Appendix

Lifetime risk of Marital Instability in Women

In the adult sample 18.4% reported a lifetime history of divorce or marital separation. The Kaplan-Meier nonparametric estimate of the lifetime risk of marital instability by the age of 80 (Prob.=.44, .43-.46) is consistent with estimates of relationship disruption for women in the United States (Bramlett & Mosher, 2002). The risk of separation or divorce was .44 for the adult females in Virginia 30,000. The probabilities for separation from first marriages for non-Hispanic, white women was .42 (Bramlett & Mosher, 2002, Table 21), and the probability of first cohabitation disruption for non-hispanic white females was .68 (Bramlett & Mosher, 2002, Table 15). Few women (approximately 10%) in the cohort would have ever cohabitated; therefore, a weighted average for the probability of divorce or disruption of a cohabitating relationship in the US was 45%.

Response Rates in the Offspring of Twins

The response rate for all of the relatives of twins was 45%. For the offspring of twins, the overall response rate was 41%. Because some of the data in the study are no longer accessible, it was not possible to directly test whether there was a differential response rate in offspring of divorced and intact twins. Only adult offspring of the twins were targeted for the study, but we are unable to currently identify which offspring met the age criteria for inclusion at the time of the study. We were, however, able to calculate the response rates based on the total number of children in each family (those old enough to be originally included and those too young to be sent a questionnaire). The entire sample includes 22% of all offspring of twins (whether old enough to participate in the study or not). In intact families, 23% of all offspring participated, compared to 20% in divorced families. Although the difference in response rates is statistically significant ($t=3.39$, $p<.05$), the magnitude of the difference is relatively small.

Univariate Twin Analysis of Marital Instability

Univariate twin analyses were conducted to determine the influence of additive genetic, shared environmental, and nonshared environmental effects on marital instability in the current sample. Tetrachoric correlations and proband concordance rates were calculated for MZ and DZ twin pairs, separately by gender of the twins. The concordance rates provided an initial perspective into the underlying structure of marital instability. A structural equation model was then fit to the raw data so that twin pairs with missing data could also be included in the analyses. The model estimated the proportion of variance in marital instability which were attributed to additive genetic, shared environmental, and nonshared environmental factors. Twin models were based on the entire sample of child bearing age and the twins pairs in which offspring of at least one of the twins participated.

All of the offspring in the study had parents over the age of 35. Therefore, the twin correlations and concordance rates were based on 4,329 complete pairs of twins of known zygosity which were above the age of 35. Table A presents the twin correlations and concordance rates for the five zygosity groups. The tetrachoric correlations and concordance rates are higher for the monozygotic twins (MZ) than they are for the dizygotic twins (DZ), suggesting some genetic variation in marital instability. The DZ concordance is only slightly larger than half of the MZ concordance, indicating that shared environmental factors may minimally influence divorce. Finally, the overwhelming majority of the variation in divorce appears to be due to the nonshared environment because the MZ correlations are so low. Because there was no difference in the opposite sex DZ concordance rates compared to the same-sex DZ pairs, the sexes were combined. The tetrachoric correlations (r) and concordance rates (CR) for the MZ twins ($r = .34$, $CR = .38$, $N=2,041$) were higher than the DZ twins ($r = .20$, $CR = .29$, $N=2,288$) when the sexes were combined. A full univariate twin model indicated that the percentage of variation in divorce accounted for by genetic factors (h^2) was .15 (95% confidence interval = .04-.20). Shared environmental influences were not large (c^2=.04, .00-.06), whereas nonshared environmental influences accounted for most of the variation (e^2=.81, .77-.85). A twin study, only using twin pairs where at least one offspring of the twins participated, resulted in variance estimates commensurate with the entire sample. Additive genetic factors (7%, CI=0-22%) and shared environmental factors (8%, CI=0-19%) account for small amounts of variance in marital instability. The majority of the variance was due to nonshared environmental factors (83%, 78-90%).

The heritability for marital instability in the current analyses is lower than twin studies from Minnesota, but they are generally consistent with estimates from twin studies in Australia, the WWII Twin Registry, Finland, and another twin sample from Virginia (review in D'Onofrio et al., 2005).

Risks of Offspring Variables by Zygosity and Family Structure

The risks for each categorical variable were calculated separately by family structure and zygosity. The risks for lifetime history variables were based on Kaplan-Meier nonparametric survival analysis to control for the age of the offspring or percentages (for measures of current psychological adjustment). First, the risks are presented for unrelated offspring in intact and divorced families to establish the divorce effect in the sample. Second, the risks were broken down by family structure and twin zygosity. Family structure was separated into two categories: offspring from the divorced co-twin in discordant pairs and offspring form the co-twin who did not get divorced. Comparing the risk in these groups separately for MZ and DZ twins suggests which processes are responsible for the association of parental characteristics and offspring variables (D'Onofrio et al., 2003, Gottesman, & Bertelsen, 1989). In brief, if offspring from the divorced co-twin in MZ twins discordant for divorce have a higher risk for adjustment problems than their cousins from intact households, the findings would be consistent with a causal hypothesis. However, if the difference between offspring of the MZ twins discordant for divorce is smaller than the difference in unrelated offspring, the pattern would suggest that selection factors account for part of the relation between offspring adjustment and parental divorce. If the offspring problems associated with parental divorce were due to genetic factors, the differences between the children of discordant MZ twins would be smaller than the difference between offspring of DZ twins discordant for divorce.

The risks for the categorical offspring variables in the offspring by zygosity and family structure are presented in Table B The comparison for of unrelated offspring illustrates that parental divorce is associated with increased risk for lifetime alcohol problems, cigarette smoking, emotional problems, and depression. The comparison of offspring of discordant twins suggests the underlying causal mechanisms depend on the outcome measure. The risks in the offspring of discordant DZ *and* MZ twins for a lifetime history of alcohol problems and cigarette smoking are consistent with the comparison of unrelated offspring, suggesting that unmeasured genetic and environmental confounds do not confound the intergenerational association. The results are in contrast to the risk of internalizing problems. There was no difference in the offspring of discordant MZ twins for emotional problems or lifetime history of depression. The differences in the offspring of discordant DZ twins are larger for both measures. The pattern of results suggests that the associations between internalizing problems and parental divorce may be genetically mediated.

Hierarchical Linear Models Utilizing Methodological and Statistical Controls

A series of HLM models were fit to the data to utilize the methodological controls inherent in the CoT design and statistically control for measures of parental psychopathology. Each HLM estimated the residual variances (random effects) at the three levels to take into account the nested nature of the data. Model one estimated the relation between parental marital instability and the outcome. The model compared children of divorced families to unrelated offspring of intact families and provided a parameter referred to as the phenotypic association.

Model two estimated the same comparison, a phenotypic association, but also included measures of adult covariates. These variables were added to statistically control for characteristics of the parents which could lead to both marital separation and offspring behavior problems. The same measures of offspring functioning, but measured in the adult twins, were added to the model to statistically control for the intergenerational transmission of psychopathology. Model two represent the traditional approach to control for confounds.

Model three estimated two divorce effects. The model estimated a proxy of the between-family effect by including the average number of divorces in the twin family (0, .5, or 1) into the HLM (Jinks & Fulker, 1970). The model also compared offspring of all twins discordant for divorce by estimating the within-family effect of divorce in these families. The within-family effect compares offspring of discordant twins where one twin is not divorced (within-family variable = -.5) and the co-twin has been separated (within-family variable = .5). The coding effectively uses contrast codes to compare cousins differentially exposed to parental divorce. Model four included the measured covariates to also statistically control for selection factors.

Model five compared offspring of MZ twins discordant for divorce. The parameter represents the purest measure of the environmental association between marital instability and offspring characteristics in the design because it is not confounded by genetic and environmental factors related to the twins. The model also included the difference (DZ-MZ) in the magnitude of the within-family parameter estimates in the two twin types. If the DZ within-family estimate is larger than the MZ within-family estimate, the results suggest that shared genetic liability in both generations account for part of the intergenerational association.

Model six estimated the same parameters in model five, with respect to parental divorce (approximation of the between-family association, the MZ within-family parameter, and the difference between the within-family MZ and DZ parameters), but the model also included all of the statistical controls of parental variables. Therefore, model six combines the statistical controls with the methodological controls inherent in the CoT design. For a complete description of the analytical approach, such as the algebraic equations for each model, see D'Onofrio et al. (2005).

Results of the HLMs for lifetime history of alcohol problems and lifetime history of cigarette use are presented in Table C. The results for emotional problems and lifetime history of depression are presented in Table D. The odds ratios for the divorce effect using the various comparison groups and use of statistical covariates are also presented in Figure A. The results illustrate how the divorce effect for substance use problems remained robust to the use of statistical controls and the methodological controls (comparison of cousins) in the CoT design. In contrast, the divorce effect was negligible for the internalizing measures when offspring of discordant MZ twins were compared, suggesting internalizing problems associated with parental divorce are due to selection factors. For both measures of internalizing the comparison of offspring of discordant DZ twins was much larger than the comparison of discordant MZ twins, a pattern that implies genetic factors account for the selection factors.

Table A.
Twin Correlations and Concordance Rates for Relationship Instability

Zygosity	Tetrachoric Correlations	Concordance Rate[a]	N
MZ Male	.35	.38	580
MZ Female	.33	.37	1461
DZ Male	.23	.30	396
DZ Female	.20	.29	922
DZ Male-Female	.19	.29	970

Note. Marital instability includes divorce and separation from a cohabiting relationship. [a]Proband concordance rate are presented.

Table B.
Risk of Offspring Psychopathology by Zygosity and Family Structure

Family Structure	Lifetime Alcohol Problems[a]		Cigarette Smoking[a]		Emotional Problems[b]		Lifetime Depression[a]	
	Risk	N	Risk	N	Risk	N	Risk	N
				Unrelated Comparison[c]				
Intact	1.0	1498	37.2	1498	18.8	1769	11.7	1498
Divorced	3.2	380	52.2	379	24.6	439	24.6	380
				Offspring of Discordant DZ Twins				
Intact	1.8	277	43.8	279	17.0	277	22.1	277
Divorced	3.1	225	56.4	225	25.7	222	27.4	225
				Offspring of Discordant MZ Twins				
Intact	1.4	341	43.6	340	24.5	338	26.3	341
Divorced	4.2	312	57.7	311	24.7	308	23.8	312

Note. [a]Risks of lifetime reported problems are percentages based on Kaplan-Meier nonparametric survival analysis at the last age all groups could be compared. [b]Risks for emotional problems, as measured by the top 20% on the SCL, are based on crude percentages. [c]Unrelated comparison only uses offspring from one co-twin per twin family.

Table C.
Parameter Estimates for Substance Use Problems

	Models											
	Lifetime History of Alcohol Problems						Lifetime History of Cigarette Use					
Parameter	1	2	3	4	5	6	1	2	3	4	5	6
Divorce Effect												
Phenotypic	.74*	.66*					.16*	.10*				
Between			.65*	.49*	.65*	.49*			.17*	.08	.17*	.08
Within			.86*	.81*					.16*	.12		
Within MZ					.71*	.69*					.19*	.17*
Within (DZ-MZ)					.35	.38					-.09	-.11
Offspring gender	.79*	.79*	.79*	.79*	.79*	.79*	.05*	.06	.06*	.06	.06	.06*
Twin Parent												
Education		-.23*		-.23*		-.23*		-.02		-.02		-.02
Alcohol freq.		-.06		-.06		-.06		.01		.01		.01
LT alcohol probs.		.86*		.85*		.86*		.36*		.36*		.35*
LT cigarette use		.53*		.53*		.53*		.16*		.16*		.17*
Emotional diff.		.02		.02		.02		.04*		.04*		.04*
LT depression		.21		.21		.21		-.11		-.11		-.11
Spouse												
Education		.18		.18		.18		-.01		-.01		-.01
Alcohol freq.		.20		.20		.20		.04*		.04*		.04*
LT alcohol probs.		.66		.67		.67		-.05		-.04		-.04
LT cigarette use		-.11		-.11		-.11		.13*		.13*		.13*
Emotional diff.		-.14		-.14		-.14		.05		.05		.05
LT depression		-.31		-.31		-.31		-.08		-.08		-.08

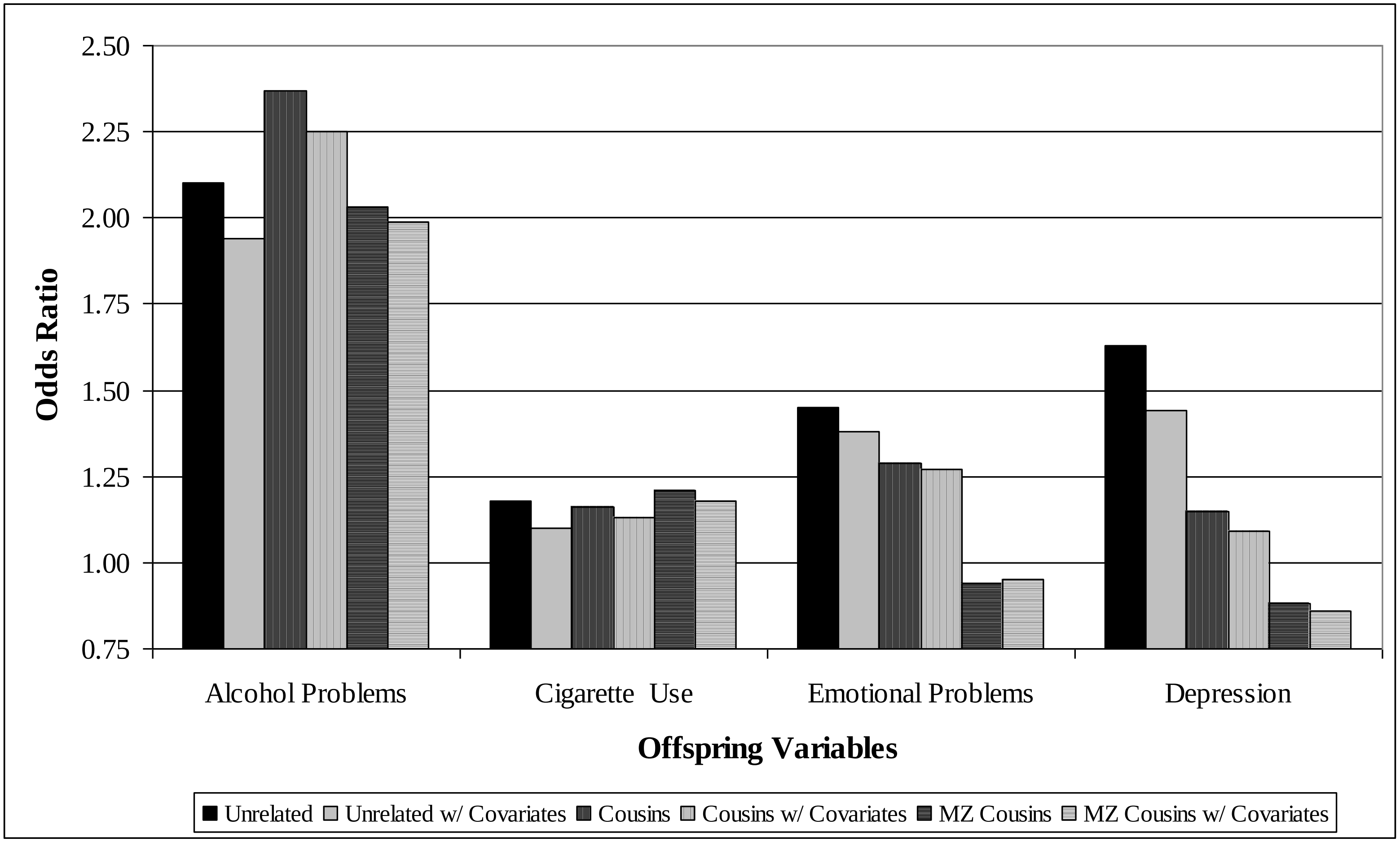
Note. LT is lifetime. *p< .05. Variance estimates at level two and three are not shown.

Table D.
Parameter Estimates for Internalizing Problems

	Models											
	Emotional Problems						Lifetime History of Depression					
Parameter	1	2	3	4	5	6	1	2	3	4	5	6
Divorce Effect												
Phenotypic	.37*	.32*					.49*	.37*				
Between			.46*	.39*	.46*	.39*			.76*	.60*	.76*	.60*
Within			.26*	.24					.14	.08		
Within MZ					-.06	-.05					-.13	-.15
Within (DZ-MZ)					.62*	.58*					.62*	.56
Offspring gender	-.51*	-.50*	-.51*	-.50*	-.50*	-.50	-.87*	-.87*	-.87*	-.87*	-.87*	-.87*
Twin Parent												
Education		-.04		-.04		-.04		.15*		.16*		.16*
Alcohol freq.		.03		.02		.02		.02		.02		.02
LT alcohol probs.		-.82*		-.81*		-.81*		-.26		-.25		-.25
LT cigarette use		-.04		-.04		-.04		.20		.19		.18
Emotional diff.		.22*		.21*		.21*		.08*		.08*		.08*
LT depression		.15		.14		.14		.87*		.87*		.87*
Spouse												
Education		-.04		-.04		-.04		-.03		-.03		-.03
Alcohol freq.		-.06		-.05		-.05		-.11*		-.11*		-.11*
LT alcohol probs.		.25		.25		.25		.54		.54		.54
LT cigarette use		.18		.17		.17		.41*		.41*		.41*
Emotional diff.		.10		.10		.10		.05		.05		.05
LT depression		.40		.30		.30		.27		.27		.27

Note. See note on Table 3.

Figure A.
Divorce Effects Using Different Control Groups and Statistical Controls



Note. The comparison of cousins was the within twin-family divorce effect, regardless of the zygosity of the twins. The MZ cousins comparison was the divorce effect in offspring of MZ twins discordant for divorce.