Genetic and Environmental Contributions to the Covariance Between Occupational Status, Educational Attainment, and IQ: A Study of Twins

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Scores of occupational status, educational attainment, and IQ were obtained for 507 monozygotic and 575 dizygotic male twin pairs born 1931–1935 and 1944–1960. A multivariate genetic analysis with statistics from different cohorts showed heterogeneity between cohorts, and analyses were performed in four separate cohorts. The only set of results which departed clearly from the rest was found for the group born 1931–1935, where the ratio of environmental to genetic effects exceeded those of the other groups. Typical heritability values in the three youngest groups (weighted means) were .43, .51, and .66 for occupation, education, and IQ, respectively. The values in the oldest group were .16, .10, and .37, but this sample is small and the estimates are unstable. Genetic variance influencing educational attainment also contributed approximately one-fourth of the genetic variance for occupational status and nearly half the genetic variance for IQ. The values for the between-families variances (reflecting family environment and assortative mating) varied from 2 to 35% in the three youngest groups but were higher for education (62%) and IQ (45%) in the oldest groups. All the between-families variance was common to all three variables. For educational attainment and IQ, the bulk of this between-families variance is probably genetic variance due to assortative mating. The common-factor environmental within-family variances were generally small, and the specific estimates seemed to contain mainly measurement error.

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INTRODUCTION

The substantial intercorrelations among psychometrical intelligence (IQ), educational attainment, and occupational status are well documented. These relations are predictable a priori from the fact that intelligence tests were originally validated against school performance, which in turn influences career advancement. Still, the causal relationships are far from clear-cut and can be illuminated (if not elucidated) by considering the relative impact of environmental and genetic factors and the extent to which such impacts are common or specific for each of the variables. This study offers some tentative answers to these questions, using the method developed by Martin and Eaves (1977).

In large samples of Norwegian twins, including the subjects from the present study, Heath *et al.* (1985a,b) have shown that the relative contributions from genetic and environmental sources vary across cohorts for education, and Sundet *et al.* (1988) have shown a similar trend for IQ. Even in a smaller sample, we were able to explore such trends further, also examining the trends for occupational status and for the relative values of common and specific variances.

A number of twin studies (Martin and Eaves, 1977; Fulker, 1978; Martin *et al.*, 1984; Tambs *et al.*, 1986) have shown that the between-family variance, V_B, for various abilities, education, and socioeconomic variables appears to be due to a single common factor. This is to say that any genetic effect due to assortative mating is common for these variables, and so is any effect of the family environment (Eaves *et al.*, 1984). An important objective of this study was to test the expectation of no V_B specific to any single measure.

MATERIALS AND METHODS

Sample

The sample consisted of 507 male monozygotic (MZ) pairs and 575 male dizygotic (DZ) pairs. At age 18–19 years, about 90% of the male population is investigated physically and psychologically before the entrance to the compulsory military service. From the army files, IQ scores were available for the cohorts born 1931–1935 and 1944–1960.

The data were obtained by the matching of the army files with the Norwegian Twin Panel. The panel contains all Norwegian like-sexed twin pairs born 1915–1960 where both were alive at age 20 and for whom addresses could be found in census data. Zygosity has been assigned for 80% of the pairs, in which at least one of the twins returned a mailed

questionnaire. This questionnaire has been shown to misclassify less than 3% of the cases (Magnus *et al.*, 1983).

In about 60% of the pairs with known zygosity, both twins have responded to a second questionnaire, containing, among others, questions about profession and education. In 1850 pairs, zygosity and IQ were retrieved for both twins. From this sample, complete data from the second questionnaire were obtained in 1082 pairs, or about 31% of the total male twin panel population from the 22 year classes.

Test and Questionnaire

The ability testing of army recruits was started in 1950 with recruits born 1931. Three test scores are recorded, from which only one, "general ability level," was available for the total present sample. This general ability test is composed of three subtests: "arithmetic problems," "word similarities" (Faglig Memorandum No. 12, 1956), and "figure rules" (Lundgren and Skjenstad, 1953), which is a slightly modified version of Raven's Progressive Matrices. The test is scaled as "stanine" scores, a normal distribution with range 1–9, mean 5.00, and standard deviation 1.96. The test–retest reliabilities of the subtests are .84, .90, and .72, respectively, the corresponding Cronbach's alphas are .87, .93, and .94 (Faglig Memorandum No. 12, 1956). Unfortunately, no exact estimates of correlations with other tests are known, but for 48 of the twins, Wechsler Adult Intelligence Scale (WAIS) scores from 1981 to 1984 were available. With time spans between the two test sessions varying from 2 to 25 years, the correlation was .75.

Two different measures of educational attainment were recorded, educational *level*, which ranged from 1 to 4, and *years* of education. The two measures were converted to z scores and summed. Using this composite instead of educational level has the disadvantage that a person who progresses slowly to reach a certain level is scored as more highly educated than a person who proceeds at an ordinary rate. On the other hand, unlike the level scale, the composite is sensitive to education which is not closely tied to or necessary for the ultimate vocational education. For instance, a teacher who is also educated as an engineer will have a higher score than a person educated as either an engineer or a teacher. Besides, the composite is probably more statistically reliable than each of its components. From the intercorrelation of .85, the reliability for the composite may be estimated at .92. The distribution of years of education was skewed with the tail upward, whereas the distribution of educational level was approximately normal. The skewness and kurtosis of the sum score were .67 and .61, respectively.

Occupational status was scaled 0–4 according to the scoring key:
(4) white-collar supervisory, runs own business, professionals;
(3) white-collar intermediate, runs small business;
(2) white-collar lower level, skilled workers;
(1) workers, students; and
(0) no paid work.

Occupation was recorded in a somewhat crude way, applying only the first two digits in Nordisk Yrkeklassifisering (1978). In this classification system, which is routinely applied in Scandinavia and Finland, occupations are assigned by means of a five digit code. Using only two digits, some of the categories become rather heterogeneous, e.g., the teacher group includes university professors as well as nursery teachers. As a result, some subjects may have been misclassified on the status scale, impairing the reliability of occupational status.

Model

The model and estimation procedure are thoroughly described by Martin and Eaves (1977). Models describing both the *sources* and the *structure* of covariation are fitted to the variances (mean squares) and covariances (mean products) of the variable within and between MZ and DZ pairs, by a maximum-likelihood procedure. Genetic and environmental variance components common for all variables and components specific for each variable are estimated. Suffice it here to describe the model by the equations:

$$\sum\nolimits_{\text{WMZ}} = E_{\text{WC}}E_{\text{WC}}' + E_{\text{WS}}^2,$$

$$\sum\nolimits_{\text{BMZ}} = 2(G_{\text{C}}G_{\text{C}}' + G_{\text{S}}^2) + E_{\text{WC}}E_{\text{WC}}' + E_{\text{WS}}^2 + 2(E_{\text{BC}}E_{\text{BC}}' + E_{\text{BS}}^2),$$

$$\sum\nolimits_{\text{WDZ}} = \frac{1}{2}(G_{\text{C}}G_{\text{C}}' + G_{\text{S}}^2) + E_{\text{WC}}E_{\text{WC}}' + E_{\text{WS}}^2,$$

$$\sum\nolimits_{\text{BDZ}} = \frac{3}{2}(G_{\text{C}}G_{\text{C}}' + G_{\text{S}}^2) + E_{\text{WC}}E_{\text{WC}}' + E_{\text{WS}}^2 + 2(E_{\text{BC}}E_{\text{BC}}' + E_{\text{BS}}^2),$$

where the matrices $\sum_{\text{WMZ}}$, $\sum_{\text{BMZ}}$, $\sum_{\text{WDZ}}$, and $\sum_{\text{BDZ}}$ represent the (expected) mean squares and mean products within and between MZ and DZ pairs, respectively. G_{C}, E_{WC}, and E_{BC} are the matrices of loadings on genetic, environmental within-family, and between-families factors, respectively. G_{S}^2, E_{WS}^2, and E_{BS} are the diagonal matrices of the corresponding specific variances.

The model rests on the usual set of assumptions for the classical twin design, discussed by Eaves *et al.* (1978). Of special importance here is

the assumption of no genetic spouse correlation, since assortative mating is, in fact, substantial. The effect is to increase the additive genetic variance but this will be completely confounded with the effect of the family environment.

Estimation Procedure

Estimates of the parameters were obtained by use of the LISREL Version IV computer program (Jöreskog and Sörbom, 1978). Given observed mean squares and products, this program arrives at maximum-likelihood estimates of the model parameters by means of an iterative procedure. The program also supplies a chi-square value, indicating the model fit, and standard errors of (the square root of) the estimated variance components. A check of the identification status of the model is performed.

RESULTS

Table I shows means, standard deviations, and secular trends for all variables. Occupational status is, of course, highly age dependent. Means increase from the youngest groups until the age of about 35 and tend to

Table I. Means and Standard Deviations for Occupational Status, Education, and IQ and Trends in These with Birth Cohort

Twins born	N of pairs	Occupational status		Years of education		IQ	
		$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD
1931–1933	50	2.20	.94	9.61	2.98	4.89	1.90
1933–1935	42	2.25	.97	10.12	3.26	5.42	1.80
1944–1946	140	2.22	.91	11.25	3.78	5.41	1.90
1947–1949	167	2.34	.85	11.67	3.77	5.47	1.79
1950–1952	171	2.23	.86	11.86	3.77	5.78	1.71
1953–1955	159	2.14	.77	11.92	3.46	5.81	1.69
1956–1958	198	1.96	.62	11.53	2.72	6.06	1.55
1959–1960	154	1.74	.59	10.69	2.27	5.79	1.56
All MZs	506	2.12	.80	11.30	3.32	5.63	1.70
All DZs	575	2.11	.82	11.42	3.41	5.74	1.75
Total	1081	2.11	.81	11.36	3.36	5.69	1.73
R^{2}*		.026		.007		.021	
η^{2}**		.057		.034		.027	

  * $p < .001$ for all values of R^{2} (linear cohort trends).
** $p < .05$ for all deviations from linearity, $\eta^{2} - R^{2}$.

decrease from the age of 50. Mean educational attainment in twins in-creases dramatically over the three decades. From 1957, however, there is a decline in mean values and standard deviations, which is probably due to the young age of these respondents at the time of the data collec-tion. Receiving the questionnaire at age 20–24, some of the twins had not finished their education, and this results in a ceiling effect in the youngest groups. No differences in means or variances between MZ and DZ twins reach significance.

The army tests have not been renormed so secular trends for IQ are reflected directly by the stanine scores. The mean scores increase and the standard deviations decrease toward the younger groups, a trend also observed in performances on the WAIS test (Engvik and Tambs, 1985).

Mean IQ scores close to the population mean suggest that no sample selection has occurred. Still, a comparison with the scores of twins who did not respond to the questionnaires shows a selection effect, originally camouflaged by a tendency for twins to score below the population mean. Means and standard deviations for questionnaire responders and nonre-sponders are shown in Table II. The response ratio is somewhat higher for MZs than DZs. Young twins respond more frequently than old twins. From the sample with known IQ, 33% of the oldest group and 53% of the youngest group have returned the second questionnaire.

Lykken *et al.* (1987) have suggested that the willingness to participate in twin studies may be directly affected by differences within pairs on certain salient traits. They showed that such recruitment bias can have large effects on the results. Just like individual selection, selection against large pair differences is likely to be accompanied by a reduction in total variance which is larger for DZs than MZs. It may also be detected as a correlation between willingness to respond and absolute differences within pairs. A "responsiveness" scale was computed, with the values 0

Table II. Selection Effect; Mean IQ Scores for Responders and Nonresponders to the Questionnaires[a]

Zygosity	Responded to both questionnaires			Responded only to the zygosity class. questionnaire			Non-responders		
	$\overline{X}$	σ	N	$\overline{X}$	σ	N	$\overline{X}$	σ	N
Monozygotic	5.58	1.76	1387	5.11	1.85	547	5.09	2.02	99
Dizygotic	5.59	1.77	1904	5.09	1.85	1066	4.68	1.85	237
Unknown							4.70	1.98	718

[a] No mean values or standard deviations are significantly different between zygosity groups.

(nonresponders), 1 (returned only the zygosity classification question-
naire), and 2 (returned the second or both questionnaires). The correlation
between responsiveness and IQ was .19 and the cotwin correlation for
responsiveness was .37 for MZs and .17 for DZs. The correlation between
absolute differences in IQ within pairs and individual responsiveness was
.012 for MZs and − .005 for DZs. These correlations were computed in
slightly truncated samples, omitting subjects from 229 concordant pairs
of nonresponders where zygosity was unknown. Even in the total sample
(including the group with unknown zygosity) the correlation coefficient
did not attain clear significance ($r = -.038$, $z = 1.83$). What slight cor-
relation is found probably reflects a spurious effect from zygosity. That
is, the response ratio is slightly lower, and IQ differences are larger, in
DZs than MZs. The mean squares for IQ within pairs did not vary sig-
nificantly between the final sample and the pairs with incomplete ques-
tionnaire data ($F = 1.03$ in MZs and $F = 1.10$ in DZs).

Data on the occupation of the twin spouses and on educational at-
tainment for parents were available. The spouse correlation for occupa-
tional status was .27 (before and after controlling for age). While nearly
nonexistent among the (male) twins, housework, which was scored as the
lowest category, was quite common among their spouses, probably re-
sulting in somewhat decreased spouse correlation. In the four age groups,
the correlations were .21, .28, .31, and .13 for the oldest to the youngest,
respectively. The spouse correlation for the educational attainment com-
posite was .67, reduced only to .66 after controlling for age. The values
for each age group were .86, .70, .63, and .52, respectively, decreasing
with year of birth.

Intercorrelations of the five observed variables are shown in Table
III. The measures of education are highly correlated with IQ and occu-
pational status. In the further analyses, only the composite measure (level
and number of years) was applied for education. The correlations of this
composite with IQ and occupational status were .62 and .45, respectively.

Table III.   Intercorrelations of all Observed Variables*

	2	3	4	5
1. Occupational status	.41	.46	.33	.17
2. Years of education		.70	.53	− .08
3. Educational level			.52	− .20
4. Intelligence				− .14
5. Twins' age				

* df = 2161, p <.001, for all correlations.

The correlation between IQ and occupational status (.32) is only slightly larger than expected from their common relationship with education alone.

Genetic Analysis

The results of Heath et al. (1985a,b) and Sundet et al. (1988) showed secular trends for education and IQ for the relative contributions of genetic and environmental sources. To test for heterogeneity between cohorts, the observed mean squares/products from four age groups for occupation, education, and IQ were analyzed separately in each age groups, and the model was fitted to the four sets of statistics simultaneously. The chi-square values and the degrees of freedom for each separate analysis were then subtracted from those for the latter analysis. The age groups consisted of 97 pairs born 1931–1935, 361 pairs born 1944–1950, 399 pairs born 1951–1957, and 221 pairs born 1958–1960. Only the year classes 1958–1960 are included in the youngest group. In this way, the ceiling effect for education, due to the young age at the time of reporting, is limited to the smallest possible sample. The trends for mean values and standard deviations (Table I) hardly reflect directly the distribution differences for genes and environmental factors. For example, due to scale assymmetries or otherwise, the standard deviations may depend on mean scores. To have such effects removed, the scores were rescaled to z scores separately for each age group.

In all age groups, the fit of the model did not deteriorate by fixing the V_B (variance between families) specifics to zero, consistent with the notion that V_B in all three measurements is due to a single common factor. The model fits were mostly good in the various groups (oldest to youngest): $\chi_9^2 = 7.07$, $p = .63$; $\chi_9^2 = 17.79$, $p = .04$; $\chi_9^2 = 11.01$, $p = .28$; and $\chi_9^2 = 7.47$, $p = .59$. When inspecting the residuals (observed–expected statistics) the main problem in the 1944–1950 group turned out to be too small mean squares for occupation in the MZ sample and correspondingly large in DZs. For the analysis of all the statistics combined, χ^2 with 81 df was 118.43 ($p = .005$). The chi-square value for the difference of the model fit, $\chi_{45}^2 = 75.09$ ($p = .005$), shows heterogeneity between cohorts.

The results for each age group are shown in Fig. 1. In the 1931–1935 group, the values of genetic variance, V_G, were 16, 10, and 37% for occupation, education, and IQ, respectively. All the genetic variance was common for occupation and education; 30% was specific for IQ. The corresponding values for (common) V_B, were 6, 62, and 45%. In the 1944–1950 group the values for V_G were 51% (26% specific), 70% (all common), and 71% (32% specific), and those for V_B were 2, 7, and 12%. The cor-
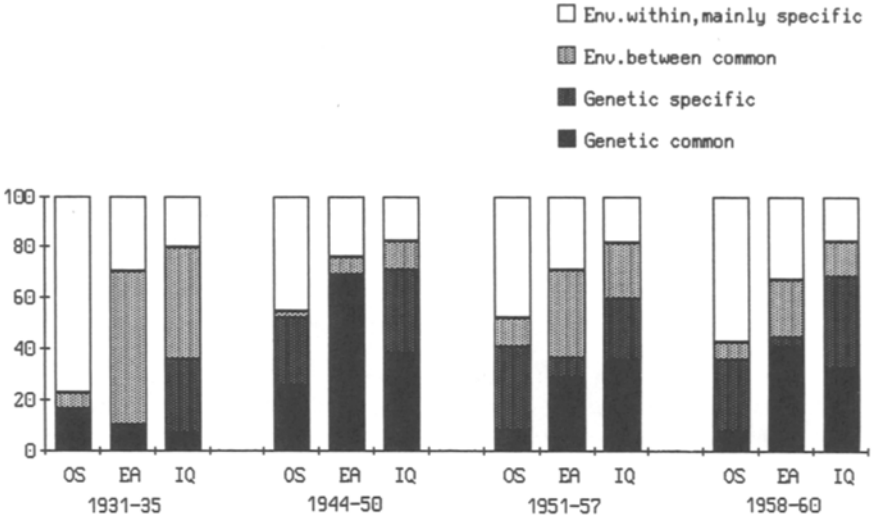
Fig. 1. Genetic and environmental variances in different age groups. All the between-families variances are common for all three variables. Nearly all the environmental within-families variances are specific.

responding estimates for the 1950–1957 group were 40% (32% specific), 37% (8%), and 59% (23%) for V_G and 12, 35, and 22% for V_B. For the 1958–1960 group, the estimates were 36% (29%), 45% (4%), and 71% (37%) for V_G and 7, 22, and 14% for V_B. In the oldest group, only V_G for IQ and V_B for education and IQ are significantly different from zero at the 5% level. In the other groups, all the estimates have significant values except V_B for occupation and education in the 1944–1950 group and V_B for occupation in the youngest group.

Most of the individual environmental variance is specific to each measurement in all age groups. For occupation, the estimates vary from 75% in the oldest group to 45 and 47% in the two intermediate groups. This variable is measured rather crudely, and with the possible exception of the oldest group, most of the individual environmental variance is probably due to measurement error. For education and IQ the estimates vary only marginally across cohorts, the typical values being 30 and 20%, respectively. Considering the internal consistency reliabilities at the upper limit of .90, error variance is likely to contribute substantially to individual environmental variance for these variables as well.

Generally, the results from the 1931–1935 sample are the most divergent, but also by far the most unstable ones, due to the small sample

size. The main tendency is small genetic effects and larger between-families effects in this age group, especially for educational attainment. Only two pairs of corresponding estimates vary across subsamples with significantly different values, both for educational attainment in the two oldest groups: common (and, for this variable, total) genetic variance is larger in the 1944–1950 than in the 1931–1935 group ($z = 2.08, p < .04$), and V_B is larger in the 1931–1935 group than in the 1944–1950 group ($z = 2.25, p < .03$).

Correcting for Assortative Mating

Assortative mating represents a problem in the comparison of MZ and DZ twins, resulting in additive genetic variance which is confounded with environmental family variance in the estimate of V_B. Martin (1978) has suggested an easy correction procedure. The between-family variance may be expressed as

$$V_B = V_{EB} + AM,$$

where V_{EB} is the variance due to family environment and AM is the genetic effect due to assortative mating. The latter may be expressed as $AM = V_G A/(1 - A)$, where V_G is the random mating additive genetic variance and A the correlation between the additive deviations of spouses. A is related to the spouse correlation, μ, by $A = h^2 \mu$ or $h^2 = A/\mu$, where h^2 is the narrow heritability. h^2 contains V_G and AM and may also be expressed as

$$h^2 = \frac{V_G + AM}{V_T},$$

where V_T is the total variance. Substituting h^2 with A/μ, and AM with $V_G A/(1 - A)$, A may now be expressed as a function of V_G, V_T, and μ, for which there are observed or estimated values, and AM and h^2 may be estimated.

No estimate of the spouse correlation for IQ was available but Grøndahl (1985) reported a correlation of .30 between 250 twins and their spouses for the WAIS test. Substituting this value for μ for all three variables gives calculated values for AM which approach or exceed those for V_B in all but the oldest group. The values for occupation, education, and IQ are .01, .01, and .05 in the 1931–1935 group, larger than V_B for all variables in the 1944–1950 group, .06, .20, and .18 in the 1951–1957 group, and .05, .30, and larger than V_B in the 1958–1960 group. In the 1944–1950 group, spouse correlation values as low as .08 for occupation,

.12 for education, and .17 for IQ were sufficient for $AM = V_B$, compared to the observed values of .27, .70, and .30.

DISCUSSION

Means and standard deviations do not vary significantly across zygosity, but for IQ they vary across questionnaire responders and nonresponders. Still, the nonsignificant relationship between liability to respond and cotwin differences for IQ suggests no large sample selection bias for the genetic analysis. In a univeriate genetic analysis described elsewhere (Tambs *et al.*, 1989), no heterogeneity between the statistics for IQ scores from different selection groups could be detected.

The ratios of estimated genetic and environmental effects are generally in line with earlier findings. For *occupational attainment*, definitions and methods of measurement probably vary considerably across cultures. Nevertheless, the results for genetic variance (weighted mean of 41% across cohorts) accords with Fulker's (1978) findings, ranging from 28 to 46%, depending on age and statistical models. Tambs and Sundet (1985) have estimated the genetic variance for this variable at 32–64%.

Assuming that the major part of V_B is genetic variance due to assortative mating, the results indicate a total genetic variance (V_G and AM) of approximately 60% for *educational attainment*, which is in line with earlier results. Fulker (1978) has estimated genetic variance at 45–46% in schooling (1978), reanalyzing Taubman's (1977) data. Vogler and Fulker (1983) have estimated the heritability for educational attainment at about .60 in males, reanalyzing a number of data sets. In a more complete sample of Norwegian twins with parents, Heath *et al.* (1985a,b) have estimated the heritability of educational attainment applying polychoric correlations in a path-analytical design. In three subsamples of males born 1915–1939, 1940–1949, and 1950–1959, the estimates including dominance variation were 48, 74, and 67%, respectively.

The weighted mean value for genetic variance for *IQ* is 64%, increasing to approximately 80% when correcting for *AM*. This is slightly larger than the typical values from the literature (Bouchard and McGue, 1981). On the other hand, Tambs *et al.* (1984, 1986) and Tambs and Sundet (1985) estimated values of V_G in full-scale and subscale WAIS scores in Norwegian twins at 55–85%, not including the genetic effect due to *AM*. In a large sample including the present one, Sundet *et al.* (1988) estimated V_G at 68%, applying a univariate model.

The effects of specific genotypes on IQ and occupational status may seem surprisingly large. However, Fulker's (1978) results indicate that

only a minor part of the genetic effects on schooling and occupational status was common.

The lack of any specific V_B is in full agreement with earlier evidence for occupation, education, and IQ (Fulker, 1978; Tambs and Sundet, 1985) and for different abilities (Martin and Eaves, 1977; Martin *et al.*, 1984, Tambs *et al.*, 1986). The V_B is substantial for educational attainment and IQ. In some of the age groups, the observed value of the spouse correlation for education greatly exceeds the value corresponding to $V_B = AM$. This may suggest the existence of some bias effects, neutralizing AM to some extent, so that a full correction for AM is tantamount to an overcorrection. Nevertheless, with the exception of the oldest group, most of the between-family effect is probably due to assortative mating. The result of no specific between-family effects is in line with Eaves *et al.* (1984). They concluded that the effects of assortative mating may well be generalized for multiple abilities and educational and socioeconomic variables, meaning that all spouse correlations for such variables and across such variables stem from a single common factor.

In isolation, the results do not permit many safe conclusions about secular trends, but the tendencies are in line with earlier findings. One major trend is small heritability for the oldest group. Heritability is greatest for subjects born 1940–1950 and tends to decrease slightly for the younger groups, and this accords with results from Heath *et al.* (1985a, b) and Sundet *et al.* (1988). For occupational status, V_{EW} seems to replace some of the V_G in the oldest group. One may speculate whether happenstance may have determined to a large extent the choice of occupation during the first postwar years or whether the reliability of measurement is simply lower for the oldest group. The large V_B for the oldest group for education and IQ may well reflect sociocultural differences between families during the "hard thirties." Correspondingly, it is tempting to attribute the lack of environmental family effect for the younger groups to social conditions during childhood and adolescence. In this period Norwegian society, and particularly the educational system, was characterized by social-democratic egalitarian politics.

ACKNOWLEDGMENTS

Coucheron Thrane. Torbjørn Moum, Department of Behavioural Sciences in Medicine, University of Oslo, offered valuable advice.

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Edited by N. G. Martin