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Direct Marital Assortment for Cognitive and Personality Variables

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Recent advances in linear modeling in human genetics permit the resolution of the sources of assortative mating. Using these methods we examined the multivariate assortment relationships among education, general cognitive ability, and personality traits in two large samples of spouses from the Colorado Adoption Project (N = 334 couples) and the Hawaii Family Study of Cognition (N = 1165 couples). Results indicate a direct pairing of mates on the basis of educational level and general intelligence but no cross-assortment between the two. Thus, the indirect marital correlation between education in one spouse and intelligence in the other is due only to the direct pairing on education and on intelligence and to the within-person correlation between the two traits. We also found direct isomorphic assortment as well as direct cross-assortment on some personality characteristics. However, there was no cross-assortment between the personality and the cognitive domains. Results from models

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based on conditional path assortment parameters differ markedly from those obtained directly from observed marital correlations.

KEY WORDS: direct marital assortment; conditional path.

INTRODUCTION

Assortative mating poses a unique problem to human genetics. Not only is assortment an interesting phenomenon in its own right, but also it has significant consequences for the structural modeling of familial resemblance. The precise effect of assortative mating, however, depends on the origin of spouse resemblance. Direct inspection of the matrix of spousal correlations (**M**) is not informative because marital correlations can reflect the within-individual phenotypic correlations and assortment on many different phenotypes. In the case of general intelligence, for example, the spouse correlation may reflect direct mate attraction for intellectual ability or the indirect effect of assortment on a correlated variable, such as educational level (Loehlin, 1979; Cloninger, 1980). Direct assortment for intelligence will increase genetic resemblance for intelligence among relatives more than will indirect assortment for education. Thus, if marital correlations for intelligence are modeled from homogamy via education, genetic effects may be underestimated and cultural transmission overestimated. On the other hand, modeling the marital correlation from direct assortment on intelligence when, in fact, it is due to education will overestimate heredity's contribution and underestimate cultural effects.

Initially, researchers examined the partial spouse correlation for one variable, controlling for one or more other variables (Warren, 1966; Johnson *et al.*, 1976). This method, however, necessitates the assumption that the controlled variables are ones on which direct assortment occurs. Recently, the series of methodological innovations involving the developments of the copath (Cloninger, 1980), the delta path (Van Eerdewegh, 1982), and the conditional path (Carey, 1986; also see Fulker, 1988) do permit the resolution of the sources of assortment within a linear multivariate system. In the application reported here, all three path methods give identical results. We refer to the concept as the conditional path, following the notation of Carey (1986).

Modeling phenotypic assortment using conditional paths, in which direct assortment is represented by a conditional path matrix **D** of latent direct assortment effects, leads to the expectation that

$$\mathbf{M} = \mathbf{R}_{\mathbf{P}i}\,\mathbf{D}\,\mathbf{R}_{\mathbf{P}j}, \tag{1}$$

where **M** is the matrix of marital correlations and $\mathbf{R_P}$ is the correlation matrix within individuals for mating gender *i* or *j*. The homogeneity of $\mathbf{R_P}$ across husbands and wives is an empirical question that can be tested. A conditional path between mate phenotypes is a coefficient that represents the extent to which mates assort *directly* on those phenotypes. A marital correlation is a function of direct and indirect assortment on many phenotypes. For example, if traits X and Y are correlated within individuals, the marital correlation for trait X in the husband and trait Y in the wife includes the effect of the direct assortment on the husband's X and the wife's Y plus the indirect efects of assortment on (1) the husband's X and wife's X, (2) the husband's Y and wife's X, and (3) the husband's Y and wife's Y. The advantage of this approach is its flexibility in modeling marital correlations. If, for example, the marital correlation for general intelligence were due solely to education, one conditional path between educational levels of mates could be used to predict the four correlations among spouses' intelligence and education.

Inspection of the elements of **D** and subsequent tests of significance regarding its structure should shed some light on the independence or nonindependence of assortment for a set of related variables. This is a report of two series of comparisons of assortative mating models, one based on the conditional path method and one based on the traditional **M** matrix. Each series involves the same steps of progressive elimination of some of the elements of the assortment matrix.

METHODS

The study is based on data collected from adult samples participating in the Colorado Adoption Project (CAP) (Plomin and DeFries, 1985) and the Hawaii Family Study of Cognition (HFSC) (DeFries *et al.*, 1979). Complete data were available for 178 adoptive and 156 nonadoptive couples in the CAP sample. Six CAP measures, representing both cognitive and personality domains, were selected for the first analysis: the unrotated first principal component, or *g*-factor, from a battery of specific cognitive abilities tests; the educational level at the time of testing; and the four second-order personality factors of Cattell's 16PF (Cattell *et al.*, 1970)—extraversion, anxiety, tough poise, and independence. These second-order factors were constructed by means of scaled scores, according to Cattell's guidelines. The *g*-factor scores were age and sex corrected prior to analyses. In the HFSC, education and age- and sex-corrected *g*-factor data were available from two samples: 862 couples of Caucasian ancestry and 303 couples of Japanese ancestry. The specific cognitive abilities test batteries used in the CAP and HFSC are highly similar although not identical.

Table I. Within-Person Correlations for the CAP Sample (N = 334 Couples)[a]

	gfac	educ	extr	anx	tough	ind
gfac	1.00	0.41	0.01	−0.03	0.04	0.14
educ	0.45	1.00	0.15	−0.07	0.02	0.24
extr	−0.02	0.09	1.00	−0.02	0.64	0.27
anx	−0.10	−0.14	−0.28	1.00	0.12	−0.12
tough	0.05	−0.06	0.11	0.01	1.00	0.32
ind	0.24	0.23	0.45	−0.43	0.12	1.00

[a] Correlations for wives are given above, and for husbands below, the diagonal. gfac, *g*-factor; educ, education; extr, extraversion; anx, anxiety; tough, tough poise; ind, independence.

The first set of model comparisons was applied to the six variables from the CAP sample. We pooled the weighted adoptive and nonadoptive spousal covariance matrices because the preliminary test for heterogeneity was not significant ($\chi^2_{78} = 65.26, P > 0.80$). The second preliminary homogeneity test indicated that the $\mathbf{R_P}$ submatrices for men and women could not be pooled ($\chi^2_{63} = 179.17, P < 0.0005$); we thus retained separate matrices for husbands and wives. Inspection of the CAP correlation matrices, which are given in Table I, suggests that the personality variables contribute most to the lack of homogeneity. The pooled CAP **M** matrix is given in Table II.

The second set of models was fitted to data from both the CAP and the two HFSC samples.

In testing the various models of assortment, the expected $\mathbf{R_P}$ submatrices were set equal to the observed, with only the **M** submatrix (and **M**′ below the diagonal) varying as a function of the particular reduced model of assortment being tested. Models were fitted to the underlying

Table II. Pooled **M** in the CAP (N = 334 Couples)[a]

	Husbands					
Wives	gfac	educ	extr	anx	tough	ind
gfac	0.20	0.18	0.09	0.03	0.11	0.07
educ	0.24	0.43	0.05	−0.07	0.01	0.08
extr	0.04	0.16	0.24	−0.04	0.01	0.07
anx	−0.03	−0.07	−0.05	0.09	−0.02	0.06
tough	0.07	0.03	0.11	0.02	0.05	0.09
ind	0.22	0.23	0.05	−0.02	0.10	0.19

[a] For abbreviations see Table I, footnote *a*.

correlational structure of the covariance matrix by setting expected equal to observed variances. We used a maximum-likelihood estimation procedure, assuming multivariate normality, to minimize the function

$$F = N\,[\ln|\mathbf{E(S)}| - \ln|\mathbf{S}| + \mathrm{tr}(\mathbf{S}\,\mathbf{E(S)}^{-1}) - p], \qquad (2)$$

where N is the sample size minus one, **E(S)** and **S** are the expected and observed covariance matrices, respectively, and p is the order of the matrix.

RESULTS

In modeling assortment, we searched for a parsimonious **D** structure that could account for the observed correlations in the CAP.

The first test was for the symmetry of **D**. This test yielded a nonsignificant result ($\chi^2_{15} = 20.09$, $P > 0.10$); therefore, we adopted this model for subsequent comparisons with reduced models. Acceptance of this model implies symmetrical assortment; that is, gender is not a factor in the pattern of assortment for these traits.

A two-domain model was tested in which a cognitive domain was defined by g-factor and education, with the four personality scales constituting the second domain. The cross-domain assortment elements of **D** were set to zero. This model could not be rejected ($\chi^2_{23} = 27.42$, $P > 0.20$), suggesting no significant cross-assortment between cognitive and personality variables.

Next, all elements off the diagonal were set to zero. Although the goodness of fit was acceptable ($\chi^2_{30} = 41.53$, $P > 0.05$), the likelihood-ratio chi-square was significant ($\chi^2_7 = 14.11$, $P < 0.05$), and we rejected this model. Cross-assortment within domains, therefore, is required to explain the observed covariances.

The first domain, then, was tested separately for cross-assortment, and the off-diagonal element representing assortment between g-factor and education was dropped. The loss in fit was negligible ($\chi^2_1 = 0.33$, $P > 0.50$). We then tested the isomorphic diagonal elements for g-factor and education by dropping them independently. Here, the direct conditional path between g-factor scores of mates could not be dropped ($\chi^2_1 = 4.35$, $P < 0.05$). Nor could the path between spouses' educational levels be set to zero ($\chi^2_1 = 57.52$, $P < 0.0005$). Thus, in the cognitive domain, there is evidence of direct assortment for education that is independent of intelligence and also direct assortment for intelligence that is independent of education. The reduced model estimates are given in Table III.

Various indices other than chi-square have been proposed to assess the adequacy of structural models (see McArdle, 1986). One of these, the

Table III. Final Model Estimates of Direct Assortment in the CAP ($N = 334$ Couples)[a]

	Husbands					
Wives	gfac	educ	extr	anx	tough	ind
gfac	0.11	0	0	0	0	0
educ	0	0.40	0	0	0	0
extr	0	0	0.34	−0.02	−0.08	−0.14
anx	0	0	−0.02	0.10	0.02	0.04
tough	0	0	−0.08	0.02	0.05	0.08
ind	0	0	−0.14	0.04	0.08	0.23

[a] For abbreviations see Table I, footnote *a*.

Akaike Information Criterion, or AIC (Akaike, 1973, 1974), was designed to balance loss of fit in chi-square with gains in parsimony. This index minimizes negentropy, or prediction error, by increasingly penalizing the use of parameters in model fitting, according to the formula

$$\mathrm{AIC} = \chi^2 + 2k, \quad (3)$$

where k is the number of parameters used in fitting the model (see Larimore and Mehra, 1985). This approach to model fitting is particularly appropriate in the present context, where a series of plausible models is evaluated without strong theoretical justification. The AIC indices agree with the chi-square criteria presented above. Thus, the model we selected is the most parsimonious of all those tested.

In order to highlight the difference between applying conditional paths and modeling marital correlations directly, we fitted simple estimates of **M** to the observed **M** values. The test of the symmetry of **M** yielded a good fit ($\chi^2_{15} = 16.42, P > 0.30$), so a symmetric **M** was retained for subsequent comparisons.

The two-domain model failed in absolute fit ($\chi^2_{23} = 58.24$, $P < 0.0005$) as well as in likelihood-ratio comparison ($\chi^2_8 = 41.82$, $P < 0.0005$). The cross-domain assortment elements of **M** appear to have nonzero values; the results from the analysis of **D**, however, give no evidence for direct cross-assortment between the cognitive and the personality domains.

The cross-assortment element in **M** for *g*-factor and education was tested separately, as in the **D** series. The loss in fit was highly significant in this case ($\chi^2_1 = 31.37$, $P < 0.0005$), giving the opposite impression from that based on conditional paths. As in the cross-domain test, the **M** matrix can give an impression that cross-assortment exists within the cognitive domain.

Table IV. Observed Spousal Correlation Matrices for Cognitive Domain Variables in the HFSC Samples[a]

	Wives		Husbands	
	gfac	educ	gfac	educ
	Caucasian (N = 862 couples)			
Wives				
gfac	1.00	0.41	0.20	0.18
educ	0.41	1.00	0.24	0.43
Husbands				
gfac	0.20	0.24	1.00	0.45
educ	0.18	0.43	0.45	1.00
	Japanese (N = 303 couples)			
Wives				
gfac	1.00	0.47	0.14	0.24
educ	0.47	1.00	0.20	0.37
Husbands				
gfac	0.14	0.20	1.00	0.43
educ	0.24	0.37	0.43	1.00

[a] For abbreviations see Table I, footnote *a*.

In order to test the findings for education and intelligence more extensively, a second series of models was applied to only *g*-factor and education from both the CAP and the two HFSC samples. The observed full spousal correlation matrices from the HFSC samples are given in Table IV. As before, the within-person correlation matrices and all variances were fixed at observed values.

A single **D** matrix was fitted to all three samples. The fit was strikingly good ($\chi^2_8 = 5.80$, $P > 0.60$), given the large joint sample size of 1499 couples.

Next, both off-diagonal elements for cross-assortment between *g*-factor and education were set to zero. This model also fit well, both in absolute fit ($\chi^2_{10} = 6.21$, $P > 0.70$) and in change in fit ($\chi^2_2 = 0.41$, $P > 0.80$). The direct isomorphic assortment element for *g*-factor was then set to zero. Again, there was substantial loss in fit ($\chi^2_1 = 28.07$, $P < 0.0005$). As before, it can be concluded from the results of this joint analysis that there is direct independent assortment in the populations sampled for general cognitive ability and for education but that there is no cross-assortment. The final **D** estimates from the combined analysis are given in Table V.

As before, a comparison series of models was explored using marital correlations. Simple estimates of **M** were fitted to observed values. The

Table V. Final Estimates of Direct Assortment in the CAP and HFSC Samples (N = 1499 Couples)[a]

	Husbands	
Wives	gfac	educ
gfac	0.13	0
educ	0	0.40

[a] For abbreviations see Table I, footnote *a*.

full model estimating a single **M** submatrix was applied successfully to the data from all three samples ($\chi^2_8 = 6.80$, $P > 0.50$). However, setting the off-diagonal elements of **M** to zero worsened the fit considerably ($\chi^2_2 = 142.07$, $P < 0.0005$). Once again, analysis based on **M** yielded the impression of significant cross-assortment between education and general cognitive ability.

DISCUSSION

The results reported here provide evidence for direct isomorphic assortment for general cognitive ability, education, and personality traits, as well as within-domain cross-assortment for personality. The results for cognitive ability and education are of particular interest due to phenotypic homogamy versus social homogamy hypotheses regarding assortment. One social homogamy model of assortment would hypothesize that the marital correlation for general cognitive ability is merely a by-product of the impact of education on the sociospatial clustering of individuals. Our results suggest that there is direct assortment for cognitive ability independent of education and that the marital correlation for education is not exclusively due to mate attraction for intelligence.

These results also highlight the different interpretations that can arise from the analysis of marital correlations as opposed to the direct modeling of assortment parameters. In the analyses presented here, marital assortment across cognitive and personality domains appears to occur when the model is fitted to **M**; the model fitted to the **D** conditional path matrix, however, gives the opposite result, indicating no assortment between personality and cognitive domain variables. Similarly, unlike the tests based on **M**, the results based on the use of **D** indicate no cross-assortment between general cognitive ability and education, both of which show independent isomorphic assortment.

A caveat which must be stressed is that in any structural or path model, whether estimating the values of the elements of the direct assortment matrix or not, the upper limit to the model's utility is the extent to which the important explanatory variables have been included and properly specified. Wright was explicit in his caution that "the strict validity of the method depends on the properties of formally complete linear systems of unitary variables" (1968, p. 300). Future research should explore the effects of model misspecification and omission of critical variables.

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