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Cognition Level and Change in Cognition During Adolescence are Associated with Cognition in Midlife

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Abstract

Purpose: Cognitive development during adolescence affects health long-term. We investigated whether level of, and change in, language-based cognition during adolescence are associated with cognitive performance in midlife.

Methods: Participants were enrolled in the Child Health and Development Study and followed during midlife (47–52 yrs). Adolescent cognition was measured with the *Peabody Picture Vocabulary Test a*t ages 9–11 (PPVT-9) and 15–17 (PPVT-15). We examined PPVT-9, as well as a PPVT change-score (derived using the standardized regression-based method) in relation to midlife cognition measures of Wechsler Test of Adult Reading (WTAR), Verbal Fluency (VF), and Digit Symbol (DS) tests. Linear regression models were adjusted for childhood socioeconomic status, age, sex, race, and midlife marital status, education, and occupational score.

Results: In 357 participants (52.1% female, 25.6% African-American), both PPVT-9 (β [95% CI] =0.26 [0.18,0.34]) and PPVT change-score (β[95% CI] = 2.03 [1.27,2.80] were associated with WTAR at midlife. PPVT-9 was associated with midlife VF (β [95% CI] =0.18 [0.10,0.25]), while PPVT change-score was not (β [95% CI] =−0.01 [−0.68,0.67]). Neither PPVT-9 nor PPVT change-score were associated with midlife DS.

Conclusions: Both level of, and change in, language-based cognition during adolescence were associated with midlife vocabulary and language function, even after controlling for midlife occupation and education.

Keywords

Cognition; Adolescence; verbal intelligence; language functioning; birth cohort

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INTRODUCTION

Adolescence marks a period of major brain development,[1–3] when neurophysiological changes and crucial maturation of the cognitive system takes place.[1,4,5] Large longitudinal studies across Europe and the US find that adolescent cognition is related to cognitive outcomes at older ages,[6–8] as well as overall and all-cause mortality risk[9,10] and cardiovascular disease risk.[11–13] However, relatively few studies have examined the impact of adolescent cognition on cognitive function at midlife as opposed to older ages. The observation that dementia has a long preclinical period has led to calls for the study of risk factors and cognitive outcomes many years prior to the clinical diagnosis of disease.[14,15] Furthermore, prior studies have not examined whether the amount of cognitive change during adolescence, independently of the level of cognition measured at one time point, impacts cognitive function in midlife. The degree of increase, stability or decrease in cognition during adolescence has been shown to be linked with brain maturation that demonstrates increased neurophysiological dynamics as compared to earlier periods of brain growth.[5] Thus, the degree of change or lack of change in cognition in this period may be reflective of maturational derailments which may be difficult to remediate, thus setting the course for poor cognitive functioning at midlife and beyond.

We examined whether language-based cognition, measured by the Peabody Picture Vocabulary Test (PPVT) in early adolescence (age 9–11) is associated with various measures of cognitive function assessed at midlife, including the Wechsler Test of Adult Reading (WTAR), Verbal Fluency test (VF); and the WAIS-R Digit Symbol (DS) test. We hypothesize that the language-based adolescent cognition measures in this study will most strongly be associated with midlife measures of cognition that capture vocabulary and verbal function, namely WTAR and VF (while controlling for measures of fluid cognition at midlife). In addition, we examined whether change in PPVT scores between early (age 9–11) and late (age 15–17) adolescence is associated with cognitive performance in midlife, independent of language-based cognitive performance at age 9–11.

METHODS

Study Population

Participants in this study were the adult offspring of mothers who were originally recruited as part of the Child Health and Development Studies (CHDS). Briefly, all pregnant women receiving prenatal care between 1959 and 1967 from the Kaiser Foundation Health Plan in Oakland, California were invited to participate; with a total of 19,044 live births among participating women.[16] In-person interviews and medical records provided extensive demographic, behavioral, and clinical information on the pregnant women and their offspring. Follow-up examinations of offspring and interviews with their primary caregivers (predominantly mothers) were subsequently conducted at offspring ages 5, 9–11, and 15–17 for subsets of the cohort. Recruitment procedures for the midlife Child Health and Development Disparities (DISPAR) study are presented in detail in Link et al.[17] Briefly, a subset of 1,633 offspring were identified for potential inclusion at approximately age 50 (further **details in** supplement).[17] Of the 1633 eligible for DISPAR, 985 were successfully contacted, of which 605 were successfully enrolled to make up the CHDS DISPAR Study

Sample.[17] Human subjects approval was obtained from the IRB's at Columbia University and the Public Health Institute, Oakland California.[17] From the 510 participants who completed the home visit, 31 participants were excluded due to missing information on midlife cognitive variables, and a further 122 were excluded due to missing information on one or both of the adolescent PPVT variables (i.e. either age 9–11 or age 15–17), resulting in a final sample size of 357 for the current longitudinal analyses. Those included in the analyses (n=357) vs. excluded (n=248) were more likely to be white or married (Table 1).

Measures of Adolescent Cognitive Function

The Peabody Picture Vocabulary Test (PPVT), a test of receptive vocabulary and language processing, was administered to participants both at the age 9–11 and 15–17 examinations. Participants are shown a series of sheets, each with 4 pictures displayed. The examiner says a target word aloud, and the participant is asked to indicate which of the 4 pictures best represents the said word[18] (**details in** Supplement).

The Raven Coloured Progressive Matrices (RCPM)[19] test was administered in its complete form but only at the age 9–11 examination. The test represents a test of logical reasoning, and consists of series of items each containing a matrix display of 12 graphical patterns from which one element is missing. The participants are provided with 6 alternative patterns and must choose which best fits the missing element (**details in** Supplement).

Measures of Midlife Cognitive Function

The cognitive tests were administered during home visits. Wechsler Test of Adult Reading WTAR (WTAR) captures crystallized intelligence, which relies on long-term memory and reflects the ability to use experience and knowledge (e.g., vocabulary). Conversely, Verbal Fluency (VF) and WAIS-R Digit Symbol Substitution Test (DS or DSST) capture fluid intelligence, which refers to the capacity to process complex information involved in reasoning and problem-solving tasks.[20]

For the WTAR,[21] the participant is presented with a list of 50 phonetically incorrect words and asked to pronounce each. The raw score is obtained by summing the number of correctly pronounced words, ranging from 0–50.

The VF test[22,23] was conducted by asking participants to name as many animals as possible within 1 minute. Raw scores are obtained by tallying the number of correct responses (excluding any repeats or errors). The administration of WTAR and VF were taped and scored independently by two research staff, with excellent reliability (ICC = 0.989).

For the DSST,[24,25] each participant is presented with a sheet with a number-to-symbol key at the top, along with a grid of numbers and corresponding blank boxes. In this 90-second test, the participant is required to write down as many correct corresponding symbols underneath each number. The score is the count of numbers correctly translated to symbols, with a possible range of 0–133.

Additional variables

Race/Ethnicity was based on participant self-identification at midlife, and categorized as non-Hispanic white, Black, and other race/ethnicity. A composite childhood socioeconomic status (SES) index, described in Link *et al.*,[17] was developed by combining assessments of maternal education at birth, and paternal occupation and family income at birth, 9–11 and 15–17 follow ups. Similarly, a midlife occupational standing score, which takes into account the average yearly income and minimum level of education for a given occupation, was created using data from the (2010) US Bureau of Labor Statistics (details in Supplementary Methods). Midlife education was measured as highest grade of school completed, and analyzed continuously as years of education. Midlife marital status was categorized as single, married/living with partner, and separated/divorced/widowed. Parental divorce or separation during adolescence was defined as a change of parental marital status from being married at the age 9–11 exam to divorced/separated at adolescent age 15–17 exam. Age 9–11 school progress was categorized as normal or skipped a grade vs. held back a grade (these last two variables are included as descriptive variables but not included in multi-variable models).

Statistical Analyses

We used PPVT-9 as a measure of cognition level at baseline, and derived a change-score using the standardized regression-based approach (SRB) as a measure of change in cognition between age 9–11 and 15–17.[26,27] This PPVT change-score was created as follows: 1) a regression equation, with PPVT-15 as the dependent variable and PPVT-9, age, and sex as independent variables (model adjusted R-squared=0.54), was used to derive predicted PPVT-15 scores; 2) the change-score was then created as (actual PPVT-15 score minus predicted PPVT score) divided by the standard error of the estimate (=10.76) from the prediction regression equation. Thus, the change-score provides a measure of what the observed level of age 15–17 cognition was in comparison to what would be predicted based on age 9–11 cognition and related factors. The change-score derived with the SRB method has been shown to be an accurate and reliable method for capturing both normal cognitive change as well as diagnostic change.[26,28]

Linear regression models assessed associations of PPVT-9 and PPVT change-score, with each of the midlife cognitive test scores. Models were initially adjusted for childhood SES index, age at midlife assessment, sex, race, and midlife marital status, followed by adjustment for age-9 Raven test scores (RCPM-9) in order to account for other components of cognitive ability (i.e. fluid cognition) that are not captured by PPVT. Given the evidence that one way early-life cognition can influence later health and cognition is through educational attainment,[10,29–31] we further adjusted for midlife education and occupational standing in final models to determine whether any association between adolescent cognitive development and midlife cognition would remain after such adjustment.

Multiple imputation by chained equations was used to impute missing values for race (n=2 missing), midlife education (n=1 missing), and midlife occupational score (n=19 missing) in linear regression models. Analyses were conducted in R.

In sensitivity analyses, we used standardized PPVT-9 and PPVT-15 scores instead of raw test scores (details in Supplementary Methods) to conduct the above analyses. In additional sensitivity analyses, we used a PPVT difference-score (PPVT-15 – PPVT-9) as a measure of change instead of the PPVT change-score, in order to evaluate whether results obtained with a simple difference measure were in agreement with that observed using our derived change-score.

RESULTS

The 357 participants had a mean (SD) age of 49.5 (1.0) years at midlife, 52% were women, 26% African American, and 69% were either married or living with a partner at midlife. Subjective health ratings in midlife indicate that the majority of the sample (83.8%) was in good health (Table 1).

Mean (range) PPVT-9 and PPVT-15 scores were 81.9 (58–128) and 114.6 (69–146), respectively, and the Pearson correlation between PPVY-9 and PPVT-15 was 0.71. The PPVT change-score ranged from a minimum of −3.3 to a maximum of +2.5, meaning that an individual with a change-score of −3.3, for example, had an observed PPVT-15 score 3.3 points lower than what was predicted based on his/her PPVT-9 score. Whites and those categorized as ‘Other race’ had positive and higher PPVT change-scores in comparison to African-Americans. Similarly, those who had normal school progress or skipped a grade during adolescence, as well as those who did not experience a parental divorce during the course of adolescence, had positive and higher change-scores, in comparison to those who were held back a grade, and those who experienced parental divorce during adolescence. Finally, those with higher education and occupational score in midlife had positive and higher change-scores, in comparison to those with lower midlife education and occupational scores (Table 2).

Both PPVT-9 and PPVT change-score were associated with midlife WTAR, after initial adjustment for age, sex, race, childhood SES index, and midlife marital status (β [95% CI]=0.40 [0.31,0.48] per unit increase in PPVT-9 score and 3.33 [2.45,4.21] per unit increase in PPVT change-score, Table 3 and 4, respectively), as well as final adjustment for RCPM-9, midlife education, and midlife occupational score (β [95% CI]=0.26 [0.18,0.34] per unit increase in PPVT-9 score and 2.03 [1.27,2.80] per unit increase in PPVT change-score, Table 3 and 4, respectively). In contrast, PPVT-9 but not PPVT change-score was associated with midlife VF in fully-adjusted models (β [95% CI]= 0.18 [010,0.25] per unit increase in PPVT-9 score and −0.01 [−0.68,0.67] per unit increase in PPVT change-score. Neither PPVT-9 nor PPVT change-score were associated with midlife DS in any of the multivariable adjusted models (Table 3 and 4, respectively).

In order to facilitate comparison of the magnitude of effect of adolescent cognition on the 3 different midlife cognition outcomes, we additionally conducted the above analyses after standardizing the midlife cognition variables (Supplementary Tables 1 and 2). Finally, results were not altered when all analyses were conducted using standardized PPVT-9 and PPVT-15 scores (Supplementary Tables 3 and 4) as opposed to when using the raw scores. In addition, patterns of association were the same when using PPVT difference score (i.e.

PPVT-15 – PPVT-9) as a measure of change instead of using the PPVT change-score (Supplementary Table 5).

DISCUSSION

Summary and Implications

As measures of adolescent language-based cognition, both PPVT-9 and PPVT change-score were associated with midlife WTAR, a cognitive test that primarily assesses an individual's semantic vocabulary and language function. However, PPVT-9 but not PPVT change-score was associated with midlife VF, a cognitive test that mainly capture's an individual's executive functioning and processing speed, but also requires language processing for successful performance on the test.[32] Finally, neither PPVT-9 nor PPVT change-score were associated with DS, a cognitive test that more exclusively measures processing speed and executive function and does not have a language component. All associations were robust to adjustment for fluid cognitive performance at age 9–11 (i.e. RCPM-9), socio-demographic factors in early life and midlife, as well as midlife education and occupational score. Together, these patterns of associations suggest that not only language-based cognitive levels, but cognitive change during the course of adolescence (a critical developmental period), maintain their impact and importance all the way to language-based cognitive functioning in midlife, and cannot be compensated for by eventually attained educational level or occupational settings.

It is also worth mentioning that in this study sample, we observed notable differences in adolescent cognitive change when comparing Blacks and Whites (Table 2 of Results), with a higher, positive change seen among Whites and a lower, negative change seen among Blacks. Similarly, we observed differences in cognitive change according to occurrence of parental divorce during adolescence. There is evidence that children and adolescents who experience parental divorce have higher levels of externalizing behaviors/internalizing problems as well as lower academic achievement.[33]

In the Context of Prior Findings

Studies in the Scottish Mental Health Survey and the Lothian Birth cohorts reported age 11 Terman-Merrill Binet Test and Moray House Test (MHT) scores to be strongly correlated with National Adult Reading Test (NART), perceptual reasoning, verbal fluency, and logical memory at age 70 and beyond.[6,7,34] In growth curve models accounting for age, social class, years of education, and smoking status, age 11 MHT performance was the strongest single predictor of overall IQ between age 79–87 the Lothian Birth Cohorts.[7]

Rarely have studies examined adolescent cognition in relation to midlife cognition. One exception is a 1946 birth cohort study in Great Britain, which found that age 15–17 measures of verbal and reading comprehension were associated with a 10-year decline in memory (measured via a word list) and search speed and concentration (measured via timed letter search) at midlife,[8] both of which are cognitive measures that mainly assess fluid intelligence. Our study is similar to this study to some extent, in that our exposure was adolescent cognition measured as verbal and language function. However, the British study did not assess cognitive change during adolescence as an exposure, nor did it assess measures of language-based cognition (i.e crystallized intelligence) at midlife as an outcome. Thus, our study extends on their findings. Overall, our study is unique, in that it highlights the impact of cognitive change during adolescence on midlife. As opposed to a one-time static measure of cognition, understanding the impact of cognitive change in adolescence is a better reflection of the underlying neurophysiological development taking (or not taking) place during adolescence.

Mechanisms

Early-life cognition is proposed to influence later health and cognition largely through educational attainment.[10,29–31] In analyses based on observational data from three birth cohorts, Clouston *et al.*[29] reported that a university education had a robust impact on adulthood fluid cognition after adjustment for adolescent (age 15–17) cognition, and concluded that differences in adulthood cognition derive in large part from educational experiences after adolescence. In our study, we had two measures of cognition during adolescence and were thus able to assess both level of and change in adolescent cognition in relation to not only fluid but also crystallized measures of midlife cognition. Our findings of no associations between adolescent cognition and fluid midlife cognition are similar to Clouston *et al.*'s. However, we did observe that level of and change in adolescent cognition were strongly associated with crystallized cognition at midlife, and were only modestly attenuated after adjustment for midlife education and occupational score. It is generally recognized that it is difficult to disentangle the independent effect of education and cognition on health and function.[10,31] However, our finding of a robust effect of language-based change during adolescence on midlife verbal ability, independent of initial cognition levels (both fluid and crystallized), highlights the importance of cognitive change during adolescence.

Limitations and Strengths

Given that the RCPM test (which measures fluid cognition) was only administered in early adolescence, we could not assess change in fluid cognition during adolescence. However, compared to many prior studies that have measured adolescent cognition at one time point only, and predominantly in European populations, this study of language-based cognitive change during adolescence in a US sample[17] serves as a meaningful and unique addition to the literature. Nevertheless, selection of participants into the original CHDS study was based on those pregnant women who were receiving prenatal care from the Kaiser Foundation Health Plan, and furthermore, selection of participants (i.e. offspring of the pregnant women) into the DISPAR study at midlife (N=605) was limited to those who continued to live in California at midlife. These criteria may have served as sources of selection bias. Additionally, our findings may not be generalizable to ethnicities and minority groups not well represented in the study. However, as previously reported, there was little evidence of bias when comparing various sociodemographic factors in potential participants who moved out of California vs. those who stayed on, and additionally when comparing those who were contacted to participate in the DISPAR Study and did so vs. those contacted who did not.[17] Differences between those included in these analyses (N=357 of 605 DISPAR study participants) vs. those excluded (N=248 of 605 DISPAR study participants) may bias estimates of association observed. Those excluded were more likely to be divorced/Single or African-American. Given that these subgroups were more likely to have lower or negative adolescent change-scores, it is more likely that any selection bias would be in a direction away from the null, thus our current results potentially be underestimating the true association between adolescent cognitive development and midlife cognitive performance.

Conclusion

Cognition is recognized as an essential component of health and well-being across the life course. Our findings highlight the impact of the developmental trajectory of cognition during adolescence, and show that support for adolescent language-based cognitive development may have long-lasting benefits into adulthood.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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References

1. Keating DP. Cognitive and brain development Handbook of Adolescent Psychology. 2nd ed: Wiley; 2004:45–84.
2. Paus T, Zijdenbos A, Worsley K, et al. Structural maturation of neural pathways in children and adolescents: in vivo study. Science. 3 19 1999;283(5409):1908–1911. [PubMed: 10082463]
3. Sowell ER, Trauner DA, Gamst A, Jernigan TL. Development of cortical and subcortical brain structures in childhood and adolescence: a structural MRI study. Developmental medicine and child neurology. 1 2002;44(1):4–16. [PubMed: 11811649]
4. Spear LP. The adolescent brain and age-related behavioral manifestations. Neuroscience and biobehavioral reviews. 6 2000;24(4):417–463. [PubMed: 10817843]
5. Steinberg L Cognitive and affective development in adolescence. Trends Cogn Sci. 2 2005;9(2):69–74. [PubMed: 15668099]
6. Deary IJ, Brett CE. Predicting and retrodicting intelligence between childhood and old age in the 6-Day Sample of the Scottish Mental Survey 1947. Intelligence. May-Jun 2015;50:1–9. [PubMed: 26207078]
7. Gow AJ, Johnson W, Pattie A, et al. Stability and change in intelligence from age 11 to ages 70, 79, and 87: the Lothian Birth Cohorts of 1921 and 1936. Psychol Aging. 3 2011;26(1):232–240. [PubMed: 20973608]
8. Richards M, Shipley B, Fuhrer R, Wadsworth ME. Cognitive ability in childhood and cognitive decline in mid-life: longitudinal birth cohort study. BMJ. 3 06 2004;328(7439):552. [PubMed: 14761906]
9. Batty GD, Deary IJ, Gottfredson LS. Premorbid (early life) IQ and later mortality risk: systematic review. Ann Epidemiol. 4 2007;17(4):278–288. [PubMed: 17174570]
10. Calvin CM, Deary IJ, Fenton C, et al. Intelligence in youth and all-cause-mortality: systematic review with meta-analysis. International journal of epidemiology. 6 2011;40(3):626–644. [PubMed: 21037248]

11. Hart CL, Taylor MD, Smith GD, et al. Childhood IQ and cardiovascular disease in adulthood: prospective observational study linking the Scottish Mental Survey 1932 and the Midspan studies. Social science & medicine. 11 2004;59(10):2131–2138. [PubMed: 15351478]
12. Wraw C, Deary IJ, Gale CR, Der G. Intelligence in youth and health at age 50. Intelligence. Nov-Dec 2015;53:23–32. [PubMed: 26766880]
13. Johnson W, Corley J, Starr JM, Deary IJ. Psychological and physical health at age 70 in the Lothian Birth Cohort 1936: links with early life IQ, SES, and current cognitive function and neighborhood environment. Health psychology : official journal of the Division of Health Psychology, American Psychological Association. 1 2011;30(1):1–11.
14. Curb JD. The tangled story of plaques and arteries. Journal of the American Geriatrics Society. 7 2005;53(7):1257–1258. [PubMed: 16108950]
15. Launer LJ. The epidemiologic study of dementia: a life-long quest? Neurobiology of aging. 3 2005;26(3):335–340. [PubMed: 15639311]
16. van den Berg BJ, Christianson RE, Oechsli FW. The California Child Health and Development Studies of the School of Public Health, University of California at Berkeley. Paediatric and perinatal epidemiology. 7 1988;2(3):265–282. [PubMed: 3070486]
17. Link BG, Susser ES, Factor-Litvak P, et al. Disparities in self-rated health across generations and through the life course. Social science & medicine. 2 2017;174:17–25. [PubMed: 27987434]
18. Dunn LM. Expanded Manual for the Peabody Picture Vocabulary Test. American Guidance Service, Inc., Circle Pines, Minn; 1965.
19. Raven JC. Guide to Using the Coloured Progressive Matrices. H.K.Lewis and Co., Ltd., London; 1965.
20. Cattell RB. The theory of fluid and crystallized general intelligence checked at the 5–6 year-old level. Br J Educ Psychol. 6 1967;37(2):209–224. [PubMed: 6063107]
21. Wechsler D Wechsler Test of Adult Reading: WTAR. San Antonio (TX): Psychological Corporation 2001.
22. Brickman AM, Paul RH, Cohen RA, et al. Category and letter verbal fluency across the adult lifespan: relationship to EEG theta power. Archives of clinical neuropsychology : the official journal of the National Academy of Neuropsychologists. 7 2005;20(5):561–573. [PubMed: 15939182]
23. Lezak M Neuropsychologial assessment. 3rd ed: New York: Oxford University Press; 1995.
24. Wechsler D Wechsler Adult Intelligence Scale-Revised. New York, NY: Psychological Corp.; 1981.
25. Wechsler D Wechsler Adult Intelligence Scale—Third edition (WAIS-III). Psychological Corporation; San Antonio, TX; 1997.
26. Sawrie SM, Marson DC, Boothe AL, Harrell LE. A method for assessing clinically relevant individual cognitive change in older adult populations. J Gerontol B Psychol Sci Soc Sci. 3 1999;54(2):P116–124. [PubMed: 10097774]
27. McSweeny AJ, Naugle RI, Chelune GJ, Lüders H. “TScores for Change”: An illustration of a regression approach to depicting change in clinical neuropsychology. Clinical Neuropsychologist. 1993/07/01 1993;7(3):300–312.
28. Frerichs RJ, Tuokko HA. A comparison of methods for measuring cognitive change in older adults. Archives of clinical neuropsychology : the official journal of the National Academy of Neuropsychologists. 5 2005;20(3):321–333. [PubMed: 15797168]
29. Clouston SA, Kuh D, Herd P, Elliott J, Richards M, Hofer SM. Benefits of educational attainment on adult fluid cognition: international evidence from three birth cohorts. International journal of epidemiology. 12 2012;41(6):1729–1736. [PubMed: 23108707]
30. Clouston SA, Richards M, Cadar D, Hofer SM. Educational Inequalities in Health Behaviors at Midlife: Is There a Role for Early-life Cognition? J Health Soc Behav. 9 2015;56(3):323–340. [PubMed: 26315501]
31. Hofer SM, Clouston S. Commentary: On the Importance of Early Life Cognitive Abilities in Shaping Later Life Outcomes. Res Hum Dev. 1 01 2014;11(3):241–246. [PubMed: 25309140]
32. Whiteside DM, Kealey T, Semla M, et al. Verbal Fluency: Language or Executive Function Measure? Appl Neuropsychol Adult. 2016;23(1):29–34. [PubMed: 26111011]

33. Lansford JE. Parental Divorce and Children's Adjustment. Perspect Psychol Sci. 3 2009;4(2):140–152. [PubMed: 26158941]

34. Gow AJ, Johnson W, Pattie A, Whiteman MC, Starr J, Deary IJ. Mental ability in childhood and cognitive aging. Gerontology. 2008;54(3):177–186. [PubMed: 18287787]

Table 1.

Characteristics of the Child Health and Development Study (CHDS) DISPAR participants included in this study (N=357) vs. those excluded (N=248)

	Included	Excluded
Midlife age, mean(SD)	49.5 (1.0)	49.3 (1.5)
Female, N (%)	186 (52.1)	116 (46.7)
Race		
White, N (%)	232 (65.3)	76 (30.7)
African American, N (%)	91 (25.6)	153 (61.7
Other, N (%)	32 (9.0)	19 (7.7)
Midlife marital Status		
Married/living with parnter, N (%)	246 (69.0)	129 (52.0)
Single, N (%)	67 (18.8)	72 (29.0)
Divorced/separated/widowed, N (%)	44 (12.3)	47 (19.0)
Years of education at midlife, mean (SD)	14.9 (0.14)	14.5 (0.15)
Occupational score at midlife, mean (SD)	57.5 (1.4)	53.6 (1.6)
Self-rated health at midlife		
Excellent/very good/good, N (%)	269 (83.8)	127 (80.9)
Fair, N (%)	40 (12.5)	26 (16.6)
Poor, N (%)	12 (3.7)	4 (2.3)

Total N for some variables may not sum to 357 due to missing values N=32 missing for Race, 36 missing for Self-rated health at midlife

Table 2.

Adolescent Peabody Picture Vocabulary Test (PPVT) change-score[†] according to factors in early life, adolescence, and midlife(N=357)

	N (%)	PPVT change-score	
		Mean (SD)	P^{*}_{treand}
Race			
White	232 (65.0)	0.17 (1.0)	
Other	32 (9.0)	0.15 (0.9)	<0.001
African American	91 (25.5)	−0.5 (1.0)	
Childhood SES index			
Tertile 1	119 (33.3)	−0.01 (1.1)	
Tertile 2	119 (33.3)	0.01 (0.9)	0.88
Tertile 3	119 (33.3)	0.00 (1.0)	
School progress at age 9–11			
Normal or skipped a grade	318 (89.1)	0.02 (1.0)	0.03
Held back a grade	20 (5.6)	−0.48 (0.9)	
Parental divorce during adolescence			
Yes	21 (5.9)	−0.57 (1.0)	0.01
No	318 (89.1)	0.02 (1.0)	
Marital Status at midlife			
Married/living with partner	246 (69.0)	0.05 (1.0)	
Divorced/separated/widowed	67 (18.8)	−0.19 (0.9)	0.07
Single	44 (12.3)	0.02 (1.1)	
Education at midlife			
Post-Graduate	62 (17.4)	0.45 (0.7)	
College degree	106 (29.7)	0.14 (1.1)	<0.001
Some college	91 (25.5)	−0.11 (1.0)	
≤ 12 years	97 (27.2)	−0.34 (1.0)	
Midlife occupation score			
Tertile 1	112 (31.4)	−0.21 (0.9)	
Tertile 2	113 (31.7)	0.06 (1.0)	<0.001
Tertile 3	113 (31.7)	0.20 (0.9)	

Total N for some variables may not sum to 357 due to missing values – N missing = 2 for race, 19 for Age 9 School progress, =18 for Parental divorce, 1 for Education, 19 for occupation score

[†] Change-score was generated in 2 steps: 1) a prediction regression equation, with PPVT age 15 as dependent variable and PPVT age 9, midlife age, and sex as predictors, was used to derive predicted PPVT 15 scores; 2) the change-score is created as (actual PPVT 15 score minus predicted PPVT score) divided by the standard error of the estimate from the prediction regression equation.

[*] p-values calculated using tests for linear trend in means, or difference in means with t-test procedure

Table 3.

Association of Peabody Picture Vocabulary Test age 9–11 (PPVT-9) with midlife Wechsler Test of Adult Reading (WTAR), Verbal Fluency test (VF), and Digit Symbol test (DS)

	Adjusted for age, sex, race, marital status, childhood SES index	Further adjusted for Age 9 Raven Test scores	Further adjusted for education and occupation
		β (95% CIs) from linear regression models	
WTAR	0.40 (0.31,0.48)	0.29 (0.2,0.38)	0.26 (0.18,0.34)
VF	0.22 (0.16,0.29)	0.18 (0.11,0.25)	0.18 (0.1,0.25)
DS	0.19 (−0.01,0.39)	0.11 (−0.11,0.33)	0.06 (−0.15,0.28)

Possible range for each the midlife cognition scores are as follows: WTAR: 0–50; VF: no predefined range; DS: 0–133.

Table 4.

Association of Peabody Picture Vocabulary Test (PPVT) change-score† with midlife Wechsler Test of Adult Reading (WTAR), Verbal Fluency test (VF), and Digit Symbol test (DS)

	Adjusted* for race, marital status, childhood SES index	Further adjusted for Age 9 RCPM Test scores	Further adjusted for education and occupation
		β (95% CIs) from linear regression models	
WTAR	3.33 (2.45, 4.21)	2.64 (1.84,3.44)	2.03 (1.27,2.80)
VF	0.46 (−0.21,1.13)	0.12 (−0.53,0.78)	−0.01 (−0.68,0.67)
DS	1.40 (−0.57,3.37)	0.87 (−1.11,2.86)	0.00 (−1.98,1.98)

†Change-score was generated in 2 steps: 1) a prediction regression equation, with PPVT age 15 as dependent variable and PPVT age 9, midlife age, and sex as predictors, was used to derive predicted PPVT 15 scores; 2) the change-score is created as (actual PPVT 15 score minus predicted PPVT score) divided by the standard error of the estimate from the prediction regression equation.

*Age and sex were adjusted for in the prediction equation for deriving the change-score, thus they were not additionally adjusted for in this initial regression model, in order to avoid double-adjustment.