Behav Genet (2015) 45:635–639
DOI 10.1007/s10519-015-9760-4

ORIGINAL RESEARCH

The Scarr-Rowe Interaction in Complete Seven-Year WISC Data from the Louisville Twin Study: Preliminary Report

Eric Turkheimer[1] · Christopher E. Beam[2] · Deborah W. Davis[3]

Received: 3 August 2015 / Accepted: 7 October 2015 / Published online: 26 October 2015

Abstract We examine updated Wechsler IQ data in 7-year old twins from the Louisville Twin Study for evidence of an interaction between the heritability of IQ and socioeconomic status. Data records that had never been entered were recovered, allowing us to increase previously reported sample sizes by more than 20 %. Twin families were assigned socioeconomic status scores using a Hollingshead index based on parental education and occupation. A structural equation model in which genetic and environmental variances were modeled as squared linear functions of SES provided ambiguous replication of earlier findings from the National Collaborative Perinatal Project: relations between SES and heritability for performance and full scale IQ were in the same direction as the previous report, but at $p < 0.07$. As was the case in Turkheimer et al. (Psychol Sci 14(6):623–628, 2003), no interaction was found for VIQ. These results cannot yet be taken as a definitive replication of Turkheimer et al. (Psychol Sci 14(6):623–628, 2003). Many more measurement occasions, subtests and environmental moderators remain to be analyzed.

Keywords GE interaction · Wechsler intelligence scale for children · Socioeconomic status

✉ Eric Turkheimer
ent3c@virginia.edu

[1] Department of Psychology, University of Virginia, PO Box 400400, Charlottesville, VA 22904-4400, USA

[2] University of Southern California, Los Angeles, USA

[3] University of Louisville, Louisville, USA

Introduction

The Scarr-Rowe hypothesis refers to the possibility that the heritability of cognitive ability is attenuated in relatively poor environments. First observed by Sandra Scarr in a sample of twins from the Philadelphia school system in 1971 (Scarr-Salapatek 1971), the finding was replicated in Sweden by Fischbein (1980), and then in the United States by Rowe et al. (1999). Turkheimer et al. (2003) conducted an analysis of 7-year old twins from the National Collaborative Perinatal Project, finding heritabilities near zero in the poorest families, and shared environmental components near zero among the twins with higher socioeconomic status. The Scarr-Rowe hypothesis has been confirmed in several American twin samples since then (Tucker-Drob et al. 2011; Bates et al. 2013; Kirkpatrick et al. 2015) but has failed to replicate in others (Grant et al. 2010). The interaction has not been observed in European samples in the Netherlands (van der Sluis et al. 2008; Bates et al. 2013) or Great Britain (Asbury et al. 2005). A more comprehensive analysis of the British sample, however, suggested declining shared environmental effects at higher levels of socioeconomic status (Hanscombe et al. 2012), which is consistent with the Scarr-Rowe hypothesis. A fairly recent narrative review of this literature can be found in Turkheimer and Horn (2014). An in press meta-analysis confirms the geographic pattern: reliable interactions in the United States, not in Europe (Tucker-Drob and Bates 2014).

The Louisville Twin Study was conducted between 1957 and 2002. Twins were recruited from Board of Health records in the Louisville area. Efforts were made to recruit twins who were "representative as possible," with 27 % of the twin families recruited from the lowest two deciles of the occupational status scale (Wilson 1983). Approximately 1700 twins from the Louisville area were enrolled in the study, then followed intensively between birth and 15 years of age. Ability scores were obtained at 16 occasions between a three-month Infant Bayley exam and WISC scores obtained at age fifteen. Many classic studies of the genetic and environmental components of development of individual differences in cognitive ability were conducted using the LTS (e.g., Wilson 1983).

When the LTS was discontinued in 2003, a large amount of data had been collected but not yet recorded. These data have sat unused ever since. We have initiated a project to recover these lost data and rebuild the LTS, with a long-range goal of making it available for analysis by the scientific community. In this preliminary report, we use the newly restored dataset of Wechsler Intelligence Scale for Children (WISC) scores collected at age seven to attempt the closest possible replication of the Scarr-Rowe interaction for seven-year Wechsler IQ as reported in Turkheimer et al. (2003). Results from of ability tests from infancy (Bayley Scales of Infant Development) and early school years (Wechsler Preschool and Primary School Scales of Intelligence), as well as integration of twin data with ability data from siblings and parents, will be reserved for a future report.

Method

Participants

The sample consisted of 472 pairs of twins who were tested with one of three forms of the WISC at 7 years of age. Zygosity was determined by blood sera analysis. The sample included 234 MZ (41 % female) and 238 DZ pairs (26 % male–male, 32 % female–female, 42 % opposite sex). Participants were 89 % White, 10 % Black, and the remainder other or unknown.

Measures

Three different versions of the Wechsler Intelligence Scale for Children were administered during the course of the study. Two hundred and twenty-two participants took the WISC, 532 took the WISC-R and 190 took the WISC-III. Full-scale IQ (FSIQ), Verbal IQ (VIQ), Performance IQ (PIQ) and eleven subtests of the WISC were included in the analysis. Socioeconomic status was determined using the Hollingshead Scale from 0 to 100, based on parental education and occupation at time of registration in the study.

Procedure

Data were analyzed using the structural equation modeling program Mplus 7.3 (Muthen and Muthen 1998–2015). For descriptive purposes we estimated MZ and DZ twin correlations in the full sample and in subsamples split at the midpoint (50) of the SES scale. We then fit an interaction model in which the magnitude of the A, C and E variance components were modeled as a squared-linear function of SES. In the interaction models we removed the linear effects of SES from the outcomes, as recommended by Purcell (2002).

For each outcome we modeled the A, C and E variances as squared-linear functions of SES. SES was centered on 50, and scaled so that one unit was equal to its approximate standard deviation of 25. So, for each outcome, we fit a simple twin model:

$$\mathrm{var}(IQ) = A + C + E$$

$$\mathrm{cov}(MZ) = A + C$$

$$\mathrm{cov}(DZ) = \frac{1}{2}A + C$$

In a twin interaction model, however, the A, C and E variance components are random variables drawn from a distribution that can be modeled as a squared linear function of SES. For A, for example, the variance for the *ith* participant is modeled as,

$$\mathrm{A_i} = (\mathrm{b_0} + \mathrm{b_1} \times \mathrm{SES})^2.$$

The model thus estimates an ACE variance as at the midpoint (0) of SES, which then varies quadratically as SES deviates from the midpoint. As in Turkheimer et al. (2003) we tested the individual interaction terms for significance, and also tested the hypothesis that all three interaction terms for A, C and E were equal to 1.0, with three degrees of freedom.

Results

Descriptive statistics are given in Table 1 for the IQ scores and SES. IQ scores ranged from 46 to 143, with typical standard deviations close to fifteen. SES had a mean of 47 and a standard deviation of 26. The IQ scores were roughly normally distributed, as illustrated in Fig. 1. SES was more rectangularly distributed. Parental SES was correlated 0.39, 0.39 and 0.29 with FSIQ, VIQ and PIQ, respectively. The relationship between FSIQ and SES is illustrated in Fig. 2.

Table 1 Descriptive statistics for IQ tests and SES

	Mean	SD	Min	Max	r_{SES}
VIQ	96.11	14.83	46	143	0.39
PIQ	101.10	14.09	52	141	0.29
FSIQ	98.26	14.05	52	135	0.39
SES	47.04	26.90	1	96	–

Mother's education ranged from 7 to 20 years, with a mean of 13.2 years (SD = 2.4). Father's education ranged from 6 to 20 years, with a mean of 13.6 (SD = 3.0). FSIQ was correlated 0.37 with mother's education and 0.39 with father's education; mother's and father's education were correlated 0.72 with each other.

MZ and DZ twin correlations for the IQ measures are given in Table 2. MZ twins were more correlated than DZ twins for all IQ scores. Table 2 also gives the results MZ and DZ twin correlations for pairs reared in homes above and below the SES median.

Table 3 shows the results of the interaction analyses. The columns of Table 3 labeled A_0, C_0 and E_0 list the standard deviations of A, C and E at the midpoint (50) of the SES scale. The columns labeled A_1, C_1 and E_1 show the squared-linear interaction parameter corresponding to approximately one SD of the SES scale. So, for example, the C_0 column for FSIQ shows that the C variance was estimated as $5.20^2 = 27.04$ at an SES of 50. The interaction parameter of -1.36 means that at an SES of 75 the C variance would be predicted to be $(5.20\text{-}1.36)^2 = 15.52$. The rightmost column of Table 3 shows the Wald Chi square with 3 df testing the hypothesis that all three interaction parameters are equal to 1.0. Parameters significant at $p < 0.05$ are shaded. Although none of the individual interaction parameters or the Wald Chi squares reached $p < 0.05$, all interactions were in the same direction as reported in Turkheimer et al. (2003), and two of the three Chi squares were less than $p = 0.10$.

The interactions for the three IQ scores are illustrated in Fig. 3. The figures are in the form of "stacked" variance plots, with the modeled A, C and E variances accumulated on top of each other. The top line of each graph represents the model of the full phenotypic variance as a function of SES. Similar results were obtained using maternal or paternal education in place of SES, or by using exponential modifier functions in place of squared-linear.

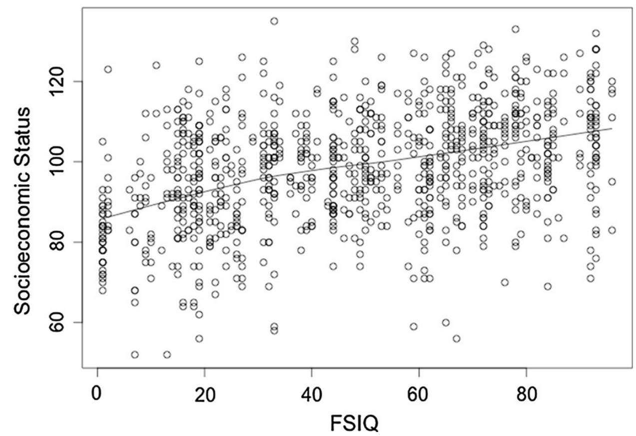

Fig. 2 Scatter plot of socioeconomic status and 7-year WISC scores

Table 2 Twin correlations for full sample, and above and below median of SES

Test	rMZ	rDZ	SES			
			Low		High	
			rMZ	rDZ	rMZ	rDZ
FSIQ	0.83	0.62	0.83	0.57	0.78	0.52
VIQ	0.79	0.64	0.71	0.57	0.76	0.56
PIQ	0.75	0.45	0.80	0.48	0.64	0.36

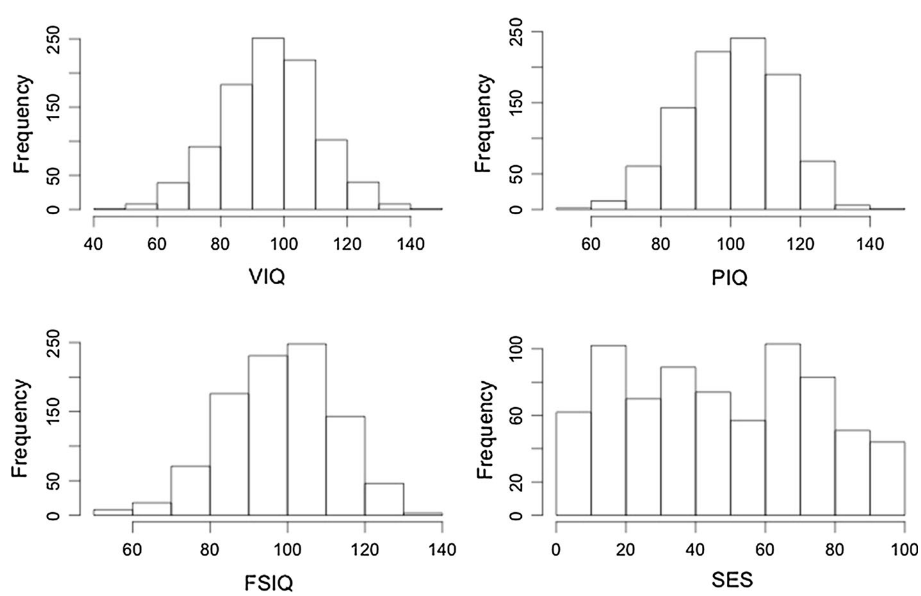

Fig. 1 Histograms of VIQ, PIQ, FSIQ and socioeconomic status

Table 3 Results of moderated ACE modeling

Test	A_0	A_1	C_0	C_1	E_0	E_1	χ^2 (3)
VIQ	**9.76 (0.96)**	0.18 (0.94)	**7.21 (1.30)**	−0.71 (1.25)	**6.40 (0.17)**	0.17 (0.33)	0.94
PIQ	**11.21 (0.64)**	−0.03 (0.64)	2.41 (2.91)	−2.60 (1.87)	**6.65 (0.31)**	**0.60 (0.28)**	7.19
FSIQ	**10.60 (1.38)**	0.31 (1.44)	5.20 (3.97)	−1.36 (4.04)	**5.35 (0.28)**	**0.61 (0.27)**	7.18

Parameters in bold are $p < 0.05$

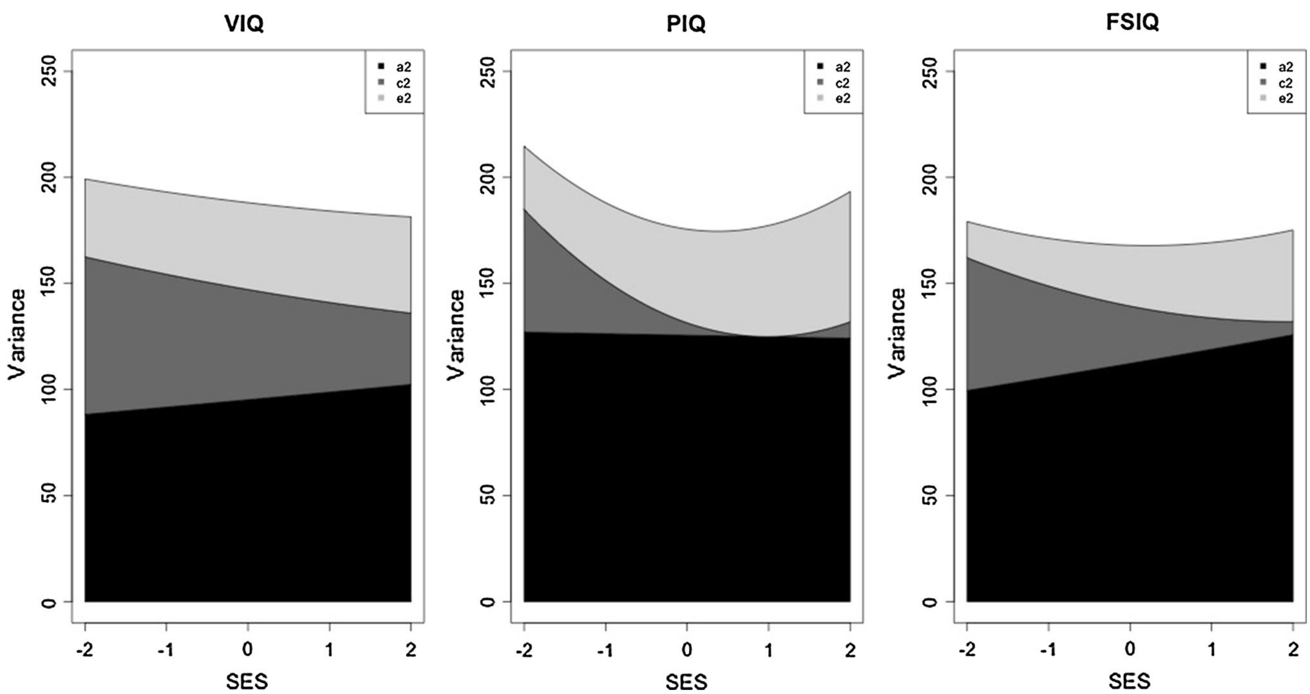

Fig. 3 Stacked variance plots showing A, C and E variances as an exponential-linear function of socioeconomic status for VIQ, PIQ and FSIQ

Discussion

At a descriptive level, the results are quite similar to those reported in Turkheimer et al. 2003. In Turkheimer et al. (2003), significant results were obtained for PIQ and FSIQ but not VIQ, with A variance increasing and C variance decreasing with increasing SES. In the current study the same pattern of results obtained, although all results were somewhat weaker and none achieved statistical significance at $p < 0.05$. The stacked variance plots in Fig. 2 reproduce the results reported in Turkheimer et al. (2003) quite closely.

Nevertheless, the results of the current investigation should be regarded as preliminary and mixed, pending further analyses of other tests and ages, more detailed environmental measures and application of more comprehensive multivariate models. To address head-on one particularly troublesome issue, in a conference presentation our group reported completely negative results based on absolute differences between members of twin pairs (Turkheimer et al. 2015). The absolute pair difference method employed in that analysis was clearly inadequate, and fails to detect the modeled results we have reported here.

In any event, many questions about the Scarr-Rowe interaction remain unanswered. Stronger interactions for PIQ relative to VIQ have been reported in both the National Collaborative Perinatal Project and the Louisville Twin Study, but other reports have not been based on Wechsler scales in a way that would allow the pattern to be replicated by independent researchers. It is also not known what characteristics of the socioeconomic environment are responsible for the interaction when it does occur. SES and parental education have been used more or less interchangeably in prior analyses, and they produce similar (suggestive, consistent, and non-significant) results in these data. Whatever it is about the family or cultural environment that suppresses heritability in lower class families, it appears to be a factor that is more widely operative in the United States as opposed to Europe. Unequal access to education in the United States would appear to be a plausible explanation for the difference, but remains speculation awaiting detailed analysis.

Most important, of course, is understanding the developmental processes that cause the interaction to occur at all. We and others have hypothesized that the mechanism is related to the best-known modifier of the heritability of intelligence, which is age. As twins grow through childhood and early adolescence the heritability of intelligence increases sharply. This appears to be largely the result of decreases in the similarity of DZ twins (Turkheimer and Horn 2014). One possibility is that increasing dissimilarity in DZ twin pairs is the result of accumulating within-pair gene-environment correlation, as twins demonstrating relatively greater ability are systematically exposed to superior environments relevant to their co-twin (Beam and Turkheimer 2013; Dolan et al. 2014). In twin pairs raised in deprived circumstances such processes would not be able to occur because there are no enhanced environments into which relatively talented twins can select. The newly renovated data from the Louisville Twin Study should be an ideal platform for the study of processes such as these.

Acknowledgments This work was supported by grants 1R03 AG048850-01, T32AG020500, T32AG000037-37, F31AG044047-01A1 from the National Institute of Aging.

Compliance with Ethical Standards

Conflict of Interest Eric Turkheimer, Christopher E. Beam and Deborah W. Davis declare that they have no conflict of interest.

Human and Animal Rights and Informed Consent The secondary data analysis reported here was approved by the Institutional Review Board for the Social and Behavioral Sciences at the University of Virginia. All procedures followed in the secondary data analysis reported here were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2000 (5). Informed consent was obtained from all patients for being included in the study.

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