implications for the cognitive reserve hypothesis. The American journal of psychiatry. 1997; 154(2):165–172. [PubMed: 9016263]

Andel R, Vigen C, Mack WJ, Clark LJ, Gatz M. The effect of education and occupational complexity on rate of cognitive decline in Alzheimer's patients. Journal of the International Neuropsychological Society : JINS. 2006; 12(1):147–152. [PubMed: 16433954]

Backman L, Small BJ, Fratiglioni L. Stability of the preclinical episodic memory deficit in Alzheimer's disease. Brain. 2001; 124(Pt 1):96–102. [PubMed: 11133790]

Borghans L, Duckworth AL, Heckman JJ, ter Weel B. The Economics and Psychology of Personality Traits. Journal of Human Resources. 2008; 43(4):972–1059.

Brandt J, Spencer M, Folstein M. The Telephone Interview for Cognitive Status. Neuropsychiatry, Neuropsychology, & Behavioral Neurology. 1988; 1(2):111–118.

Cohan SL, Jang KL, Stein MB. Confirmatory factor analysis of a short form of the coping inventory for stressful situations. Journal of Clinical Psychology. 2006; 62(3):273–283. [PubMed: 16299755]

Duckworth AL, Gross JJ. Self-control and grit: related but separable determinants of success. Current Directions in Psychological Science. 2014; 23(5):319–325. [PubMed: 26855479]

Duckworth AL, Peterson C, Matthews MD, Kelly DR. Grit: perseverance and passion for long-term goals. Journal of personality and social psychology. 2007; 92(6):1087–1101. [PubMed: 17547490]

Duckworth AL, Quinn PD. Development and validation of the short grit scale (grit-s). Journal of personality assessment. 2009; 91(2):166–174. [PubMed: 19205937]

Friborg O, Barlaug D, Martinussen M, Rosenvinge JH, Hjemdal O. Resilience in relation to personality and intelligence. International Journal of Methods in Psychiatric Research. 2005; 14(1):29–42. [PubMed: 16097398]

Friedland R. Epidemiology, education and the ecology of alzheimer's disease. Neurology. 1993; 41:1886–1892.

Gibson, C., Jung, K. Historical Census Statistics on Population Totals by Race, 1790 to 1990, and by Hispanic Origin, 1790 to 1990, for the United States, Regions, Divisions, and States. Washington, DC: US Census Bureau; 2002.

Hauser, RM., Sewell, WH., Herd, P. Version 13.03. [machine-readable data file]. Madison, WI: University of Wisconsin-Madison, WLS. [distributor]; 2012. Wisconsin Longitudinal Study (WLS) [graduates, siblings, and spouses]: 1957–2012.

Henmon, V. The Henmon-Nelson tests of mental ability. Manual for administration. Chicago: Houghton-Mifflin; 1954.

Herd P, Carr D, Roan C. Cohort profile: Wisconsin longitudinal study (WLS). International Journal of Epidemiology. 2014; 43(1):34–41. [PubMed: 24585852]

Kautz, T., Zanoni, W. Measuring and fostering non-cognitive skills in adolescents: Evidence from Chicago Public Schools and the Onegoal Program. University of Chicago: 2015.

Manly JJ, Schupf N, Tang M-X, Stern Y. Cognitive decline and literacy among ethnically diverse elders. Journal of geriatric psychiatry and neurology. 2005; 18(4):213–217. [PubMed: 16306242]

Manly JJ, Touradji P, Tang M-X, Stern Y. Literacy and memory decline among ethnically diverse elders. Journal of clinical and experimental neuropsychology. 2003; 25(5):680–690. [PubMed: 12815505]

Richards M, Sacker A. Lifetime antecedents of cognitive reserve. Journal of clinical and experimental neuropsychology. 2003; 25(5):614–624. [PubMed: 12815499]

Robertson-Kraft C, Duckworth A. True grit: Trait-level perseverance and passion for long-term goals predicts effectiveness and retention among novice teachers. Teachers College Record. 2013 Mar. 116:1–27. 2014.

Salthouse, TA. Interrelations of aging, knowledge, and cognitive performance. In: Staudinger, U., Lindenberger, U., editors. Understanding Human Development: Dialogues with Lifespan Psychology. Berlin: Kluwer Academic Publishers; 2003.

Satz P, Cole MA, Hardy DJ, Rassovsky Y. Brain and cognitive reserve: mediator(s) and construct validity, a critique. Journal of clinical and experimental neuropsychology. 2011; 33(1):121–130. [PubMed: 20680883]

Scarmeas N, Levy G, Tang M, Manly J, Stern Y. Influence of leisure activity on the incidence of Alzheimer ' s Disease. Neurology. 2001; 57(12):2236–2242. [PubMed: 11756603]

Simeon D, Yehuda R, Cunill R, Knutelska M, Putnam FW, Smith LM. Factors associated with resilience in healthy adults. Psychoneuroendocrinology. 2007; 32(8–10):1149–1152. [PubMed: 17913377]

Stern Y. What is cognitive reserve? Theory and research application of the reserve concept. Journal of the International Neuropsychological Society : JINS. 2002; 8(3):448–460. [PubMed: 11939702]

Stern Y. Cognitive reserve. Neuropsychologia. 2009

Stern Y, Alexander GE, Prohovnik I, Mayeux R. Inverse relationship between education and parietotemporal perfusion deficit in Alzheimer's disease. Annals of neurology. 1992; 32(3):371–375. [PubMed: 1416806]

Stern Y, Gurland B, Tatemichi TK, Tang MX, Wilder D, Mayeux R. Influence of education and occupation on the incidence of Alzheimer's disease. JAMA : the journal of the American Medical Association. 1994; 271(13):1004–1010. [PubMed: 8139057]

Swaab DF, Lucassen PJ, Salehi A, Scherder EJ, van Someren EJ, Verwer RW. Reduced neuronal activity and reactivation in Alzheimer's disease. Progress in brain research. 1998; 117:343–377. [PubMed: 9932420]

Tucker-Drob EM, Johnson KE, Jones RN. The cognitive reserve hypothesis: a longitudinal examination of age-associated declines in reasoning and processing speed. Developmental psychology. 2009; 45(2):431–446. [PubMed: 19271829]

Tucker AM, Stern Y. Cognitive reserve in aging. Current Alzheimer research. 2011; 8(4):354–360. [PubMed: 21222591]

Watson CG, Klett WG, Kucala T, Nixon C, Schaefer A, Gasser B. Prediction of the Wais scores from the 1973 Henmon-Nelson revision. Journal of Clinical Psychology. 1981; 37(4):840–842. [PubMed: 7309874]

Watson CG, Plemel D, Schaefer a, Raden M, Alfano, a M, Anderson PE, Anderson D. The comparative concurrent validities of the Shipley Institute of Living Scale and the Henmon-Nelson Tests of Mental Ability. Journal of clinical psychology. 1992; 48(2):233–9. [PubMed: 1573026]

Wilson RS, Arnold SE, Schneider JA, Kelly JF, Tang Y, Bennett DA. Chronic psychological distress and risk of Alzheimer's disease in old age. Neuroepidemiology. 2006; 27(3):143–153. [PubMed: 16974109]

Wilson RS, Bennett DA, Mendes De Leon CF, Bienias JL, Morris MC, Evans DA. Distress proneness and cognitive decline in a population of older persons. Psychoneuroendocrinology. 2005; 30(1): 11–17. [PubMed: 15358438]

Wilson RS, Bienias JL, Berry-Kravis E, Evans DA, Bennett DA. The apolipoprotein E epsilon 2 allele and decline in episodic memory. Journal of neurology, neurosurgery, and psychiatry. 2002; 73(6): 672–7.

Wilson RS, Evans DA, Bienias JL, Mendes de Leon CF, Schneider JA, Bennett DA. Proneness to psychological distress is associated with risk of Alzheimer's disease. Neurology. 2003; 61(11): 1479–1485. [PubMed: 14663028]

Wilson RS, Schneider JA, Arnold SE, Bienias JL, Bennett DA. Conscientiousness and the incidence of Alzheimer disease and mild cognitive impairment. Archives of General Psychiatry. 2007; 64(10): 1204–1212. [PubMed: 17909133]

Wisconsin Longitudinal Study. (n.d.).

Zahodne LB, Glymour MM, Sparks C, Bontempo D, Dixon RA, MacDonald SWS, Manly JJ. Education Does Not Slow Cognitive Decline with Aging: 12-Year Evidence from the Victoria Longitudinal Study. Journal of the International Neuropsychological Society. 2011

Zahodne LB, Stern Y, Manly JJ. Differing effects of education on cognitive decline in diverse elders with low versus high educational attainment. Neuropsychology. 2015; 29(4):649–57. [PubMed: 25222199]

Table 1

Participant characteristics (*N* = 3,826)

% Women	**54**
High school class rank (normalized)	102.95 (14.51)
Adolescent IQ	103.11 (14.61)
Age in 2004	64.30 (0.66)
Immediate recall in 2004[*]	6.20 (1.73)
Delayed recall in 2004[*]	4.13 (2.12)
Age in 2011	71.19 (0.91)
Immediate recall in 2011[*]	5.52 (1.42)
Delayed recall in 2011[*]	3.50 (1.77)

Note. Results are presented as M (SD) unless otherwise noted.

[*] Total words recalled out of 10.

Table 2

Correlations Among Variables of Interest ($N = 3{,}826$)

	1	**2**	**3**	**4**	**5**	**6**
1. High school class rank	—	0.59 *	0.19 *	0.12 *	0.28 *	0.23 *
2. Adolescent IQ		—	0.20 *	0.17 *	0.25 *	0.23 *
3. Immediate recall at age 64			—	0.72 *	0.30 *	0.28 *
4. Delayed recall at age 64				—	0.27 *	0.36 *
5. Immediate recall at age 71					—	0.61 *
6. Delayed recall at age 71						—

Note. Results are presented as Pearson correlations (r).

* $p < .001$.

Table 3

Immediate Recall as a Function of Class Rank and IQ ($N = 3,826$)

	***B* (*SE*)**	**β**	***t***
Predictors of immediate recall at age 64[a]			
Class rank	.016 (.002)	0.14	7.02*
Adolescent IQ	.012 (.002)	0.10	5.32*
Predictors of immediate recall at age 71[b]			
Class rank	.014 (.002)	0.14	7.27*
Adolescent IQ	.019 (.002)	0.19	10.05*
Predictors of change in immediate recall[c]			
Class rank	.010 (.002)	0.11	5.62*
Adolescent IQ	.016 (.002)	0.17	8.96*

Note. Model summary:

[a] $F(2, 3823) = 93.81$*, $R^2 = 0.05$;

[b] $F(2, 3823) = 185.34$*, $R^2 = 0.09$;

[c] $F(3, 3822) = 221.49$*, $R^2 = 0.15$; effect of immediate recall at age 64: $\beta = .25$, $t = 16.37$*.

* $p < .001$.

Table 4

Delayed Recall as a Function of Class Rank and IQ ($N = 3,826$)

	B (SE)	β	t
Predictors of delayed recall at age 64[a]			
Class rank	.022 (.003)	0.15	7.53*
Adolescent IQ	.005 (.003)	0.03	1.63^
Predictors of delayed recall at age 71[b]			
Class rank	.018 (.002)	0.15	7.68*
Adolescent IQ	.017 (.002)	0.14	7.22*
Predictors of change in delayed recall[c]			
Class rank	.012 (.002)	0.10	5.45*
Adolescent IQ	.016 (.002)	0.13	7.08*

Note. Model summary statistics:

[a] $F(2, 3823) = 56.99^*$, $R^2 = 0.03$;

[b] $F(2, 3823) = 136.36^*$, $R^2 = 0.07$;

[c] $F(3, 3822) = 260.42^*$, $R^2 = 0.17$; effect of delayed recall at age 64: $\beta = .33$, $t = 21.79^*$.

* $p < .001$,

^ $p = .103$.