The Assessment of Peer Selection and Peer Environmental Influences on Behavior Using Pairs of Siblings or Twins

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Many studies have found strong peer correlations for a variety of problem behaviors that begin in adolescence (e.g. substance use). Such correlations are commonly attributed to peer influences, but could also be explained by selective ('assortative') friendship: the tendency for those with similar patterns of behavior to become friends. Here we show how, under certain assumptions, cross-sectional data from pairs of siblings or twins and their peers may be used to resolve the contributions of peer selection and reciprocal peer environmental influences to peer resemblance. We performed power calculations to determine necessary sample sizes for rejecting with 80% power, at the 5% significance level, the hypothesis of only peer selection effects, or only reciprocal peer environmental effects. A false hypothesis of only selective friendship effects was always easier to reject than a false hypothesis of only reciprocal peer environmental influences. Limitations of these simulations, including uncertainty about the most appropriate way to model peer selection, are discussed.

Adult and adolescent twin studies have consistently found greater similarity in monozygotic (MZ) than dizygotic (DZ) pairs for substance use (Heath et al., 1997; Heath & Madden, 1995; Kendler & Presott, 1998; Maes et al., 1999; McGue, 1993) and other problem behaviors (Lyons et al., 1995; Slutske et al., 1997), suggesting a subsubstantial genetic influence on these traits. However, a critical assumption of twin studies is that MZ twins are no more likely to share environmental experiences than DZ twins. A strong association between twin pair concordance for the behavior under study and some important environmental risk factor that is more likely to be shared by identical than fraternal twins may result in the overestimation of genetic influences. Epidemiological studies suggest that behavior in peers is a strong predictor of different stages of cigarette use (Chassin et al., 1984; Chassin et al., 1986; Fergusson et al., 1995; Flay et al., 1994; Reimers et al., 1990; van Roosmalen & McDaniel, 1989) and other drug use (Biddle et al., 1980; Huba & Bentler, 1980; Kandel et al., 1978; Newcomb et al., 1986) and other forms of deviant behavior in adolescents and young adults (Fergusson et al., 1995; Kandel et al., 1978). Kandel (1978, 1985) has noted that, aside from socio-demographic factors (i.e. sex, age, etc.), adolescent peers are more similar with respect to drug use behaviors than they are on most other attributes, including self-report values (e.g. political or academic), and psychological traits (e.g. depressed mood). More recently, a greater similarity among pairs of friends for anti-social behaviors (e.g. starting fights, bullying, etc.) was observed in school-aged children than for other characteristics, including pro-social behaviors (e.g. cooperativeness), popularity among peers, and depressed mood (Hadelager et al., 1998). Since it is known that MZ twins are more likely than DZ twins to share the same friends (Madden et al., 1999) and to socialise together (Kendler & Gardner, 1998), it is important to determine the extent to which the strong similarity observed between pairs of siblings for the onset of and persistence of a given behavior is due to socialising with peers outside of the family.

It has frequently been assumed that similarity in the behavior of friends is due to the imitation of peer behavior or to some other form of environmental influence. Alternatively, peer resemblance might result from peer selection, where adolescents with given genetic predispositions tend to actively seek out certain environmental experiences that may increase their risk for the development of some behaviors (Plomin et al., 1977; Scarr & McCartney, 1983). It is important to evaluate the extent to which a characteristic shared by peers is due to selective (assortative) friendship, i.e. peer relations are a *consequence of* behavioral likenesses (Bauman & Ennett, 1996; Fisher & Bauman, 1988; Kandel, 1978), before assuming that the source of peer similarity is largely the product of the direct and indirect social influence of peers on one another (i.e. reciprocal peer environmental influences).

The relative importance of these two sources of peer resemblance has typically been evaluated using prospective data obtained from adolescent friendship pairs (Kandel, 1978, 1985) and groups (see Bauman & Ennett, 1996 for a review; Cohen, 1977; Fisher & Bauman, 1988). In these studies, selective friendship was indicated by a high degree of similarity between peers on some characteristic prior to the initiation of friendship (or group formation), or when

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friendships between unlike peers terminated (or odd peers left the group; i.e. peer de-selection); and an important role for peer influence was suggested when behavioral similarity between peers first occurred, or increased during the course of friendship. However, this method of examining sources of phenotypic similarity among peers has certain limitations, including the requirement that prospective data be obtained on at least two occasions, and the uninformativeness of the approach when friendship patterns have stabilised.

Here we present a method for examining sources of behavioral resemblance between peers using covariance matrices generated from cross-sectional data obtained from pairs of twins or siblings and their friends, based on a mate selection model described by Heath & Eaves (1985; see also Heath, 1987). Models devised to test the relative importance of selective friendship vs. reciprocal peer environmental influences using data on pairs of siblings and their peers are presented, along with the results of power calculations which indicate the sample sizes required to test these models.

Method

Structural Equation Model

We have used a linear structural equation model, based on earlier work by Carey (1986; see also Heath, 1987) on reciprocal sibling environmental influences, to represent the effects of peer environmental influences and selective friendship on the similarity between friends (see Bollen, 1989, for a detailed discussion of structural equation modeling). The full model, illustrated in Figure 1, is nonrecursive and hypothesises that the behavior of siblings 1 and 2 is correlated with the same behavior in their respective peers

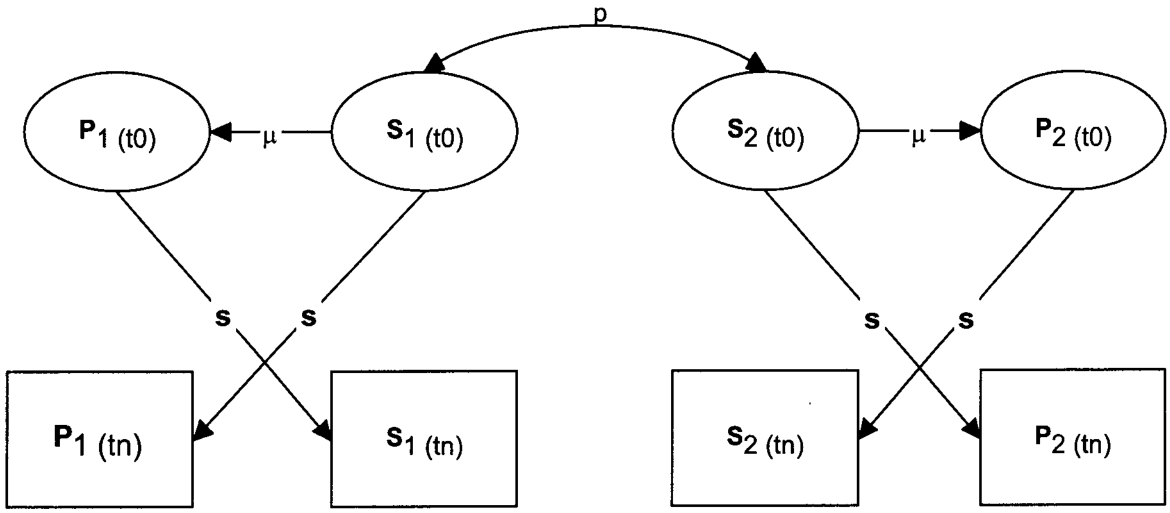

Figure 1

Path model for the resemblance of sib pairs and their peers. S_1, S_2, P_1 and P_2 denote observed variables on first and second sibs and their respective peers. ρ denotes the correlation between full siblings prior to (i.e. in the absence of) any reciprocal sibling environmental influences; μ the correlation between peers induced by peer selection; and s the direct environmental effect of one peer's behavior on that of the other peer. Subscripts (t0) and (tn) distinguish between variables at baseline (i.e. before any reciprocal peer environmental effects have occurred), and at equilibrium after changes induced by reciprocal peer influences have stabilized. In the case of data on MZ and DZ twin pairs and their peers, separate twin correlations ρ MZ or ρ DZ would be substituted for ρ, but other elements of the model will remain unchanged.

Table 1

Expected Covariance Matrix for Sib Pairs and Their Peers under a Model That Allows For Assortative Friendship (Parameter μ), and Reciprocal Peer Environmental Influences (Parameter s) (V Denotes the Total Phenotypic Variance Prior to Any Reciprocal Peer Environmental Influences, and ρ the Sibling Correlation. In Case of Data on Twin Pairs, Separate Twin Correlations ρMZ or ρDZ Would Be Substituted For ρ, Therefore, Separate Covariance Matrices Would Result For MZ Pairs and Their Peers Versus DZ Pairs and Their Peers, Unless There Were No Genetic Effects on the Trait Under Study.)

$$\frac{V}{1-s^2}\begin{array}{cccc} \text{Peer 1} & \text{Sib 1} & \text{Sib 2} & \text{Peer 2} \\ \left[\begin{array}{c} 1+2\mu s+s^2 \\ \mu+2s+\mu s^2 \\ \rho(\mu+s)(1+\mu s) \\ \rho(\mu+s)^2 \end{array}\right. & \begin{array}{c} \mu+2s+\mu s^2 \\ 1+2\mu s+s^2 \\ \rho(1+\mu s)^2 \\ \rho(\mu+s)(1+\mu s) \end{array} & \begin{array}{c} \rho(\mu+s)(1+\mu s) \\ \rho(1+\mu s)^2 \\ 1+2\mu s+s^2 \\ \mu+2s+\mu s^2 \end{array} & \left.\begin{array}{c} \rho(\mu+s)^2 \\ \rho(\mu+s)(1+\mu s) \\ \mu+2s+\mu s^2 \\ 1+2\mu s+s^2 \end{array}\right] \end{array}$$

through selective friendship (parameter μ, the path regression of peer behavior, "P", on the behavior observed in her friend, "S", who is one of the siblings). In addition, there is also a reciprocal environmental influence of the behavior of one peer on the behavior of a sibling, and vice versa (path regressions). Following Carey (1986), we derived expectations for the variances and covariances of sib pairs and their peers under the assumption that the reciprocal peer environmental influences have reached equilibrium, implying that established rather than recently formed relationships are being studied. Key assumptions implicit in this model are that siblings select peers independently, and that there is no environmental influence of the peer of one sib on the peer of the other sib. In practice, these assumptions imply that studies of same-age sibling pairs (i.e. twins) are likely to be less useful than studies of siblings who differ in age except, perhaps, in the case of models for peer selection or peer influence involving opposite-sex peers (where it is more plausible that two twins from a pair will not be attempting to date the same girlfriend or boyfriend). In Figure 1, ρ is the covariance of pairs of siblings (i.e. S_1 and S_2) prior to any reciprocal peer influences, which in the case of twin pair data may be allowed to vary as a function of zygosity. Submodels maybe compared in which (i) there is no peer selection effect (i.e. the path coefficient $\mu = 0$); and (ii) there is no reciprocal peer environmental influence (i.e. the path coefficient $s = 0$). Setting $s = 0$ implies that there is no causal influence of peers on sibling behavior, and vice versa, so that the association between the observed behavior in peers and siblings is entirely due to selective friendship p ('only selective friendship' submodel). Setting $\mu = 0$ yields a model in which associations between behavior observed in siblings and peers are only due to reciprocal environmental influences, i.e. a form of peer socialisation ('only peer influence' submodel) with no peer selection effect.

Expected Variances and Covariances

Table 1 presents the expected variances and covariances for behavior in pairs of siblings and their peers, predicted as a function of the unknown model parameters under the full model (see Figure 1), and derived by matrix algebra using the standard rules of path analysis (Bollen, 1989). Here V denotes the hypothetical variance *prior* to peer interaction, and $V/(1 + 2\mu + s^2)(1 - s^2)^{-1,}$ the variance at equilibrium after peer environmental effects have stabilised. Maximum likelihood estimates of parameters s, μ and ρ may be derived using a structural equation modeling program, such as LISREL (Joreskog & Sorbom, 1993) or MX (Neale, 1997).

Stimulation Study

In order to determine the sample sizes required to resolve peer selection and peer environmental influence hypotheses in siblings and their peers, a series of simulations was conducted. Using parameter values shown in Table 2, expected covariance matrices were generated using MX under three models: (1) the full (or mixed) model, (2) the selective friendship model, and (3) the reciprocal peer environmental influence model. Predicted sibling correlations of either 0.60 (indicating a very strong correlation between the observed behavior in siblings, such as might be observed in MZ pairs) or 0.40 (an intermediate sibling correlation, such as might be observed in DZ or full sibling pairs) were selected, as were a range of predicted peer correlations (0.65 to 0.25). Predicted sample sizes for a study combining MZ and DZ twin pairs and their peers would be expected to be intermediate between these two cases. Under the full model, the path coefficients s and μ were chosen so that peer selection and peer reciprocal environmental influences made approximately equal contributions to the predicted peer correlation. False models assuming *only* selective friendship, or *only* reciprocal peer influence effects, were fitted to the generated covariance matrices by maximum likelihood (Bollen, 1989). This procedure yields a χ^2 value that estimates the non-centrality parameter, λ' of the likelihood-ratio asymptotic χ^2 distribution. The number of sets of sibling pairs, N, with peer information needed to reject the false model at the 5% significance level, with 80% power was estimated assuming a sample size of 1,000 sets in the initial power analysis, using the power option in MX (Neale, 1997), where:

$$N = \frac{1{,}000\lambda}{}$$

where λ is the noncentrality parameter $\lambda_{(0.05,0.80,k)}$ obtained from the table of noncentral chi-square (Pearson & Hartley, 1972), and where k is the difference between the degrees of freedom under the true and false models. In the cases presented here, k = 1 (see Martin et al., 1978).

Results

Table 2 illustrates the numerical values for expected variances and covariances of sibling pairs and their peers given a predicted sibling correlation of 0.60 and peer correlation of 0.55, for the mixed, peer selection only and peer environmental influence only cases. As shown, the magnitude of the cross correlations between the behavior of one sibling

Table 2

Numerical Values For Predicted Covariance Matrices With a Sibling Correlation of 0.6 and Peer Correlation of 0.55, Assuming Peer Resemblance is Determined (a) Equally by Peer Selection, and Peer Reciprocal Environmental Influences, (b) by Peer Selection Only, or (c) by Peer Environmental Influences Only

	P1	S1	S2	P2
Peer Selection and Peer Reciprocal Environmental Influences				
P1	1.00			
S1	0.55	1.00		
S2	0.25	0.60	1.00	
P2	0.11	0.25	0.55	1.00
Peer Selection Only				
P1	1.00			
S1	0.55	1.00		
S2	0.33	0.60	1.00	
P2	0.18	0.33	0.55	1.00
Peer Environmental Influences Only				
P1	1.00			
S1	0.55	1.00		
S2	0.18	0.60	1.00	
P2	0.05	0.18	0.55	1.00

Note: P1 denotes the peer of the first sibling, S1 the first sibling, S2 the second sibling, P2 the peer of the second sibling.

and the behavior of her brother's or sister's friend, and between the peer of the first sibling and the peer of the second sibling vary substantially under different models. Both cross correlations generated under the peer selection model (0.33 and 0.18 respectively), were larger than those generated under the peer influences model (0.18 and 0.05 respectively), with the magnitude of the correlations derived from the model allowing for both sources of peer resemblance being intermediate (0.25 and 0.11 respectively). In the case of the peer selection model, the predicted

Table 3

Total Number of Sets of Sibling Pairs and Their Peers (S–P Sets) Required for 80 Percent Power of Rejection of a Given False Model at the 5 Percent Level Under Different True Models for Peer Resemblance, for Given Values of Sibling Correlations (ρ), Peer Selective Friendship Correlations (μ), and Reciprocal Peer Influence Path(s)

TRUE MODEL					FALSE MODEL	
Mixed Model			*Predicted Correlations*		Only Peer Influence ($\mu = 0$)	Only Selective Friendship ($s = 0$)
ρ	μ	s	Peer	Sibling	Number of S–P Sets	Number of S–P Sets
0.4145	0.3250	0.2156	0.65	0.40	736	554
0.4094	0.2750	0.1665	0.55	0.40	1,064	866
0.4058	0.2250	0.1272	0.45	0.40	1,631	1,407
0.4033	0.1750	0.0940	0.35	0.40	2,748	2,474
0.4016	0.1250	0.0648	0.25	0.40	5,459	5,057
0.6218	0.3250	0.2156	0.65	0.60	262	185
0.6141	0.2750	0.1665	0.55	0.60	383	291
0.6087	0.2250	0.1272	0.45	0.60	592	474
0.6050	0.1750	0.0940	0.35	0.60	1,003	835
0.6024	0.1250	0.0648	0.25	0.60	2,003	1,710
Only Selective Friendship			*Predicted Correlations*		Only Peer Influence ($s > 0, \mu = 0$)	
ρ	μ	s	Peer	Sibling	Number of S–P Sets	
0.4000	0.6500	0.000	0.65	0.40	191	
0.4000	0.5500	0.000	0.55	0.40	273	
0.4000	0.4500	0.000	0.45	0.40	414	
0.4000	0.3500	0.000	0.35	0.40	693	
0.4000	0.2500	0.000	0.25	0.40	1370	
0.6000	0.6500	0.000	0.65	0.60	70	
0.6000	0.5500	0.000	0.55	0.60	100	
0.6000	0.4500	0.000	0.45	0.60	152	
0.6000	0.3500	0.000	0.35	0.60	255	
0.6000	0.2500	0.000	0.25	0.60	504	
Only Peer Influence			*Predicted Correlations*			Only Selective Friendship ($\mu > 0, s = 0$)
ρ	μ	s	Peer	Sibling		Number of S–P Sets
0.4546	0.0000	0.3693	0.65	0.40		138
0.4359	0.0000	0.2997	0.55	0.40		216
0.4226	0.0000	0.2377	0.45	0.40		351
0.4131	0.0000	0.1807	0.35	0.40		617
0.4065	0.0000	0.1270	0.25	0.40		1,264
0.6818	0.0000	0.3693	0.65	0.60		44
0.6539	0.0000	0.2997	0.55	0.60		70
0.6339	0.0000	0.2377	0.45	0.60		116
0.6196	0.0000	0.1807	0.35	0.60		206
0.6097	0.0000	0.1270	0.25	0.60		426

Note: Total number of sets of sibling pairs and their peers required to achieve 90% and 95% power of rejection at the 5% level may be derived by multiplying the number of pairs listed for 80% power by 1.34 and 1.66 respectively. Under the mixed model, parameter values have been chosen so that peer selection effects and peer influence effects contribute equally to sib pair resemblance.

correlation between a peer of one sibling and the other sibling is simply the product of the sibling and peer correlations; and the predicted correlation between a peer of one and a peer of a second sibling, the product of the sibling correlation and the square of the sibling-peer correlation.

Table 3 gives the numbers of sets of sibling pairs and peers required to reject false models that hypothesise only a single source of peer resemblance (i.e. 'only selective friendship' and only peer influence') for a range of path coefficients (μ and s), and sibling and peer correlations. Power to reject a false model increased with increasing magnitude of the sibling and/or peer correlations. For given values of the peer and sib correlations, it was always easier to reject a false selective friendship than a false peer influence model. If the true model was selective friendship, except in cases where the predicted peer correlation was under 0.45, fewer than 500 pairs of siblings and their peers were needed to reject a false peer influence model; and in the reverse case, when the true model was reciprocal peer influences, even smaller samples of siblings and their peers were needed to reject a false selective friendship model. Under more complex circumstances, when the true model allowed for both sources of peer resemblance (i.e. the mixed model), for traits with high sibling correlations (i.e. 0.6) and moderately high peer correlations (0.35 or higher), or high peer correlations and moderately high sibling correlations (0.55 or higher, and 0.4, respectively) required sample sizes to achieve 80% power were eminently feasible (fewer than 1,100 sets of siblings and their peers, a target sample easily achievable in questionnaire studies).

Discussion

The importance of peer environmental influences on adolescent behavior may be overestimated if the contribution of peer selection effects to peer resemblance is ignored. Previously, the etiology of peer resemblance has been examined by determining whether peer similarity in behavior remains stable or changes with transitions in peer affiliation using prospective data. However, this method cannot be applied in situations where friendship patterns are stable, or where only cross-sectional data are available. We have illustrated an approach that allows use of *cross-sectional* data on pairs of siblings and their peers to estimate the separate effects of peer selection and peer reciprocal environmental influences. The statistical power of this approach is greatest when both sibling and peer correlations are high; and the power to detect peer selection effects greater than the power to detect reciprocal peer environmental influences, even when both are present and have equally important effects.

A major limitation in our approach is the assumption that each sibling chooses friends independently from her brother or sister, and that these friends do not have either a biological relationship or a personal influence on one another. Therefore, this method to examine peer similarity in behavior may not be valid for samples that include a large number of siblings reporting on the behavior of the same friend(s), such as may be observed in the case of same-sex peers for siblings who are very close in age, or with samples of twins. It would be essential, even with siblings of quite different ages, to include questions about frequency of peer sharing among brothers and sisters. We might expect to have less of a problem using best friends, or current boy or girl friends that are less likely to be shared by a sibling.

A second limitation of this approach is that we have assumed one particular mechanism of peer selection, that it is determined by the phenotype under study, rather than by correlated family background risk-factors ('social homogamy'). Models that have been developed for human mate selection to resolve mate selection based on phenotype versus social background (e.g. Heath and Eaves, 1985) may equally be applied to peer selection. The usefulness of such models when applied to data from MZ and DZ twin pairs and their peers, however, will again be dependent upon the assumption that twin pairs are selecting their friends independently.

In conclusion, when researching the determinants of the initiation and progression of substance use disorders or of other forms of problem behavior that usually begin in middle childhood or adolescence, during the period in development in which there may be a heightened vulnerability to the influence of friends, it is important to explore the impact of peer behavior. Here we present one strategy for examining the influence of peers that may account for the effects of peer selection and background characteristics using cross-sectional data obtained from siblings and their respective friends that may be readily incorporated into any family study design.

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