Gene x SES interaction in U.S. child achievement and cognition

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ABSTRACT

The observation that cognitive traits measured in children raised in higher socioeconomic status (SES) homes are more heritable than when measured in children raised in lower SES homes has been found in samples collected in the United States (Tucker-Drob & Bates, 2016). The present study seeks to explore the effects of this gene x SES interaction in a sample of twins participating in the Western Reserve Reading and Math Project. In total, 754 twins (MZ: n = 294 ; DZ: n = 460) living near a midwestern U.S. city were assessed on SES at both the family level and school level. IQ, reading achievement, and math achievement were collected longitudinally across 9 time points between the ages of 6 and 15 via in-person testing. The gene x SES interaction was explored using a set of models with main effects of SES in combination with moderation of A, C, and E (Purcell, 2002). Stability and change across age were also assessed. Results from gene x SES modeling with SES characterized by both family and school level will be discussed.

INTRODUCTION

SES has been demonstrated to have a moderating effect on the interplay of genes and environment on general cognitive ability (g) outcomes (Turkheimer et al, 2003). Specifically, the shared environment accounts for more variance in g at the lower end of SES, and genes account for more variance in g at the higher end of SES (Turkheimer et al, 2003). Moderation analyses of g support the bioecological model, in which genetic expression is enhanced in higher SES environments where intellectually enriching opportunities are readily available (Bronfenbrenner & Ceci, 1994). The bioecological model contrasts with the diathesis-stress model, which suggests that genetic expression of disorder would be more likely to occur in environments with more stresses, such as children raised in low SES environments (Rende & Plomin, 1992).

A person's overall ability can be summarized by g, but achievement (academic performance in a particular area) while correlated with g, accounts for additional variance in important life outcomes. The GxE interaction on achievement in the particular areas of math and reading have not been studied as widely. Studies focusing on reading in particular have had mixed results for the GxE interaction. Higher SES has been associated with higher heritability and lower shared environment influences for 5-7 year old early literacy skills (Taylor & Schatschneider, 2010) and 11.5 year olds' reading disability classification (Friend et al., 2008). However, no GxE interaction on early literacy skills was demonstrated in 2 and 4 year olds (Rhemtulla & Tucker-Drob, 2011). In addition, in 7 and 12 year olds selected on high reading ability, the opposite effect was noted; high SES was associated with lower genetic influences and higher shared environmental influences (Friend, 2009). In math, a significant GxE interaction in 4 year olds (higher influence of genetics for higher SES) (Rhemtulla & Tucker-Drob, 2011) was later reduced to nonsignifcance after learning motivation was controlled (Tucker-Drob & Harden, 2013).

GxE interaction has mostly relied on a compilation of family measures such as parental education and parental occupation as indicators of SES. However, school variables such as the number of students enrolled in a free lunch program (Hart et al., 2003) and teacher effectiveness (Taylor, Roehrig, Hensler, Connor & Schatschneider, 2010) have also been used as moderators. In both studies, genetics were found to be more highly influential at the higher end of the moderator in 8 year old children's reading achievement. Given the influence of the school environment on achievement outcomes, incorporation of a school level indication of SES is appropriate.

MATERIALS & METHODS

Cognitive ability and achievement

Cognitive ability was evaluated using the overall standardized score from the Stanford Binet, collected at age 7.2. An overall math achievement factor score was obtained for ages 8.6-10.9 using the Woodcock Johnson III Test of Achievement (WJ-III) Applied Problems, Calculation, Fluency, and Quantitative Concepts subtests (Woodcock, McGrew, & Mather, 2001) and Wide Range Achievement Test (WRAT): Arithmetic subtest (Wilkinson, 1993). The math factor score for ages 12.2 and 15.0 included WJ-III Applied Problems, Calculation, Fluency subtests (Woodcock, McGrew, & Mather, 2001).

Reading achievement was described using a factor score for ages 8.2 o 10.9, which included the Woodcock Reading Mastery Test (WRMT): Passage Comprehension, Word Attack, and Word Identification subtests (Woodcock, 1998). For ages 12.2 and 16, the Test of Word Reading Efficiency (TOWRE) sight word and phonemic decoding (Torgersen, Wagner, & Rashotte, 1999) and WJ-III Passage Comprehension subtest were used (Woodcock, McGrew, & Mather, 2001)

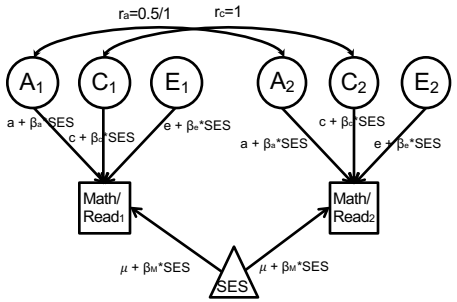
SES

SES level was determined using three indices: 1) Average parental education achieved 2) Home zip code education level 3) School district education level. The average parental education level was collected at the first home visit, when the twins were between ages 5 and 6. The education level for each parent was recorded on a scale of 1-8 (1: grade 6 or less; 2: grade 7-12 without graduating; 3: graduated high school; 4: some college; 5: graduated 2 year college; 6: graduated 4 year college; 7: attended graduate or professional school without graduating; 8: completed graduate or professional school). Both the home and school district average education level (percentage with associate degree) were obtained via census information. The three indices were then standardized and averaged to obtain an overall SES level that included parent, school, and neighborhood SES. The correlation between family and both home and school SES was moderate (r=.35 and r=.31, respectively). The correlation between home and school SES was strong (r=.77).

Data analysis

All cognition and achievement variables were standardized and residualized for the effects of age and sex. The continuous-moderator model (Purcell, 2002) was used to explore the GxE interaction for cognitive ability, reading achievement, and math achievement in the OpenMx software package in R (Neale et al., 2016). In the model, a is additive genetic influence, c is shared environmental influence, e is nonshared environmental influence, β_a is moderation of additive genetic influence, β_c is moderation of the shared environment, β_e is moderation of the nonshared environment, and β_M is the means effect. The continuous-moderator model first accounts for the direct influence of the moderator (SES) on the outcome variable (cognition/achievement) and then decomposes the variance into direct effects of A, C, and E as well as interactions of the moderator with the separate A, C, and E components. The correlation between reading and math at the same age ranged from .30 to .56.

Figure 1. Continuous-moderator model

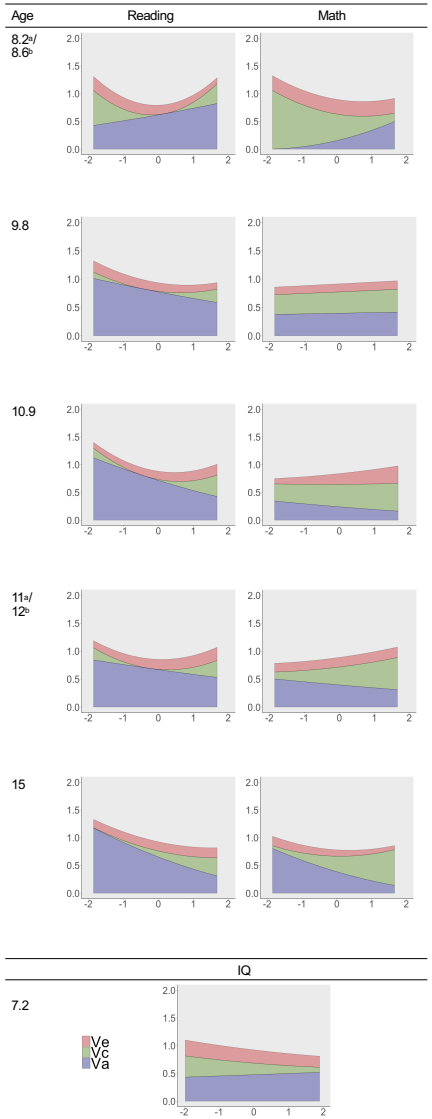


RESULTS

Table 1. Descriptive statistics

	Age	N	N_{MZ}	N_{DZ}	r_{SES}
IQ	7.16	550	220	330	.29
Reading					
	8.21	528	210	318	.21
	9.81	526	188	338	.22
	10.90	473	173	300	.21
	12.21	464	174	290	.27
	15.05	222	91	131	.29
Math					
	8.57	280	106	174	.21
	9.81	520	187	333	.25
	10.90	482	176	306	.26
	12.25	486	186	300	.24
	15.05	314	130	184	.31

Figure 2. Stacked A, C, and E variance by SES plots for reading, math, and IQ across development



a: age corresponding to reading measure; b: age corresponding to math measure

Table 2. Path coefficients of the continuous-moderator model

		a	β_a	c	β_c	e	β_e	β_M
IQ	Age	.69 (.07)	.05 (.11)	.51 (.11)	-.10 (.17)	.49 (.02)	-.03 (.03)	.25 (.04)
Reading	7.16							
	8.21	.80 (.04)	.08 (.08)	.12 (.16)	-.47 (.08)	-.05 (.025)	-.05 (.03)	.39 (.05)
	9.81	.89 (.03)	-.08 (.05)	-.11 (.11)	-.29 (.09)	.39 (.02)	-.03 (.02)	.23 (.05)
	10.90	.84 (.04)	-.11 (.05)	.15 (.12)	.38 (.09)	.39 (.02)	.03 (.02)	.28 (.05)
	12.21	.82 (.04)	-.05 (.06)	.06 (.12)	.40 (.08)	.42 (.02)	.03 (.03)	.29 (.05)
	15.05	.81 (.08)	-.17 (.09)	.33 (.20)	.30 (.15)	.41 (.03)	.01 (.05)	.33 (.07)
Math								
	8.57	.39 (.14)	.18 (.13)	.71 (.08)	-.16 (.10)	.52 (.04)	.00 (.04)	.27 (.06)
	9.81	.62 (.05)	.02 (.09)	.64 (.06)	-.01 (.10)	.38 (.02)	.005 (.02)	.30 (.05)
	10.90	.61 (.09)	.20 (.10)	.44 (.17)	-.41 (.17)	.42 (.03)	.03 (.04)	.27 (.05)
	12.25	.63 (.06)	-.05 (.08)	.59 (.07)	.13 (.09)	.42 (.02)	.01 (.03)	.30 (.05)
	15.05	.63 (.06)	-.17 (.07)	.54 (.08)	.21 (.08)	.34 (.02)	-.04 (.03)	.36 (.05)

CONCLUSIONS

Analysis of both reading and math provide evidence for developmental changes in the effects of moderation on achievement outcomes. Between ages 8.2 and 9.8, the effects of genetics on reading shift from being more highly influential at the highest end of SES (consistent with the IQ literature) to being more influential at the low end of SES. In math, the shift of higher influence of genetics at the lower end of SES does not appear until age 15.

The difference in trajectories of moderation may be due to the difference in timing of the acquisition of fundamental skills in each subject. Resources allotted to the highest end of SES are most influential on genetic expression during the phases of acquisition (before age 9.8 in reading and before age 15 in math). Most children are fluent readers with adequate reading comprehension by age 10, at which time genetic influences are more pronounced in the lowest end of SES. Acquisition of basic skills in math are witnessed later than in reading. A major shift in mathematical cognition begins occurring between ages 7 and 8, when children can accurately map numbers onto space (e.g., number line). Almost all children have fully mastered this skill by age 15, at which time genetics are influencing expression at the low end.

The GxSES effect for IQ did not reach significance in the present sample, perhaps due to issues of power, but the results contrast with the achievement results which, aside from early ages of achievement, showed the opposite trends expected from the literature exploring general cognitive ability.

Results suggest that during stages of acquisition the trends are characterized by the bioecological model (predicting higher heritability at the high end of SES), but after almost all children have reached mastery, the diathesis-stress model (predicting higher heritability at the low end of SES) seems more appropriate. Thus, the mixed literature on moderation of achievement may be due to developmental changes, as studies of children below mastery levels have been mostly consistent with the bioecological model.

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