Childhood social class and cognitive aging in the Swedish Adoption/Twin Study of Aging

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Edited by Bruce S. McEwen, The Rockefeller University, New York, NY, and approved May 16, 2017 (received for review December 15, 2016)

In this report we analyzed genetically informative data to investigate within-person change and between-person differences in late-life cognitive abilities as a function of childhood social class. We used data from nine testing occasions spanning 28 y in the Swedish Adoption/Twin Study of Aging and parental social class based on the Swedish socioeconomic index. Cognitive ability included a general factor and the four domains of verbal, fluid, memory, and perceptual speed. Latent growth curve models of the longitudinal data tested whether level and change in cognitive performance differed as a function of childhood social class. Between–within twin-pair analyses were performed on twins reared apart to assess familial confounding. Childhood social class was significantly associated with mean-level cognitive performance at age 65 y, but not with rate of cognitive change. The association decreased in magnitude but remained significant after adjustments for level of education and the degree to which the rearing family was supportive toward education. A between-pair effect of childhood social class was significant in all cognitive domains, whereas within-pair estimates were attenuated, indicating genetic confounding. Thus, childhood social class is important for cognitive performance in adulthood on a population level, but the association is largely attributable to genetic influences.

childhood social class | cognitive aging | adoption | twins

There is a well-established relationship between socioeconomic status (SES) and cognitive ability. Early cognitive performance varies as a function of parental socioeconomic measures (1, 2), where lower SES is associated with lower cognitive performance. Based on the theoretical assumption that childhood may constitute a sensitive period, suboptimal conditions may disturb formative processes and lead to life-long consequences (3). There is also an association between childhood and midlife social class and late-life cognitive performance that has been observed cross countries (4–6). However, most previous studies were based either on cross-sectional data or few assessments of the phenotypes, limiting the possibility to draw any conclusions about longitudinal changes in cognitive aging. In this report we analyze genetically informative data to investigate within-person change and between-person differences in late-life cognitive abilities as a function of childhood social class.

The effect of social class may be difficult to separate from genetic influences. Genetic factors, both independently and in interplay with the environment, are important influences on individual differences in cognitive abilities (7) and cognitive aging (8, 9). Thus, to more fully understand the role of social class on cognition there is a need for use of genetically informative samples. A metaanalysis of adoption and cognitive development showed that adoption to a family with higher social class had a positive effect on IQ of the adoptees compared with nonadopted biological siblings (10). Using data on home-reared and adopted-away siblings, Kendler et al. (11) found that IQ in late adolescence/young adulthood (age 18 y) was associated with the rearing environment, and that the observed differences in IQ were related to the rearing parents' level of education. There was also evidence for genetic influences whereby the IQ of the adopted-away children to some degree was correlated with their biological siblings' IQ. Furthermore, there is some evidence suggesting that the magnitude of genetic influences on IQ may vary across socioeconomic groups, where genetic influences are more important for variance in childhood IQ among children who grow up in socioeconomically privileged homes and environmental factors matter more for children who grow up in socioeconomically disadvantaged homes (12, 13). These studies have predominantly focused on quantifying how genetic and environmental components of variance in cross-sectional cognitive data differ as a function of childhood SES but few have examined longitudinal cognitive change and SES.

Closely related to social class and cognitive performance is educational attainment, which may be an important mediator in the association between childhood socioeconomic circumstances and later-life cognitive performance. Educational attainment has been proposed to account for the observed association between social class in childhood and cognition in midlife (14), and may be of importance for onset of cognitive decline and rate of cognitive decline (15). Because higher childhood social class is associated with higher levels of education, this may, in turn,

Significance

There is a previously well-established relationship between socioeconomic status and cognitive ability. By having access to repeated measures of cognitive data across the second part of the life span, we were able not only to study the influence of childhood social class on mean-level cognitive performance, but also on change over time. Using reared-apart monozygotic and dizygotic twins and a control sample of twins reared together, we studied the effects of childhood socioeconomic environment on cognition in later life. We found an association between childhood social class and mean levels of cognitive performance, but not longitudinal trajectories of change. When controlling for genetic influences, there was no association of childhood social class and cognitive performance late in life.

Author contributions: M.E., C.L., S.F., A.K.D.A., and N.L.P. designed research; M.E. and N.L.P. performed research; C.L., C.Z., and C.A.R. contributed new reagents/analytic tools; M.E. analyzed data; and M.E., S.F., A.K.D.A., C.A.R., and N.L.P. wrote the paper.

The authors declare no conflict of interest.

This article is a PNAS Direct Submission.

Freely available online through the PNAS open access option.

Data deposition: The raw data reported in this paper have been deposited in the National Archive of Computerized Data on Aging, https://www.icpsr.umich.edu/icpsrweb/NACDA (accession no. ICPSR 3843). The data code for the analyses in this study is available on figshare at https://doi.org/10.6084/m9.figshare.c.3794695.

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This article contains supporting information online at www.pnas.org/lookup/suppl/doi:10.1073/pnas.1620603114/-/DCSupplemental.

create a pathway to better cognitive abilities later in life. The childhood home learning environment is also of importance for the cognitive development, independently from parental social class and cognitive abilities (16).

The unique sample of twins reared apart (TRA) and a control sample of twins reared together (TRT) in the Swedish Adoption/Twin Study of Aging (SATSA) allows us to study the effects of the childhood environment on cognition in later life. We investigated the association between childhood social class and trajectories of cognitive performance from midlife to late life. To further understand this proposed association, we also explored the impact of educational factors: specifically, level of education and the degree to which the rearing family was supportive toward education. Importantly, we used the reared-apart monozygotic and dizygotic twins to investigate possible genetic confounding of the relationship between childhood social class and later-life cognitive performance. We hypothesized that: (*i*) lower childhood social class is associated with lower cognitive performance in old age and also with rate of cognitive change; (*ii*) educational factors have an impact on the association between childhood social class and later-life cognitive performance; and (*iii*) the differences in cognitive performance in late life as a function of childhood social class persist after adjusting for genetic factors.

Results

Participant characteristics as a function of rearing status are presented in Table S1. The TRA had lower childhood social class, reported having experienced less positive parental attitudes toward education during childhood, and also had lower levels of education than the TRT. The mean age at first measurement occasion was 69.7 y (SD 9.0, minimum 50.1 and maximum 96.3). Intrapair correlations of the self-reported socioeconomic measures in the TRT indicated adequate reliability of the social class measure, whereas the correlation for parental attitudes toward education was moderate (Table S2).

Longitudinal Analyses with Growth Curve Models. The six latent growth curve models that were fitted to the data to examine the level and change in adult cognitive performance as a function of childhood social class are presented in Table 1. Random quadratic effects were removed from the models with verbal, memory, and spatial abilities, as the models did not converge. In the first two models, controlling for age and birth cohort, childhood social class was positively associated with level of cognitive performance at age 65 y (intercept) in all cognitive abilities. The crude estimates varied notably between the different cognitive abilities. The largest effect sizes were found for the general [2.93 (SE 0.50)] and the smallest for the spatial abilities [1.60 (SE 0.50)]. Childhood social class was not associated with linear and quadratic change in cognitive performance (Fig. S1). In models three and four the parental attitudes toward education variable was added to the model. This slightly attenuated the effect size of childhood social class on the intercept. The independent association with parental attitudes toward education was modest and had no effect on the slopes. Educational attainment was added in model five, which also provided the best fit. Adding the effect of education on the linear and quadratic functions did not improve the model fit (model six). The effect size of education ranged between 3.47 (SE 0.52) for perceptual abilities and 5.76 (SE 0.54) for verbal abilities. Adding education to the model also lowered the effect sizes of childhood social class notably, but the association with social class remained for all cognitive abilities except spatial abilities [0.45 (SE 0.53)]. Furthermore, the association with parental attitudes toward education no longer remained after educational attainment was included in the model.

Between- and Within-Pair Analyses. The three between–within models on the subsample of the TRA, investigating familial confounding of the association between childhood social class and cognitive performance, are presented in Table 2. Linear and quadratic interaction terms were not included in the between–within analyses as they did not improve the model fit in the preceding latent growth curve models. In the fully adjusted between–within analyses on the sample of the TRA (model three), childhood social class was associated with cognitive abilities and had a meaningful effect size in all domains on the between-pair level, with the exception of the spatial factor. The between-pair estimate represents population average effect. Thus, social class contributes to differences in cognitive abilities between families. However, on the within-pair level the effect of childhood social class was small. Within-pair estimates ranged between −0.56 (CI −2.35, 1.22) in verbal abilities and 1.22 (CI −0.62, 3.07) in memory abilities. The within-pair effect represents the residual influence of childhood social class on cognitive performance after controlling for factors shared by the twin pair, such as uterine environment and genetics.

Between and within analyses comparing monozygotic and dizygotic twins are presented in Table S3. The difference between the mean pair effect and individual effect found in the initial between–within models remained. We found consistently smaller within-pair estimates among the monozygotic twins compared with the dizygotic twins, indicating genetic confounding.

Discussion

In a longitudinal study of the TRA and TRT we found that higher childhood social class was associated with higher levels of cognitive performance, but not with trajectories of cognitive change in late life. Furthermore, education predicted but did not fully explain the association between childhood social class and late-life mean-level cognitive performance. Between- and within-pair analyses on the sample of the TRA indicated that association between childhood social class and late-life cognitive performance was attributable to genetic confounding.

We hypothesized that socioeconomic circumstances in childhood are associated with (*i*) level of cognitive performance in old age and (*ii*) with rate of change. Our results show that the mean-level differences as a function of childhood social class were stable over the later part of the life-course, but that social class did not affect the rate of cognitive decline in old age. These initial findings are largely consistent with previous cross-sectional studies on the association between childhood socioeconomic circumstances and cognitive ability in old age (5, 6). In the Health and Retirement Study, Lyu and Burr (4) found evidence of an effect of some socioeconomic indicators on cognitive change over time, although the specific effect of social class was only found on mean-level differences. In our sample, differences in cognition related to childhood social class seem to occur before late life, with the largest effect size for general cognitive, verbal, and memory abilities. The findings that general cognitive ability and crystallized abilities were more associated with childhood social class were anticipated, because crystallized abilities are more sensitive to environmental influences (17).

We also hypothesized that the association between childhood social class and later-life cognitive performance would be altered by educational factors. Before taking genetic factors into account, education only partly explained the association, and rearing-home attitudes toward education had a more modest impact on the association. Consequently, our results show a relatively moderate association with education compared with Osler et al. (14), who found that education accounted for the major part of the association between childhood social class and cognition in later life. These differences can be understood from differences in the study design; Osler et al. examined a more recent cohort for whom educational attainment may have had a

Table 1. Association between childhood social class, parental attitudes toward education, education, and trajectories of late-life cognitive abilities

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Fixed effects	Estimate (SE)	Estimate (SE)	Estimate (SE)	Estimate (SE)	Estimate (SE)	Estimate (SE)
General cognitive ability						
Intercept$_{65}$	**101.96** (1.06)	**101.96** (1.06)	**102.08** (1.04)	**102.08** (1.04)	**93.23** (1.32)	**93.02** (1.34)
Social class	**2.93** (0.50)	**2.98** (0.51)	**2.68** (0.52)	**2.70** (0.52)	**1.55** (0.50)	**1.51** (0.51)
PAE			**0.32** (0.10)	**0.31** (0.10)	0.11 (0.10)	0.11 (0.10)
Education					**5.21** (0.54)	**5.37** (0.55)
Linear age$_{65}$	**2.35** (0.23)	**2.35** (0.23)	**2.34** (0.23)	**2.34** (0.23)	**2.36** (0.23)	**1.87** (0.52)
Social class		0.11 (0.25)	0.12 (0.25)	0.15 (0.26)	0.13 (0.26)	0.07 (0.27)
PAE				−0.02 (0.05)	−0.01 (0.05)	−0.03 (0.05)
Education						0.25 (0.27)
Quadratic age$_{65}$	**−0.02** (0.002)	**−0.02** (0.002)	**−0.02** (0.002)	**−0.02** (0.002)	**−0.02** (0.002)	**−0.02** (0.004)
Social class		−0.0007 (0.002)	−0.0008 (0.002)	−0.001 (0.002)	−0.009 (0.002)	−0.006 (0.002)
PAE				0.0001 (0.0004)	0.0001 (0.0003)	0.0002 (0.0004)
Education						−0.001 (0.002)
AIC (DF)	18,373.61 (12)	18,309.08 (16)	18,312.8 (18)	18,305.12 (19)	18,222.84 (22)	18,218.75 (24)
Verbal ability						
Intercept$_{70}$	**102.82** (1.02)	**102.82** (1.02)	**102.93** (1.01)	**102.94** (1.01)	**93.28** (1.30)	**93.45** (1.31)
Social class	**2.92** (0.50)	**2.80** (0.50)	**2.54** (0.51)	**2.57** (0.51)	**1.29** (0.49)	**1.32** (0.49)
PAE			**0.26** (0.10)	**0.24** (0.10)	0.01 (0.10)	0.02 (0.10)
Education					**5.76** (0.54)	**5.65** (0.55)
Linear age$_{70}$	**2.12** (0.17)	**2.12** (0.16)	**2.12** (0.16)	**2.13** (0.16)	**2.14** (0.16)	**2.35** (0.37)
Social class		−0.34 (0.18)	−0.34 (0.18)	−0.26 (0.18)	−0.27 (0.18)	−0.24 (0.19)
PAE				−0.05 (0.03)	−0.05 (0.03)	−0.05 (0.03)
Education						−0.11 (0.19)
Quadratic age$_{70}$	**−0.01** (0.001)	**−0.02** (0.001)	**−0.02** (0.001)	**−0.02** (0.001)	**−0.02** (0.001)	**−0.02** (0.003)
Social class		0.002 (0.001)	0.002 (0.001)	0.002 (0.001)	0.002 (0.001)	0.002 (0.001)
PAE				0.0004 (0.0002)	0.0004 (0.0002)	0.0004 (0.0003)
Education						0.0006 (0.001)
AIC (DF)	20,320.86 (13)	20,320.94 (15)	20,316.45 (16)	20,317.63 (18)	20,214.76 (19)	20,216.95 (21)
Spatial ability						
Intercept$_{65}$	**103.26** (1.08)	**103.28** (1.08)	**103.37** (1.06)	**103.37** (1.06)	**96.58** (1.40)	**97.04** (1.41)
Social class	**1.60** (0.50)	**1.54** (0.52)	**1.27** (0.53)	**1.29** (0.53)	0.40 (0.53)	0.45 (0.53)
PAE			**0.27** (0.10)	**0.26** (0.11)	0.10 (0.11)	0.12 (0.11)
Education					**3.95** (0.27)	**3.69** (0.57)
Linear age$_{65}$	**1.49** (0.27)	**1.49** (0.27)	**1.50** (0.27)	**1.50** (0.27)	**1.50** (0.27)	**1.29** (0.28)
Social class		0.29 (0.31)	0.29 (0.31)	0.32 (0.32)	0.29 (0.32)	0.28 (0.32)
PAE				−0.02 (0.06)	−0.01 (0.06)	−0.02 (0.06)
Education						**0.09** (0.03)
Quadratic age$_{65}$	**−0.01** (0.002)	**−0.01** (0.002)	**−0.01** (0.002)	**−0.01** (0.002)	**−0.01** (0.002)	**−0.01** (0.002)
Social class		−0.002 (0.002)	−0.002 (0.002)	−0.002 (0.002)	−0.002 (0.002)	−0.002 (0.002)
PAE				0.0001 (0.0004)	0.0001 (0.0004)	0.0001 (0.0004)
Education						
AIC (DF)	20,427.63 (13)	20,429.17 (15)	20,424.18 (16)	20,427.81 (18)	20,382.48 (19)	20,373.92 (19)
Memory						
Intercept$_{65}$	**99.69** (1.00)	**99.63** (1.00)	**99.79** (1.00)	**99.79** (1.00)	**93.36** (1.34)	**93.37** (1.37)
Social class	**2.74** (0.49)	**2.65** (0.52)	**2.41** (0.53)	**2.39** (0.53)	**1.51** (0.53)	**1.51** (0.53)
PAE			**0.24** (0.10)	**0.26** (0.11)	0.11 (0.11)	0.11 (0.11)
Education					**3.82** (0.56)	**3.81** (0.58)
Linear age$_{65}$	**1.61** (0.29)	**1.61** (0.29)	**1.60** (0.29)	**1.60** (0.29)	**1.60** (0.29)	**1.72** (0.66)
Social class		−0.04 (0.33)	−0.04 (0.33)	−0.08 (0.34)	−0.10 (0.34)	−0.09 (0.35)
PAE				0.03 (0.06)	0.04 (0.06)	0.04 (0.06)
Education						−0.06 (0.35)
Quadratic age$_{65}$	**−0.01** (0.002)	**−0.01** (0.002)	**−0.01** (0.002)	**−0.01** (0.002)	**−0.01** (0.002)	**−0.01** (0.005)
Social class		0.0004 (0.002)	0.0003 (0.002)	0.0007 (0.002)	0.0008 (0.002)	0.0007 (0.003)
PAE				−0.0003 (0.0004)	−0.0003 (0.0004)	−0.0003 (0.0004)
Education						0.0004 (0.003)
AIC (DF)	22,758.88 (13)	22,762.62 (15)	22,759.22 (16)	22,762.72 (18)	22,719.51 (19)	22,723.47 (21)
Perceptual speed						
Intercept$_{65}$	**99.45** (1.02)	**99.44** (1.02)	**99.59** (1.00)	**99.59** (1.00)	**93.74** (1.30)	**93.48** (1.32)
Social class	**2.18** (0.47)	**2.39** (0.49)	**2.01** (0.49)	**2.01** (0.49)	**1.26** (0.50)	**1.21** (0.50)
PAE			**0.40** (0.09)	**0.40** (0.10)	**0.26** (0.10)	**0.26** (0.10)
Education					**3.47** (0.52)	**3.66** (0.54)
Linear age$_{65}$	**1.92** (0.29)	**1.90** (0.29)	**1.88** (0.29)	**1.88** (0.29)	**1.88** (0.29)	1.08 (0.64)
Social class		0.32 (0.31)	0.33 (0.31)	0.33 (0.33)	0.30 (0.33)	0.20 (0.33)
PAE				−0.003 (0.002)	0.01 (0.06)	−0.01 (0.06)
Education						0.43 (0.33)
Quadratic age$_{65}$	**−0.02** (0.002)	**−0.02** (0.002)	**−0.02** (0.002)	**−0.02** (0.002)	**−0.02** (0.002)	**−0.01** (0.005)
Social class		−0.003 (0.002)	−0.003 (0.002)	−0.003 (0.002)	−0.003 (0.002)	−0.002 (0.002)
PAE				−6.88e-06 (0.0004)	−0.00006 (0.0004)	0.00008 (0.0004)
Education						−0.003 (0.002)
AIC (DF)	22,272 (16)	22,271.43 (18)	22,256.35 (19)	22,260.18 (21)	22,219.14 (22)	22,216.91 (24)

Statistically significant estimates (95% CI) presented in bold. All models were adjusted for sex and birth cohorts. AIC, Aikaike's Information Criterion; DF, degrees of freedom; PAE, parental attitudes toward education.

Table 2. **Between–within models of parental social class on longitudinal trajectories of cognitive ability in twins reared apart**

		Crude		Adjusted*		Adjusted†	
Cognitive ability	*n*	β	(95% CI)	β	(95% CI)	β	(95% CI)
General cognitive ability	392						
Between-pair		**4.44**	2.18, 6.70	**4.06**	1.85, 6.26	**2.57**	0.53, 4.62
Within-pair		1.43	−0.28, 3.15	1.04	−0.70, 2.80	0.48	−1.26, 2.21
Verbal	397						
Between-pair		**3.87**	1.54, 6.19	**3.43**	1.14, 5.72	2.08	−0.09, 4.25
Within-pair		0.43	−1.36, 2.22	−0.02	−1.83, 1.78	−0.56	−2.35, 1.22
Spatial	394						
Between-pair		**2.27**	0.05, 4.49	1.94	−0.26, 4.14	0.79	−1.35, 2.93
Within-pair		1.08	−0.73, 2.89	0.77	−1.07, 2.61	0.30	−1.51, 2.11
Memory	402						
Between-pair		**4.73**	2.56, 6.89	**4.35**	2.21, 6.49	**3.25**	1.18, 5.31
Within-pair		**2.03**	0.21, 3.84	1.68	−0.16, 3.51	1.22	−0.62, 3.07
Perceptual speed	400						
Between-pair		**3.74**	1.61, 5.87	**3.29**	1.23, 5.35	**2.18**	0.18, 4.17
Within-pair		0.97	−0.67, 2.61	0.58	−1.10, 2.26	0.15	−1.54, 1.84

Statistically significant estimates (95% CI) presented in bold. All models were adjusted for age, sex, age at separation, and degree of relationship with biological parents. Point estimates from intercept at the centered age 65 y.

*Adjusted for parental attitudes toward education.

†Adjusted for parental attitudes toward education and own education.

different impact. Furthermore, the younger ages of the participants Osler et al. studied at follow-up do not capture cognitive abilities in old age.

The third hypothesis, that differences in cognitive performance in late life as a function of childhood social class would persist after adjusting for genetic factors, was not supported. The effect of childhood social class, observed on the between-pair level, did not remain in the within-pair analysis, which means that the results could not be attributed to the rearing environment. The attenuated effect sizes for the monozygotic twins compared with the dizygotic twins further strengthened these conclusions. The findings in this study challenge the causality of the association between childhood social class and cognitive abilities found in previous research (4, 14, 18, 19). Kendler et al. (11) found evidence of both genetic and environmental influences on early adult (age 18 y) cognitive performance in their study of home-reared and adopted-away siblings. These findings are partly consistent with our study in that there was an effect of social class of approximately the same magnitude for general cognitive abilities within dizygotic pairs as within siblings for their measure of IQ. However, our absence of evidence for childhood social class influences after fully controlling for genetic confounds [genetic influences on both cognition and educational attainment (20)] differs from previous studies using adoption data (10, 11). The monozygotic within-pair analysis provides a more complete control of genetic confounds than the within-sibpair comparisons by Kendler et al. (11). The discrepancy may also come from the long follow-up time in our study; SATSA cognitive testing followed the participants from age 50 y and onwards. Cognitive abilities in early adulthood may be more strongly associated with rearing environment than cognitive abilities in late life because of temporal proximity to upbringing and school attendance.

The strengths of this study include the longitudinal design up to the highest ages, extensive cognitive testing, and the genetically informative design with twins reared apart and reared together. Nonetheless, there are potential limitations to this study. First, the measurement of childhood social class is solely based on parental occupation. It is possible that other measures of socioeconomic conditions in childhood, such as parental education or financial strain, would have led to different results. Different socioeconomic measures cannot be expected to be completely interchangeable as they reflect different resources and mechanisms. Parental education may be more strongly linked to the cognitive abilities of the parents, whereas an occupation-based measure to a larger part could reflect the social environment and access to resources. Moreover, occupational-based social class only indicates socioeconomic variation within the normal range, and not poverty or social deprivation. Thus, it is possible that there are effects of socioeconomic disadvantage during childhood on late-life cognition that are not captured in this study. Furthermore, it is not certain that these findings can be generalized to later-born cohorts. Because there have been major socioeconomic developments during the past century, it is possible that the mechanisms linking social class in childhood and cognition in later life have changed over time. For example, the educational expansion has led to increased educational opportunities across social groups, reducing the importance of social background for educational attainment. The effect of education would likely be smaller in more recent birth cohorts. Despite this possibility, the study reflects the particular conditions that prevailed during childhood for those who are very old today. Other limitations are that both parental occupation and parental attitudes toward education were self-reported and could be affected by recall bias. Although we have no objective account of parental occupation, the intrapair correlations of the self-reported measures indicated adequate reliability of the social class measure. Finally, we only used data from one country, Sweden, which may be a limitation as it was recently shown that that there are cross-national differences in gene–SES interactions (13). However, recent studies of older adults find no such differences between Scandinavia and the United States (21).

The implication of this study is that previous findings regarding the relationship between childhood social class and late-life cognitive abilities should be reconsidered. Efforts to equalize health inequalities related to cognition cannot disregard genetic susceptibility and paths of gene and environment interplay, which implies that more-focused early individualized interventions should be directed toward less-advantaged populations.

In conclusion, by using a unique sample with the TRA that allowed for further understanding factors underlying the relationship between childhood social class and late-life cognitive performance, we found an association between childhood social class and mean levels of cognitive performance, but not trajectories of change. When controlling for genetic influences, there was no association between childhood social class and cognitive performance late in life.

Measurements

The data were retrieved from SATSA (22), which originates from the population-based Swedish Twin Registry (STR) (23). Participants in SATSA are part of both the old cohort (born 1886–1925) and middle cohort (born 1926–1958) in the STR. The study contains data on twins that were separated from their cotwin before the age of 11 and reared apart, and a control sample of twins reared together, matched on gender, birth year, and county of birth. Baseline questionnaire data were collected in year 1984. Subsequently, there have been nine occasions of in-person testing (IPT). Each IPT included interviews, health examinations, and cognitive testing. Our sample consisted of 859 individuals [TRA = 425 (200 complete pairs) and TRT = 434 (220 complete pairs)], who participated in at least one testing occasion (mean 4.5, SD 2.4). We used cognitive data from nine testing occasions performed on approximately 3-y intervals. The factor scores of four cognitive domains were derived through principal component analysis of eight cognitive tests (crystallized/verbal: information; synonyms, perceptual speed: digit symbol; Figure Identification Form A, memory: Digit Span; Thurnstone's picture memory, and fluid/spatial: Koh's Block Design; Card Rotations Form A). A general ability score based on performance of all eight tests was also derived through principal component analysis (24). For the cognitive factors to be held constant over all time points, the loadings were standardized to the means and variances from IPT1. The final factor scores were transformed to scores scaled in classic IQ units with a mean of 100 (SD 15). On the basis of cognitive performance in the IPT and information from medical records, proxies, and the research nurses, suspected dementia cases were detected. Dementia diagnosis was derived based on observations, physical, and neurological testing, as well as laboratory tests. Diagnosis was set in accordance with the *Diagnostic and Statistical Manual of Mental Disorders* (DSM)-III-R or DSM-IV, depending of the year of diagnosis (25).

Childhood social class was based on self-reported data on parental occupation derived from the questionnaire in 1984. Childhood social class was coded in accordance with Swedish socioeconomic index (SEI) classification, which is a classification system that aims to reflect the social hierarchy of the labor market (26). Household social class was coded in order of dominance, meaning that the household social class is coded on the basis of the family member who has the higher individual class position. This assigned class position will presumably more accurately reflect the social class position of the family and household in which the participants were fostered (27). Retired parents were coded in accordance to their previous main occupation (n = 4). Housewives in one-person households were coded as unskilled manual workers (n = 26). The SEI categories were recoded into a five-level scale following Bukodi et al. (28): (*i*) unskilled manual employees, (*ii*) skilled manual workers, lower nonmanual employees, farmers, (*iii*) self-employed (not including professionals), (*iv*) intermediate nonmanual workers, and (*v*) higher nonmanual workers (including professionals).

Parental attitudes toward education and educational attainment were considered as possible influences on the relationship between parental SES and later-life cognitive performance. A composite score for parental attitudes toward education was created by summing the five items: (*i*) "my parents urged me to obtain an education beyond primary school," (*ii*) "my parents were interested in my school work," (*iii*) "my parents came to school and met the teacher when I started school," (*iv*) "my parents thought it was important to read," and (*v*) "my parents often read aloud to me" (29). All items used a five-point Likert scale format. A higher composite score signified a greater degree of support for education.

Education was self-reported and categorized as four-level scale on the basis of the Swedish school system. The levels of education were: (*i*) primary education, (*ii*) lower secondary or vocational, (*iii*) upper secondary education, and (*iv*) tertiary education.

The majority of the TRA were separated before the age of 2 y (mean 2.46, SD 2.89, median 1.08). There was some variation regarding the degree of relatedness to the rearing parents (30). A variable was created on a three-level scale: (*i*) biological parents or siblings, (*ii*) other relatives, and (*iii*) not related (mean 1.82, SD 0.85).

To investigate the validity of the self-reported socioeconomic measures, intrapair correlations of these items were performed on the TRT. Differences in sex, zygosity, childhood social class, parental attitudes toward education, and educational attainment, as a function of rearing status were assessed with χ^2 tests. Childhood social class and parental attitudes toward education were used as continuous variables in the statistical analyses. The scales for childhood social class and parental attitudes toward education were centered on the mean before being applied in the statistical models. Cognitive data were excluded for waves of measurement after a dementia diagnosis. Furthermore, only participants with data on childhood social class were included in the analyses. After these restrictions the sample consisted of 803 individuals (TRA, n = 396; TRT, n = 407).

Latent growth curve models were performed to test whether level and change in cognitive performance differed as a function of childhood social class on the entire sample (TRA and TRT). These models allow for analyzing both the group mean trajectories over time and the individual variation from these, and were fitted for each cognitive domain (the general ability score, crystallized/verbal, fluid/spatial, memory, and processing speed). The fitted models included fixed effects, linear, and quadratic trends. Age was centered at 65 y (age at each time point minus 65) with the exception of verbal abilities, where the centering age was set at 70 y, based on previous findings from SATSA (24). Childhood social class, parental attitudes toward education, and education were added as fixed effects and in interactions with linear and quadratic age. Model one included the fixed effects on intercept average cognitive abilities at centering age, childhood social class, and linear and quadratic terms for age representing linear and quadratic change in cognition. In model two, the interaction of the change trajectories (linear slope and quadratic term) with childhood social class were included to investigate the effects of childhood social class on rate of change. In model three parental attitudes toward education was added, first on the intercept and then, in model four, on the change trajectories. In model five, education was fitted to the model, on the intercept, and in model six on change trajectories. Adjustments were made to account for correlation within twin-pairs by modeling individuals nested in sibling pairs as random effects.

To analyze further late-life cognitive performance as a function of childhood social class and to assess familial confounding, between–within models were fitted to the data on the TRA. The between-pair effect represents the average effect in the population and the within-pair estimate will provide the effect that is not attributable to the shared pair-effect (31). The within-pair estimate is the effect of childhood social class independent of shared genetic factors and any other familial factors. Between- and within-cluster effects were tested in two steps using linear mixed models with random effects for intercept, linear age, and quadratic age for twins nested within twin pairs. Both the twin-pair mean (between-pair effect) and the deviation from the twin-pair mean (within-pair effect) were included in the models. Initially the

PSYCHOLOGICAL AND COGNITIVE SCIENCES

analyses were performed on the sample of the TRA regardless of zygosity. To separate genetic effects from other familial effects, an interaction with zygosity was included in the models. Parental attitudes toward education and educational attainment were entered one after the other in the models.

Age, sex, and birth cohort were included in all models to adjust for possible confounding. The covariate birth cohort was dichotomized (born before or after 1925), reflecting the division of the old and the middle cohort in the STR (32). In the separate analyses on the TRA, age of separation and degree of separation were also included. All statistical analyses were performed using STATA 14 software.

All participants provided informed consent. SATSA was approved by the Regional Ethics Board in Stockholm. SATSA is archived at the National Archive of Computerized Data on Aging (ICPSR 3843).

ACKNOWLEDGMENTS. SATSA was supported by NIH Grants R01 AG04563 and R01 AG10175, the MacArthur Foundation Research Network on Successful Aging, the Swedish Research Council for Working Life and Social Research (FAS; Grants 97:0147:1B, 2009-0795), and the Swedish Research Council Grants (825-2007-7460 and 825-2009-6141). This work was supported by NIH Grants R01 AG037985 and R56 AG037985, the Swedish Research Council Grant (2013-08689), and FORTE (the Swedish Research Council for Health, Working Life, and Welfare; Grant 2013-02292).

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