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Does Genetic Variance for Cognitive Abilities Account for Genetic Variance in Educational Achievement and Occupational Status? A Study of Twins Reared Apart and Twins Reared Together

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ABSTRACT: Studies of brothers and twins have shown that about 50 per cent of the variance in educational achievement and 40 per cent of the variance in occupational status reflects between-family variance. About half of the between-family variance for educational achievement and even more for occupational status is due to genetic effects and the remainder is due to sharing the same environment. With data on 35 pairs of male twins reared apart and 56 pairs reared together we investigated the extent to which genetic variance in SES can be attributed to genetic variance for cognitive abilities. For both educational achievement and occupational status there was significant genetic variance both in common with and independent of genetic variance for cognitive abilities. Thus, there are genetic effects contributing to familial similarity for SES that are not the same as those of importance for cognitive abilities. Candidate traits that may account for this remaining genetic variance in SES are personality, interests, or talents not represented in standard cognitive tests.

An interesting result from large sibling studies of socioeconomic status (SES) is that about half of the variance in educational achievement and occupational status is of between-family origin, that is, it contributes to similarity among siblings in the same family (Hauser and Featherman, 1976; Olneck, 1977; Hauser and Sewell, 1986). However, only a portion of this between-family variance in SES is explained by measures of socioeconomic background such as the occupational and educational status of fathers. Thus, there is an excess in sibling similarity (or brother similarity, which is what has been analyzed) that is not accounted for by socioeconomic status of the parents.

Several studies have shown that at least part of this excess in sibling similarity can be explained by genetic effects for SES (Behrman et al., 1980; Lichtenstein et al., 1992; Tambs et al., 1989; Teasdale and Sørensen, 1983; Scarr and Weinberg, 1994). Table 1 displays the results from some of the most relevant studies on brother resemblance for educational achievement and occupational status. As can be seen, there is considerable congruence among studies of non-twin siblings and twins in estimates of total variation attributable to between-family variance. In spite of the differences in samples with regard to countries, age groups, and measures, about 50 per cent of the variance in educational achievement and about 40 per cent of the variance in occupational status is due to between-family variation and thus contributes to sibling (familial) similarity.

TABLE 1

BETWEEN- AND WITHIN-FAMILY VARIANCE IN EDUCATIONAL ACHIEVEMENT AND OCCUPATIONAL STATUS IN MAJOR STUDIES OF BROTHERS

			Educational Achievement		Occupational Status	
Studies	Number of Pairs	Type of Siblings	Between-Family Variance	Within-Family Variance	Between-Family Variance	Within-Family Variance
Hauser and Featherman (1976)[a]	15,817	brothers	56%[h]	44%	...	...
Olneck (1977)[b]	346	brothers	55%	45%	31%	69%
Hauser and Sewell (1986)[c]	928	brothers	46%[i]	54%	38%[i]	62%
Erikson (1987)[d]	2,208	brothers	47%[h]	53%	41%[h]	59%
Heath et al. (1985)[e]	1,447	twins reared together	56%[h,i,j]	44%	...	...
% due to genetic effects	...	...	(55%)	...	...	...
% due to shared environmental effects	...	...	(45%)	...	...	...
Tambs et al. (1989)[f]	1,078	twins reared together	48%[h,j]	52%	28%[h,j]	72%
% due to genetic effects)	...	...	48%	...	75%	...
% due to shared environmental effects	...	...	52%	...	25%	...
Lichtenstein et al. (1992)[g]	148	twins reared apart	38%[j]	62%	39%[j]	61%
% due to genetic effects	...	...	45%	...	77%	...
% due to shared environmental effects	...	...	55%	...	23%	...

[a]Data from the Occupational Changes in Generations (OCG) study.
[b]Data from the Kalamazoo Brothers Study.
[c]Data from Wisconsin Longitudinal Study.
[d]Data are for brothers in the Level of Living Survey in Sweden.
[e]Data for men from the Norwegian Twin Registry.
[f]Data from a record linkage between the Norwegian Twin Registry and the Army files.
[g]Data for men <60 years in the Swedish Adoption/Twin Study of Aging (SATSA).
[h]Data pooled over age-groups.
[i]Data adjusted for reliability.
[j]Computed as the variance due to shared environment plus half of the genetic variance.

The twin studies have the advantage of being able to decompose the between-family variance into genetic and shared environmental variance.[1] As Table 1 reveals, about half of this similarity in educational achievement is due to genetic factors and about half is due to sharing the same environments. For occupational status, genetic effects seem to be more important than shared rearing environments for between-family variation.[2]

It has been suggested that genetic variation for educational achievement and occupational status can be explained, at least in part, by genetic differences in cognitive abilities (e.g., Herrnstein and Murray, 1994; Scarr, 1995). Most researchers now accept that cognitive abilities are heritable (Snyderman and Rothman, 1987). However, the degree to which genetic variation in SES is in common with genetic variation in cognitive abilities is not well documented and is crucial for any conclusion concerning the importance of genetic effects for cognitive abilities for predicting success in life. In a Norwegian twin sample, Tambs and coworkers investigated the covariation structure of occupational status, educational achievement, and cognitive abilities. They found that a common genetic factor was responsible for covariation in the measures, but that there was substantial genetic variation for both occupational status and cognitive abilities independent of genetic variation for the other measures (Tambs et al., 1989). Although not conclusive, this study suggests that there is unique genetic variation for occupational status as well as genetic variation in common with cognitive abilities and educational achivement.

The present study will extend earlier work investigating the origins of variation in SES measures using the powerful method of twins reared apart. More specifically, this paper will explore whether genetic variation in educational achievement and occupational status is in common with the genetic variation in cognitive abilities or whether the genetic influences are unique to the socioeconomic measures and thus independent of genetic influences for cognitive abilities.

MATERIALS AND METHODS

SAMPLE

This study is part of the ongoing Swedish Adoption/Twin Study of Aging (SATSA) which is based on a sample of

[1]Studies of twins have estimated that about 50 per cent of the variance in educational achievement and 60 per cent of the variance in occupational status are due to genetic effects (G), while shared environments (S) account for about 25 per cent of the variance for educational achievement and 10 per cent in occupational status. It is important to remember when studying ordinary familial relationships, such as those between fathers and sons or siblings, that genetic effects contribute to both familial similarity and differences. Siblings as well as parents and their offspring share, on average, 50 per cent of their genes. Hence, even if a phenotype was totally due to genetic effects, the siblings would only be correlated 0.50. First degree relatives share 50 per cent of their genes and the shared environment. Hence, the correlation between first degree relatives reflects both genetic similarity (degree of relatedness times genetic influence for a trait) plus shared environmental influences. The similarity for ordinary first degree relatives would therefore be computed as $0.5*G + S$. Thus, about 50 per cent of the variance in educational achievement $[(0.5*0.50) + 0.25]$ and 40 per cent $[(0.5*0.60) + 0.10]$ of the variance in occupational status contribute to resemblance between first degree relatives.

[2]Similar findings were found in a study of adult adoptees where the estimate of the genetic effects was 44 per cent (the intraclass correlation for siblings reared apart was 0.22) and the estimate of the shared environmental effects was 13 per cent (correlation for unrelated siblings reared together was 0.13). However, this study includes both men and women and is therefore not included in Table 1 (Teasdale and Owen, 1981).

591 pairs of twins reared apart and 627 twin pairs reared together identified in the population-based Swedish Twin Registry (for details about the Twin Registry, see Cederlöf and Lorich, 1978). The average age of separation was 2.8 years; 48 per cent were separated before their first birthday and 82 per cent before their fifth. The main reasons for separation were illness or death of one or both parents or economic problems. The twins reared together were matched to the separated twins on the basis of age, gender, and county of birth. The procedure for identifying the reared apart twins and the evidence for comparability of this sample with the entire Twin Registry are described in Pedersen et al., (1984).

The SATSA study began in 1984 with a two-part mailout questionnaire. The first part (Q1a) included items concerning education. Responses were received from both members of 758 twin pairs. The second part (Q1b) was mailed directly after receipt of part one and included questions about occupational status. Further, an extensive cognitive test battery was administered to a subsample of the SATSA twins in which both twins in the pair responded to Q1a (Pedersen et al., 1991).

For the present purpose, data from male twin pairs only were considered for analyses. The reason for this is partly because the previous literature almost exclusively deals with men and partly because there is a lack of variability in SES measures for women in these age groups. One hundred sixty-seven pairs of male twins pairs participated in the cognitive testing session. Because the analyses of twin data require that both twins in a pair have information on all three measures, a listwise deletion of pairs with missing data resulted in a final sample of 91 twin pairs for the present analyses. The majority of pairs were deleted due to missing occupational information or because of exclusion due to the occupational scaling procedure (see below). The rearing and zygosity status of the pairs included in the present analyses are shown in Table 2. The average age of the men was 52.6 years at the time of mailout, ranging from 27 to 80 years.

Zygosity diagnoses (identical and fraternal) were made by comparing serum proteins and red cell enzymes. This procedure gives a 99 per cent probability of correct diagnosis (Pedersen et al., 1991).

MEASURES

Education achivement.—In Q1a the respondents were asked to report all types of education they had received. The answers were coded into four categories according to the highest level achieved: (1) elementary school, (2) secondary school or vocational school, (3) junior college, and (4) university (Lichtenstein et al., 1992).

Occupational status.—Two questions concerning occupation were included in the Q1b questionnaire: occupation during greatest part of the respondent's working life and respondent's current occupation. Occupation was measured with the SEI scale (Swedish abbreviation for socioeconomic classification), a standard Swedish scale that was developed by Statistics Sweden (1983). Four categories were generated which have been ranked in the order: (1) unskilled and semiskilled workers, (2) skilled workers and assistant nonmanual employees, (3) intermediate nonmanual employees, and (4) employed and self-employed professionals, higher civil servants, and executives (Lichtenstein et al., 1992).

The SATSA sample is comprised of older people with many of the participants

TABLE 2

ZYGOSITY AND REARING STATUS FOR THE TWIN PARTICIPATING IN THIS STUDY

Twin	Reared apart	Reared together
Identical twin pairs	14	28
Fraternal twin pairs	21	28

already retired. Hence, in this study the response to the question about principal occupation during adulthood was used. If this item was left blank, the description of the current occupation was used instead. In order to obtain a more unidimensional scale, farm workers and self-employed nonprofessional persons (including farmers) were excluded (cf. Domanski and Sawinski, 1987). This exclusion reduced the number of pairs where both answered the item concerning their own occupations from 167 to 97 and resulted in a loss of power. Perhaps a more important limitation is that only the portion of the population that was gainfully employed by others was investigated.

General cognitive abilities.—The cognitive battery was comprised of 13 tests selected to provide representation both of the domains of fluid and crystallized intelligence (Horn, 1982) and of specific cognitive abilities (Nesselroade et al., 1988). Individuals' scores on the first principal component of the 13 tests were obtained and used as the measure of general cognitive ability (Pedersen et al., 1992).

Both occupational status and educational achievement are positively skewed variables with many individuals in the lower categories. For use in the model-fitting analyses, logarithmic transformations of the scales were performed. Because age can inflate twin correlations, scores were corrected by residualizing out the age effect from the scales (McGue and Bouchard, 1984).

ANALYSES

Univariate and multivariate model-fitting of the data from four different twin/adoption groups simultaneously were used to explore the etiology of the relationship between SES and cognitive abilities. The path diagram in Figure 1 specifies how each type of environmental and genetic factor contributes to the within pair covariance for a measure in the adoption/twin design, using education as an example (Neale and Cardon, 1992). The genetic and environmental factors are not measured directly and are referred to as latent factors.

Identicial twins share all their genes while dizygotic twins share, on average, 50 per cent of their segregating genes with additive effects. This is represented in Figure 1 by the correlation of 1.0 between the genetic factors (*G*) for the identical twins and a correlation of 0.5 for the fraternal twins. Rearing environmental effects (*Er*) refer to influences that create similarities among twins reared together. Therefore, the model specifies that the correlation between the *Er* factors is 1.0 for twins reared together and 0 for twins reared apart. Shared environmental experiences that are not exclusively due to the rearing home (e.g., adult contact with cotwin or shared perinatal or postnatal environment) but which also contribute to twin resemblance are called correlated environments (*Ec*). These effects may contribute to similarity in all twins regardless of rearing status and are represented in Figure 1 by the same latent factor for both twins in a pair.[3] Finally, there are *environmental effects unique to individuals* that make members of twin pairs in all rearing and zygosity groups different from each other (nonshared environmental effects, *En*), depicted by a lack of correlation between the *En* factors for the two twins in a pair in Figure 1. Nonshared environmental effects thus refer to experiences that are unique to only one of the twins in a pair.

Figure 2 is the Cholesky model used in order to explore how environmental and genetic factors contribute to the *covariation* between SES and cognitive abiliteis (Neale and Cardon, 1992). The model decomposes the variance in occupational status into variance in common to all three variables (G_a, En_a, Er_a, and Ec_a), variance in common with educational achievement (G_b, En_b, Er_b, Ec_b), and finally variance unique to occupational status (G_c, En_c, Er_c, Ec_c). For the bivariate analyses a similar model was used, with the difference that only two variables were included in the model.

The data for each twin pair were summarized in variance-covariance matrices for monozygotic twins reared apart, monozygotic twins reared together, dizygotic twins reared apart, and dyzygotic twins reared together. The LISREL VII program (Jöreskog and Sörbom, 1989) was then used to obtain maximum-likelihood estimates of the different parameters.

[3]Correlated environmental effects are not distinguishable from another type of environmental effect referred to in the adoption literature as selective placement. Resemblance of adopted-apart twins may arise, in part, from similarities in their rearing homes, as would be the case, for example, if members of reared-apart twin pairs were adopted into families with similar socioeconomic statuses.

RESULTS

Table 3 presents the phenotypic correlations between the variables studied. The correlations between all of the measures are substantial and significant at the 0.05 level.

UNIVARIATE ANALYSES

Table 4 gives the parameter estimates, standard errors, and per cent of variance explained by genetic and environmental effects for cognitive abilities and the two socioeconomic measures. These estimates are generally in agreement with earlier reports from the SATSA study, where slightly different samples have been used (Lichtenstein et al., 1992; Pedersen et al., 19920. The only difference is that genetic effects for educational achievement are estimated to be more important in this sample and that the correlated environmental effects are less important. However, rearing environmental effects continue to be important for educational achievement.

Because there is no evidence for correlated environmental effects in any of the measures, these parameters were not included in the models in the multivariate analyses.

MULTIVARIATE ANALYSES

Educational achievement.—The parameter estimates and standard errors for the bivariate model with educational achievement and cognitive abilities are presented in Table 5. The model fits the data ($\chi^2_{(33)} = 35.06$; $p = 0.37$).

As can be seen in Table 5, genetic effects contribute to the association between

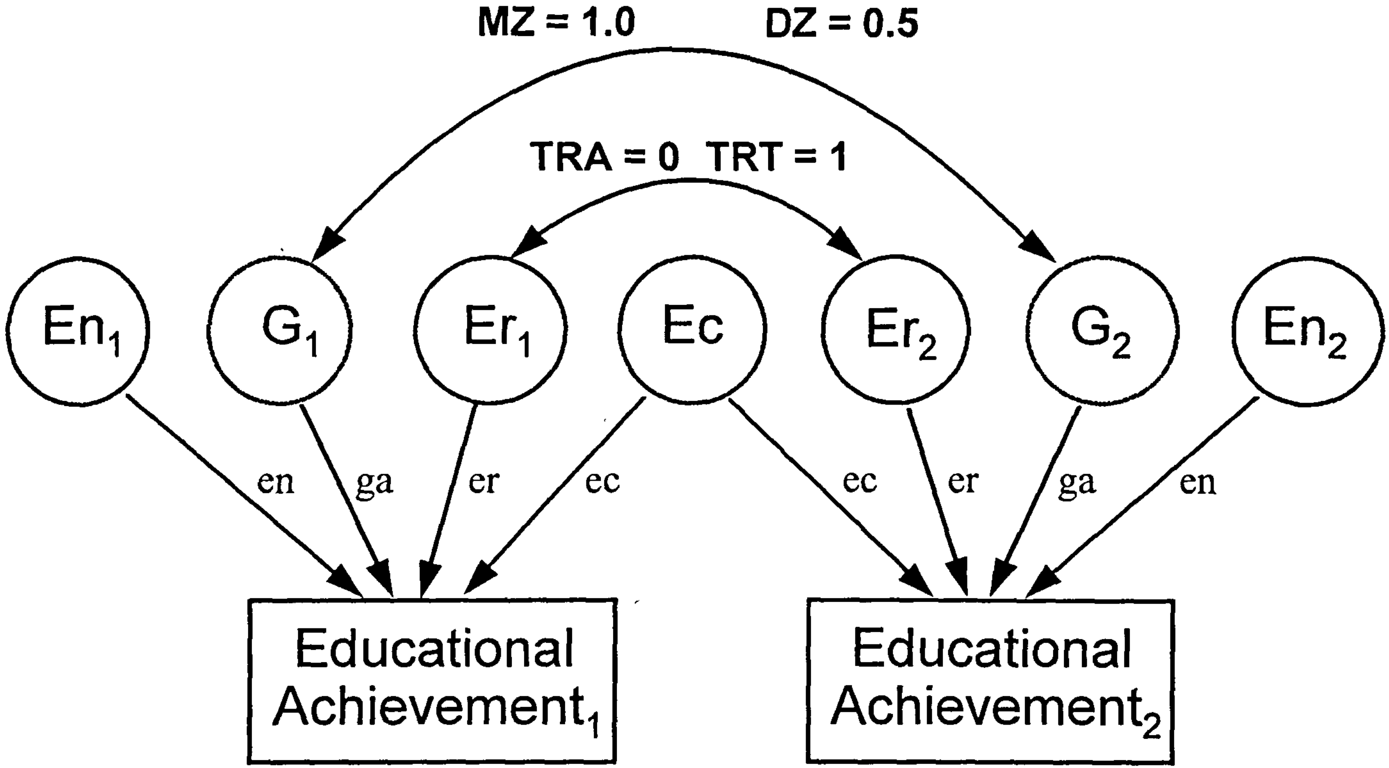

FIG. 1.—Path diagram depicting how twin similarity is modeled for genetic and environmental effects. (*Note:* G = genetic factor; g = genetic loading; En = nonshared environmental factor; en = nonshared environmental loading; Er = shared rearing environmental factor; er = shared rearing environmental loading; Ec = correlated environmental factor; ec = correlated environmental loading; MZ = monozygotic twins; DZ = dizygotic twins; TRT = twins reared together; TRA = twins reared apart.)

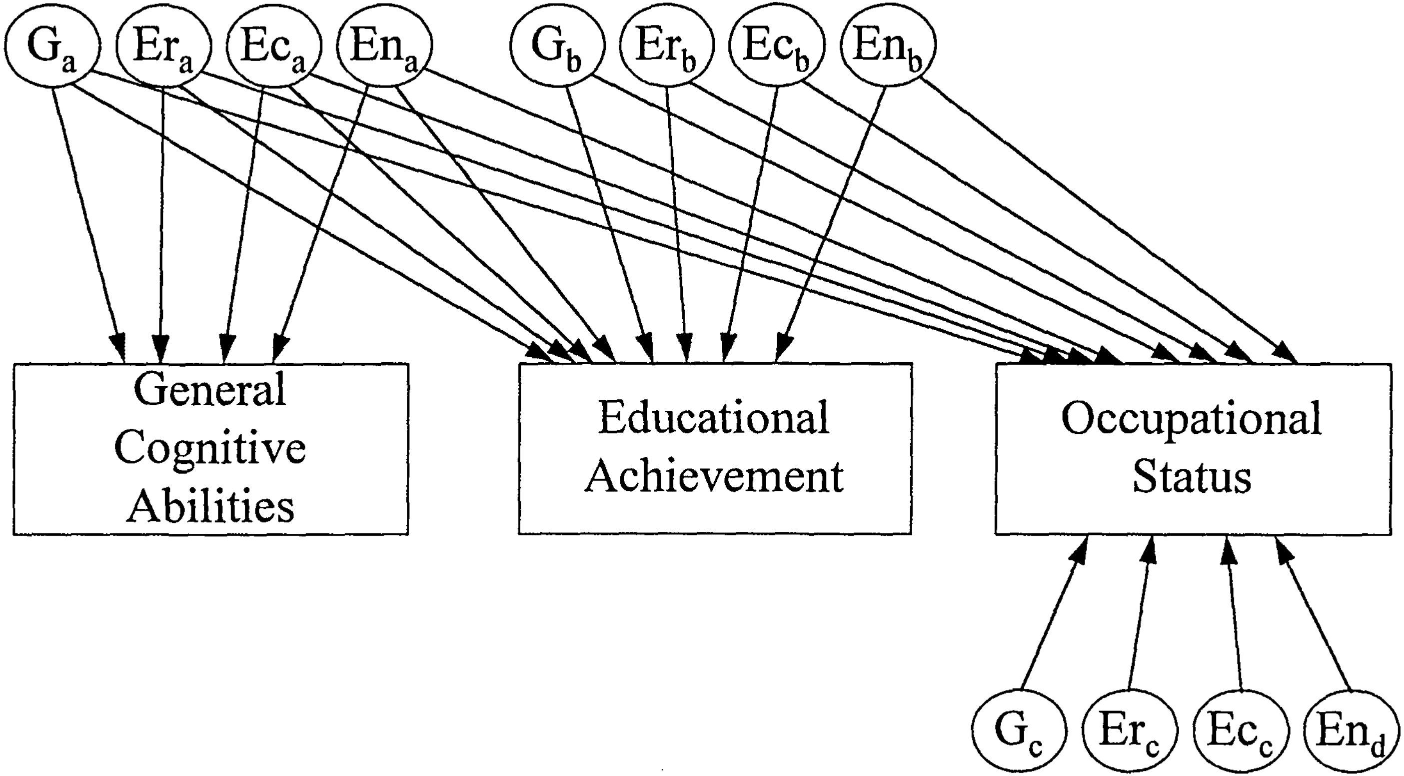

FIG. 2.—Path model depicting common and unique factors for genetic and environmental sources of variance and covariance for general cognitive abilities, educational achievement, and occupational status. (*Note:* The figure is simplified, and contains only one of the twins in the pair. G = genetic factors; g = genetic loadings; En = nonshared environmental factors; en = nonshared environmental loadings; Er = shared rearing environmental factors; er = shared rearing environmental loadings; Ec = correlated environmental factors; ec = correlated environmental loadings.)

TABLE 3

PHENOTYPIC CORRELATIONS AMONG OCCUPATIONAL STATUS, EDUCATIONAL ACHIEVEMENT, AND GENERAL COGNITIVE ABILITY[a]

Variables	Educational Achievement	General Cognitive Ability
Occupational status	0.57	0.56
Educational achievement	. . .	0.43

[a]With N = 176, all correlations are significant at the 0.05 level.

TABLE 4

UNIVARIATE MODEL-FITTING ANALYSES FOR GENERAL COGNITIVE ABILITIES, EDUCATIONAL ACHIEVEMENT, AND OCCUPATIONAL STATUS[a]

	Per Cent of Variance Parmeter Estimate ± Standard Error				Fit of Model		
VARIABLES	G	En	Er	Ec	df	X^2	p
General cognitive abilities	83 0.80±0.06	17 0.36±0.04	*	*	8	7.31	0.50
Educational achievement	58 0.39±0.06	30 0.28±0.03	13 0.18±0.10	*	8	5.31	0.72
Occupational status	61 0.38±0.05	28 0.26±0.03	11 0.16±0.10	*	8	4.19	0.84

[a]G = genetic variance; En = nonshared environmental variance; Er = rearing environmental variance; Ec = correlated environmental variance; * = parameter not identified

TABLE 5

MAXIMUM LIKELIHOOD MODEL-FITTING PARAMETER ESTIMATES (P.E.), STANDARD ERRORS (S.E.), AND PER CENT OF VARIANCE FROM THE BIVARIATE ANALYSES OF GENERAL COGNITIVE ABILITIES AND EDUCATIONAL ACHIEVEMENT[a]

	GENERAL COGNITIVE ABILITY		EDUATIONAL ACHIEVEMENT		
FACTOR LOADINGS	P.E.	S.E.	P.E.	S.E.	PER CENT OF VARIANCE
Common factor loadings					
Genetic	0.81[b]	0.06	0.17[b]	0.05	12%
Nonshared environmental	0.36[b]	0.04	0.10[c]	0.04	4%
Rearing environmental	. . .	. . .	. . .	. . .	. . .
Unique factor loadings					
Genetic	. . .	. . .	0.30[b]	0.06	36%
Nonshared environmental	. . .	. . .	0.26[b]	0.03	27%
Rearing environmental	. . .	. . .	0.23[b]	0.08	21%

[a]df = 33; $\chi^2 = 35.06$; $p = 0.37$.
[b]p<0.01.
[c]p<0.05.

cognitive abilities and educational achievement because the parameters for the paths to the common genetic factor are significant. Non-shared environmental effects also contribute significantly to the association. Of interest here is that the unique genetic parameter is significant, indicating that there is variation among individuals in educational achievement due to genetic effects that are independent of genetic variation for cognitive abilities. In addition, non-shared and shared environmental effects also contribute to variation in educational achievement that are independent of cognitive abilities.

Occupational status.—Table 6 gives the fit statistics, parameter estimates, and standard errors for the model with occupational status. The table displays a pattern for occupational status similar to that demonstrated for educational achievement. The covariation is mediated by genetic and non-shared environmental effects, but there is significant genetic variation in occupational status that is independent of genetic variation for cognitive abilities. In addition, there are independent rearing as well as non-shared environmental effects for occupationnal status.

Table 7 shows the results from the analyses with all three measures. Even when educational achievement is added as a covariate, there is still unique genetic variation in occupational status that is independent of genetic variation for cognitive abilities or educational achievement. There is also independent non-shared environmental variance, but variance due to rearing environmental effects for occupational status, on the other hand, is completely in common with rearing environmental effects for educational achievement.

DISCUSSION

The primary aim of the present study was to investigate the importance of genetic differences in cognitive abilities for individual differences in SES. First, it can be noted that the univariate results for educational achievement and occupational status fit well into the previous literature summarized in Table 1. As already mentioned, about 50 per cent of the total variation in educational achievement and about 40 per cent of the total variation in occupational status is betweeen-family variance and thus contributes to resemblance among brothers. In this study, 42 per cent of the variance in both educational achievement and occupational status is between-family variance.[4] Empirical data thus seem to converge on substantial familial similarity in SES, where about half of the between-family variance in educational achievement is due to genetic effects and the other half is due to shared environmental influences. For occupational status, genetic effects seem to be responsible for an even greater part of the between-family variance.

Data have suggested that in industrialized countries one's own achievement is most important for status attainment (Treiman and Yip, 1989). The importance

[4]In a separate publication we investigated the dimensions of occupation by using a multidimensional scaling technique (Lichtenstein et al., 1995). This method included the data from all occupational classes (i.e., even farm workers and self-employed non-professional persons). The results showed that a status dimension of occupation exists. Further, the importance of genetic and environmental influences for that status scale is nearly identical to the one presented here. Thus, it is not likely that there have been any substantial biases from the exclusions of occupational categories in this study.

TABLE 6

MAXIMUM LIKELIHOOD MODEL-FITTING PARAMETER ESTIMATES (P.E.), STANDARD ERRORS (S.E.), AND PER CENT OF VARIANCE FROM THE BIVARIATE ANALYSES OF GENERAL COGNITIVE ABILITIES AND OCCUPATIONAL STATUS[a]

	General Cognitive Ability		Occupational Status		
Factor Loadings	P.E.	S.E.	P.E.	S.E.	Per Cent of Variance
Common factor loadings					
Genetic	0.81[b]	0.06	0.25[b]	0.04	25%
Nonshared environmental	0.36[b]	0.04	0.10[c]	0.04	4%
Rearing environmental	...	...	...	...	...
Unique factor loadings					
Genetic	...	...	0.28[b]	0.05	34%
Nonshared environmental	...	...	0.24[b]	0.03	24%
Rearing environmental	...	...	0.18[c]	0.08	13%

[a]df = 33; $\chi^2 = 25.91$; $p = 0.80$.
[b]$p<0.01$.
[c]$p<0.05$.

TABLE 7

MAXIMUM LIKELIHOOD MODEL-FITTING PARAMETER ESTIMATES (P.E.), STANDARD ERRORS (S.E.), AND PER CENT OF VARIANCE FROM THE ANALYSES OF GENERAL COGNITIVE ABILITIES, EDUCATIONAL ACHIEVEMENT, AND OCCUPATIONAL STATUS[a]

	General Cognitive Ability		Educational Achievement		Occupational Status		
Factor Loadings	P.E.	S.E.	P.E.	S.E.	P.E.	S.E.	Per Cent of Variance
Common factor loadings							
All three measures							
Genetic	0.81[c]	0.06	0.18[c]	0.05	0.25[c]	0.04	26%
Nonshared environmental	0.36[c]	0.04	0.09	0.05	0.09[b]	0.04	4%
Rearing environmental	...	...	...	...	...	...	...
Two measures							
Genetic	...	...	0	...	0	...	...
Nonshared environmental	...	...	0.31[c]	0.03	0.01	0.03	0%
Rearing environmental	...	...	0.34[c]	0.04	0.21[c]	0.04	19%
Unique factor loadings							
Genetic	...	...	...	...	0.23[c]	0.04	23%
Nonshared environmental	...	...	...	...	0.26[c]	0.03	28%
Rearing environmental	...	...	...	...	0	...	...

[a]df = 69; $\chi^2 = 69.48$; $p = 0.46$.
[b]$p = 0.01$.
[c]$p = 0.05$.

of achievement versus ascription for occupational status has typically been tested by examining the relative influence of the subject's educational achievement and the father's occupation on current occupation. However, if genetic effects are of importance for status attainment, father-son similarity will in part be affected by genetic effects. We suggest that an alternative evaluation of the relative importance of achievement versus ascription should involve a comparison between genetic and shared environmental effects for occupational status. Twin studies, including the present one, indicate that genetic effects are more important than shared environmental effects for sibling resemblance in occupational status. In the multivariate analyses, the rearing environmental effects for educational achievement and occupational status were completely overlapping. This finding means that the same factors in the rearing home are making family members similar to each other for both educational achievement and occupational status. Non-genetic familial transmission of occupational status seems thus to be mediated by education. Educational policy is, therefore, probably important for the distinction between ascribed and achieved status in a society.

Nearly all of the non-shared (within-family) environmental effects for the SES measures were independent of those for cognitive abilities. This can be due to the inclusion of measurement error in the non-shared environmental parameters, but it is likely that non-shared environmental effects include the idiosyncratic events that happen to people and that affect their choices of an education or occupational path. An obvious example could be that one sibling is offered a job after finishing high school while the other sibling continues on to higher education. Another example is that an accident or disease affects one of the siblings, limiting his educational or occupational possibilities. It is important to note that non-shared effects of this type account for nearly one-third of the variation in status attainment.

The anlyses revealed that genetic variation for cognitive abilities contributes significantly to genetic variation in the SES measures. However, there is genetic variance in both educational achievement and occupational status that is independent of genetic variance for cognitive abilities. Furthermore, in the multivariate analyses, including educational achievement, significant independent genetic variance for occupational status was demonstrated. These results are in agreement with an earlier Norwegian study based on twins reared together only (Tambs et al., 1989). Because Tambs and coworkers presented this data only from a multivariate model with a single common genetic factor, the best comparison is made with results from occupational status in this study.[5] When the data were pooled over age-cohorts, they found that 14 per cent of the variance was genetic variance in common with cognitive abilities and educational achievement, but that 26 per cent of the variance in occupational status was independent of genetic effects on the other two measures (Tambs et al., 1989). The corresponding figures in this study, given in Table 7, are 26 per cent (common) and 23 per cent (independent).

[5]Because of the type of model in the Norwegian analyses, it is not possible to make comparisons with the bivariate analyses reported here for education.

Currently, there is a debate concerning how important genetic factors for IQ are for the class structure in Western societies, publicized recently because of the book *The Bell Curve* (Herrnstein and Murray, 1994). The data in this study show that *genetic influences for cognitive abilities are important for SES,* indicated by significant portions of genetic variance in common with the cognitive factors in Tables 5 and 6. On the other hand, it should be noted that *even greater portions of the genetic variance in the SES measures were independent of genetic variance for cognitive abilities.* Over 30 per cent of the variance in both educational achievement and occupational status was independent of genetic variance for cognitive abilities. Thus, IQ is not the only reason for genetic variation in SES and, as already has been discussed, rearing environmental factors are also important for variation in SES.

The challenge presented by the current results is to identify other sources of familial similarity and genetic variation for SES (Hauser and Featherman, 1976; Olneck, 1977; Hauser and Sewell, 1986). Plausible candidates responsible for the genetic mediation, which should be considered in future studies, are personality (cf. Jencks et al., 1979), health (cf. Lichtenstein, et al., 1993), interests, or talents (like musicality or handiness) that are not assessed in standard cognitive tests.

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REFERENCES

Behrman, J. R., Z. Hrubec, P. Taubman, and T. J. Wales. 1980. Socioeconomic success: A study of the effects of genetic endowments, family environment, and schooling. North-Holland, Amsterdam.

Cederlöf, R., and U. Lorich. 1978. The Swedish Twin Registry, p. 189–195. *In* W. E. Nance, G. Allen, and P. Parisi (eds.), Twin research: Biology and epidemiology. Alan R. Liss, New York.

Domanski, H., and Z. Sawinski. Dimensions of occupational mobility: The empirical invariance. Europ. Sociol. Rev. **3**:39–53.

Erikson, R. 1987. The long arm of the origin: The effects of family background on occupational and educational achievement, p. 58–76. *In* U. Bergryd and C-G. Janson (eds.), Sociological miscellany: Essays in honour of Gunnar Boal. Univ. of Stockholm Press, Stockholm.

Hauser, R. M., and D. Featherman. 1976. Equality of schooling: Trends and prospects. Sociol. Educ. **49**:99–120.

Hauser, R. M., and W. H. Sewell. 1986. Family effects in simple models of education, occupational status, and earnings: Findings from the Wisconsin and Kalamazoo studies. J. Labor Econ. **4**:S83–S120.

Heath, A. C., K. Berg, L. J. Eaves, M. H. Solaas, L. A. Corey, J. Sundet, P. Magnus, and W. E. Nance. 1985. Education policy and the heritability of educational attainment. Nature **314**:734–736.

Herrnstein, R. J., and C. Murray. 1994. The bell curve: Intelligence and class structure in American life. The Free Press, New York.

Horn, J. L. 1982. The theory of fluid and crystallized intelligence in relation to concepts of cognitive psychology and aging in adulthood, p. 237–278. *In* F. I. M. Craik, and E. E. Trehub (eds.), Aging and cognitive processes. Plenum Press, New York.

Jencks, C., S. Bartlett, M. Corcoran, J. Crouse, D. Eaglesfield, G. Jackson, K. McClelland,

P. Mueser, M. Olneck, J. Schwartz, S. Ward, and J. Williams. 1979. Who gets ahead?: The determinants of economic success in America. Basic Books, New York.

Jöreskog, K., and D. Sörbom. 1989. LISREL VII: Estimation of linear structural equation systems. Computer programs. National Educational Resources, Chicago.

Lichtenstein, P., J. R. Harris, N. L. Pedersen, and G. E. McClearn. 1993. Socioeconomic status and physical health, how are they related? An empirical study based on twins reared apart and twins reared together. Soc. Sci. Med. **36**:441–450.

Lichtenstein, P., S. L. Hershberger, N. L. Pedersen, and G. E. McClearn. 1995. Dimensions of occupations: Genetic and environmental influences. J. Biosoc. Sci. **27**:193–206.

Lichtenstein, P., N. L. Pedersen, and G. E. McClearn. 1992. The origins of individual differences in occupational status and educational level: A study of twins reared apart and together. Acta Sociol. **35**:13–31.

McGue, M., and T. J. Bouchard, Jr. 1984. Adjustment of twin data for the effects of age and sex. Behav. Genet. **14**:325–343.

Neale, M. C., and L. R. Cardon. 1992. Methodology for genetic studies of twins and families. Kluwer Academic Publishers, Dordrecht.

Nesselroade, J. R., N. L. Pedersen, G. E. McClearn, R. Plomin, and C. S. Bergeman. 1988. Factorial and criterion validities of telephone-assessed cognitive ability measures: Age and gender comparisons in adult twins. Res. Aging **10**:220–234.

Olneck, M. R. 1977. On the use of sibling data to estimate the effects of family background, cognitive skills, and schooling: Results from the Kalamazoo brothers study. *In* P. Taubman (ed.), Kinometrics: Determinanats of socioeconomic success within and between families. North-Holland, Amsterdam, The Netherlands.

Pedersen, N. L., L. Friberg, B. Floderus-Myrhed, G. E. McClearn, and R. Plomin. 1984. Swedish early separated twins: Identification and characterization. Acta Genet. Med. Gemellol. **33**:243–250.

Pedersen, N. L., G. E. McClearn, R. Plomin, J. Nesselroade, S. Berg, and U. de Faire. 1991. The Swedish Adoption/Twin Study of Aging: An update. Acta Genet. Med. Gemellol. **40**: 7–20.

Pedersen, N. L., R. Plomin, J. Nesselroade, and G. E. McClearn. 1992. A quantitative genetic analysis of cognitive abilities during the second half of the life span. Psychol. Sci. **3**:346–353.

Scarr, S. 1995. Behavior genetic and socialization theories of intelligence: Truce and reconciliation. *In* R. J. Sternberg and E. L. Grigorenko (eds.), Intelligence: Heredity and environment. Cambridge Univ. Press, New York.

Scarr, S., and R. A. Weinberg. 1994. Educational and occupational achievements of brothers and sisters in adoptive and biologically related families. Behav. Genet. **24**:301–325.

Snyderman, M., and R. Rothman. 1987. Survey of expert opinion on intelligence and aptitude testing. Amer. Psychol. **42**:137–144.

Statistics Sweden. 1983. Meddelanden i samordningsfrågor: Socioekonomisk indelning (SEI) 1982:4. [Reports on statistical co-ordination: Swedish socioeconomic classification]. SCB, Stockholm.

Tambs, K., J. M. Sundet, P. Magnus, and F. Berg. 1989. Genetic and environmental contributions to the covariance between occupational status, educational attainment, and IQ: A study of twins. Behav. Genet. **19**:209–222.

Teasdale, T. W., and D. R. Owen. 1981. Social class correlations among separately adopted siblings and unrelated individuals adopted together. Behav. Genet. **11**:577–588.

Teasdale, T. W., and T. I. A. Sørensen. 1983. Educational attainment and social class in adoptees: Genetic and environmental contributions. J. Biosoc. Sci. **15**:509–518.

Treiman, D. J., and K. B. Yip. 1989. Educational and occupational attainment in 21 countries, p. 373–394. *In* M. L. Kohn (ed.), Cross-national research in sociology. Sage, Newbury Park.