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A Genetically Informed Study of Marital Instability and Its Association With Offspring Psychopathology

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Abstract

Parental divorce is associated with a number of emotional and behavioral problems in young-adult offspring, but theoretical and empirical considerations suggest that the relation may be partially or fully accounted for by passive gene–environment correlation or environmental selection characteristics. The current study used the Children of Twins Design to explore whether shared environmental or genetic factors confound the relationship between parental marital instability and measures of psychopathology. Comparisons of the offspring of adult twins in Australia on 3 factors of abnormal behavior, including drug and alcohol, behavioral, and internalizing problems, suggest that environmental influences associated with divorce account for the higher rates of psychopathology. The results are consistent with a causal connection between marital instability and psychopathology in young-adult offspring.

Keywords

divorce; behavior genetics; children of twins; externalizing; depression

The high rate of marital divorce and separation has engendered great concern about the development of children because of the belief that being raised by both biological parents is the most optimal rearing situation (e.g., Popenoe, 1999). Yet, other researchers suggest that many different family forms can provide children with the necessary nurturance and guidance (Silverstein & Auerbach, 1999). Overall, the consequences of marital instability for children

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and society at large continue to be heavily debated in the academic and popular press (e.g., Emery, 2004; Hetherington & Kelly, 2002; Wallerstein, Lewis, & Blakeslee, 2000; review in Thompson & Wyatt, 1999).

Numerous studies have found that divorce is associated with problems for children across various domains, including academic difficulties, externalizing behaviors, depressed mood, lower social competence, lower self-esteem, and subclinical distress (reviews in Amato, 2000; Emery, 1999; Hetherington & Stanley-Hagan, 1999). Although the effect sizes are small to medium (Amato & Keith, 1991a), marital disruption is linked with a twofold increase in some problems, such as seeking mental health services. Parental divorce is also associated with negative outcomes and earlier life transitions as offspring enter young adulthood and later life. Psychological difficulties, socioeconomic status, educational attainment, subjective well-being, early sexual activity, nonmarital childbirth, earlier marriage, cohabitation, marital discord, and divorce are all associated with parental separation (reviews in Amato, 1999; Amato & Keith, 1991b; Emery, 1999; Furstenberg & Teitler, 1994). Although divorce has become more prevalent and socially accepted (Thornton & Young-DeMarco, 2001), the differences between children from intact and divorced families has not decreased over the past 40 years; rather, they have increased (Amato, 2001). Longitudinal research has also indicated that the magnitude of emotional problems associated with divorce increases when offspring reach young adulthood (A. J. Cherlin, Chase-Lansdale, & McRae, 1998). Reviews of the research in various western countries (Pryor & Rodgers, 2001), including Australia (Rodgers, 1996), have revealed similar findings.

All discussions and debates about the effects of divorce are based on strong assumptions regarding direct causation, consistent with the general historic notions in the social sciences (review in Rutter, 2000). This hypothesis will be referred to as the *causal* hypothesis throughout this article, because the higher rates of psychological and behavioral problems in the offspring of divorced parents are considered to be consequences of the marital disruption. In contrast, the *selection* hypothesis emphasizes that divorced adults are different from nondivorced parents and that these differences lead both to marital disruptions and to later adjustment problems in the offspring (e.g., Emery, Waldron, Kitzmann, & Aaron, 1999). A number of research paradigms have suggested that selection factors may account for the relation between parental divorce and offspring psychological and behavioral problems. Prospective, longitudinal studies have demonstrated that many of the psychological problems found among children after divorce were present before the parents' marital separation (Block, Block, & Gjerde, 1986; Doherty & Needle, 1991; Sun, 2001). Statistically controlling for predivorce functioning sharply reduces the association between divorce and behavior problems and achievement during childhood and adolescence (e.g., J. C. Cherlin et al., 1991). Family and parental characteristics that precede a separation, such as marital conflict (Amato, Loomis, & Booth, 1995) and parental psychopathology (Hope, Power, & Rodgers, 1999), may also account for the postdivorce behavioral problems in the offspring (Hetherington, Bridges, & Insabella, 1998). Even more distal factors, such as maternal history of delinquency, may likewise account for the adjustment problems in the offspring of divorced parents (Capaldi & Patterson, 1991; Emery, Waldron, Kitzmann, & Aaron, 1999).

Twin studies have shown that genetic factors influence divorce and marital stability (Jockin, McGue, & Lykken, 1996; McGue & Lykken, 1992; Trumbetta & Gottesman, 1997), suggesting that outcomes in offspring related to parental divorce may be due to genotypic factors. Because parents both provide the environment for their children and transmit their genes to their offspring, environmental and genetic factors are correlated. The situation in which a common genetic component influences both the environment a parent provides and the subsequent outcomes in the offspring is referred to as a *passive gene–environment correlation* (rGE; Eaves, Last, Martin, & Jinks, 1977; Plomin, DeFries, & Loehlin, 1977; Scarr & McCartney, 1983;

review in Rutter & Silberg, 2002). Under such conditions, the relationship between parental divorce and the offspring outcomes would be spurious, with parental divorce being an epiphenomenon representing genetic risk for the outcome (Rutter et al., 1997).

To date, a few genetically informed studies of children's adjustment to divorce have been conducted. O'Connor, Caspi, DeFries, and Plomin (2000) used the Colorado Adoption Project to study the environmental and genetic mechanisms that account for the increased difficulties in 12-year-old offspring of divorced families, because assuming the absence of selective placement, there is no passive rGE in adopted families. Adopted children in divorced families reported more behavior problems and substance use than did adopted children in intact families, suggesting an environmental mediation of these outcomes. In contrast, adopted children in divorced families did not differ from adopted children in intact families on school achievement and social adjustment, suggesting that passive rGE accounted for the intergenerational associations. The adoption design is considered to be the strongest test of genetic mediation of intergenerational associations because of the clear separation of genetic and environmental variation. However, the study is limited by the relatively small sample, the weak power to detect differences among families, and the assumption that divorce influences biological and adoptive children similarly (Rutter, Pickles, Murray, & Eaves, 2001).

Kendler, Neale, Kessler, Heath, and Eaves (1992) reported that parental separation was associated with an increased risk of major depression and generalized anxiety disorder in adult women when the direct measure of parental loss was included in a univariate twin analysis. However, as the authors noted, the analyses are hindered by the assumption that parental separation is a purely environmental risk factor (no passive rGE). A study of early parental loss using an extended twin-family design, a design that includes the influence of rGE, suggested that environmental mechanisms accounted for most of the association with alcohol abuse (Kendler et al., 1996). However, Meyer et al. (2000) reported that the statistical association between marital discord and adolescent conduct problems was mediated by shared genetic factors related to conduct problems in both generations. Extended twin-family studies are able to test both causal and selection processes, but the design includes several major methodological assumptions and restrictions that limit the interpretability and generalizability of the results (D'Onofrio et al., 2003; Rutter et al., 2001).

Certainly, both causal and selection mechanisms may be operating simultaneously or to different degrees, depending on the outcome. Delineating between the causal and selection processes is a major goal for divorce researchers and is especially important because the findings will help guide public policy decisions and intervention efforts. Therefore, genetically informed studies of divorce and other environmental risk factors with fewer and different methodological limitations are required, a need echoed by family researchers (e.g., Booth, Carver, & Granger, 2000) and developmental psychologists (Collins, Maccoby, Steinberg, Hetherington, & Bornstein, 2000).

Methodological Requirements for Inferring Causation

Researchers obviously cannot randomly assign children to different family environments. Thus, definitively determining whether divorce causes problems in the offspring is extremely difficult, if not impossible. This is due to the myriad alternative explanations that can account for the difference between children from divorced and intact families. Given these methodological limitations, Rutter et al. (2001) outlined several key needs for the study of environmental causal effects on behavior. In particular, the authors stressed the importance of delineating between alternative hypotheses and using quasi-experimental designs to differentiate between environmental mechanisms from alternative forms of risk mediation, especially genetic processes. This article uses the Children of Twins (CoT) Design to investigate the association between parental divorce and family outcomes.

Figure 1 is a graphical representation of how differences in the magnitude of the divorce effect from a few family designs can help account for correlated confounds (see Kendler et al., 1993, for a similar description with a co-twin control design). The first bar represents the hypothetical risk associated with parental divorce, measured as an effect size, when children of divorced families are compared with children of unrelated, intact families (i.e., the children being compared are unrelated to each other). Because of the nonexperimental nature of the studies, the between-families effects include the influence of divorce and everything that is correlated with the divorce between families (Turkheimer et al., 2005). Regression-based statistical controls can be applied for measured potential confounds, but it is, in general, not possible to determine whether all salient confounds have been included in the analyses.

An alternative methodological approach to account for between-families confounds is to study the children of related individuals, such as siblings. The second bar in Figure 1 represents the magnitude of the divorce effect when children of siblings discordant for divorce are compared. In the design, the offspring of divorced parents are compared with their cousins whose parents remained married. This comparison enables the estimation of a within-sibling-family effect free from between-sibling-families confounds (e.g., Dick, Johnson, Viken, & Rose, 2000;Rogers, Cleveland, van der Oord, & Rowe, 2000). Therefore, the design effectively pulls apart the environmental risk factor from correlated confounds associated with divorce that vary among unrelated families (between-sibling-families confounds), which can be either environmental or genetic in origin because unrelated individuals differ in both respects. To our knowledge, offspring of discordant adult siblings as a control for unmeasured between-families factors have not been used in the study of the relations between parental divorce and child characteristics.

Using offspring of discordant dizygotic (DZ) twins (the third bar in Figure 1) provides a similar comparison with the offspring of discordant siblings except that twins are born at the same time and share similar prenatal experiences. Therefore, if the within-twin-family effect size using discordant DZ twins is less than the divorce effect using discordant siblings, then age differences in the adults, certain prenatal experiences for the twins, or differential treatment of the adult twins compared with singletons may account for part of the intergenerational association.

The final bar in the graph is the magnitude of the divorce effect comparing offspring of monozygotic (MZ) twins discordant for divorce. If the effect size using discordant MZ twin families is less than the effect size in DZ discordant twin families (and making the standard assumption of no excess environmental correlation of MZ compared with DZ twins), genetic factors may account for some of the association between offspring adjustment and parental divorce. Children of MZ twins share 50% of their genes with each of their parents and with their parent's co-twin; however, only the children's parents provide the environment. As a result, all of the offspring in discordant MZ families receive the same genetic risk associated with divorce from the twins, but only the offspring of the divorced twin would experience the separation of their parents. In comparison, the children of the DZ co-twin that has not been divorced share only 25% of their genetic makeup with their divorced aunt or uncle. Therefore, children of discordant DZ twins differ with respect to their family environment and genetic risk associated with divorce from their twin parent, whereas offspring of discordant MZ twins differ only with respect to the environmental risk related to divorce.

If the within-twin-family estimate in MZ families is 0, then divorce does not cause the problems in the offspring. Such a finding would not explain whether common environments

(environments that make the twins similar) or genetic factors account for the overall correlation between parental divorce and child adjustment. However, a comparison of the within-twin-family estimates from MZ and DZ twin families can help delineate the underlying mechanisms. If the within-twin-family effect size from DZ discordant twins is larger than for MZ discordant twins, genetic factors may account for that part of the association because the only difference in the families is the degree of genetic risk associated with divorce that the offspring receive. If the within-twin-family estimate from both MZ and DZ twin families are the same and lower than the between-families estimate, then shared environmental factors are responsible for higher levels of psychopathology because offspring from intact and divorced families would share the risk factor, regardless of their genetic risk associated with divorce.

The comparison of offspring of MZ twins discordant for divorce controls for environmental factors that influence the adult twins similarly and the genetic risk associated with divorce from the twin parent of the offspring. However, the approach does not provide methodological controls for environmental risk factors that influence only one of the adult twins and their offspring (within-twin-family confounds). The design also does not account for the genetic and environmental influence of the spouses of the twins. Therefore, measured characteristics of the twins and their spouses can be included in the analysis as covariates to statistically account for these confounds (Jacob et al., 2003; Rutter et al., 2001).

This article uses a large genetically informative sample from Australia to address the limitations in the divorce literature that either ignored the role of passive rGE or used genetically informative designs that require major methodological assumptions. First, we estimated the heritability of marital instability to determine whether genetic factors influenced this trait in Australia. Second, we contrasted offspring who experienced the separation of their parents before or after the age of 16 to offspring from intact families to determine whether age of parental divorce was associated with psychopathology in young adulthood. Third, we presented the mean levels of psychopathology in offspring of MZ and DZ twins concordant and discordant for divorce to provide an initial glimpse into the underlying processes responsible for the association between parental divorce and offspring adjustment. Fourth, we fit a series of hierarchical linear models (HLMs) to compare the magnitude of the divorce effects following the logic portrayed in Figure 1 and outlined above. In various analyses, we also included measures of psychological difficulties, behavioral problems, and demographic characteristics of both parents in the models to statistically account for these covariates.

Method

Samples

Longitudinal study of adult twins and their spouses—Twins were drawn from the Australian National Twin Register (ATR), a volunteer register recruited through the media, schools, and other resources. Three major health and behavior surveys of a single cohort have been conducted on the twins and their relatives in the current cohort of the ATR. All twins in these samples were born between 1893 and 1965 (25th percentile = 1939, and 75th percentile = 1958). The first survey, referred to as the Canberra study, was a mailed questionnaire conducted in 1980–1981 (N = 8,183 individual twins, 69% response rate; Jardine & Martin, 1984). A second mailed questionnaire, the Alcohol Cohort Follow-up I study, was completed in 1988–1989, and the sampling was based on the complete pairs from the Canberra sample (N = 6,327 individuals, 83% response rate; Heath & Martin, 1994). All twins responding to this study were asked to provide the names and addresses of their parents, siblings, spouses, and children, who were then mailed a similar questionnaire. Relatives of the twins (N = 14,421), including 3,318 spouses, were assessed with a similar questionnaire (Lake, Eaves, Maes, Heath, & Martin, 2000). The third survey (Semi-Structured Assessment for the Genetics of Alcoholism [SSAGA]) consisted of a telephone interview for twins and their spouses in 1992–

1993 (*N* = 5,889 individual twins, *N* = 3,844 spouses, 86% response rate; Heath et al., 1997). The ATR is a volunteer sample, but the sample demographics are broadly consistent with the population demographics of the cohort from which the twin parents were drawn. In addition, various tests for self-selection biases in the sample have found few detectable differences in terms of risk for abnormal behavior (Heath et al., 1997; Slutske et al., 1997). The sample includes only a small numbers of ethnic minorities, consistent with the predominately White nature of the Australian population for the birth cohort.

Offspring of twins—Data have also been collected from the offspring of adult twins in three targeted subgroups and in a control group. The three at-risk groups include (a) twins with a history of alcohol dependence and/or conduct disorder, (b) twins with a history of depression, and (c) twins with a history of divorce. Offspring of both twins were targeted if either of the twins reported a history of the disorders or divorce. The adult twins were initially contacted for consent to contact their children. Once consent was given, the offspring were contacted and, if willing, completed a telephone interview and mailed survey. In total, 1,409 adult twins completed the screening interview (85% response rate), and 2,554 offspring completed the telephone interview (82% response rate). A majority of the offspring (51%, *n* = 1,296) came from nuclear families in which the twin parent did not endorse a history of alcohol dependence, conduct disorder, depression, or divorce. Approximately a quarter (24%, *n* = 601) of the offspring came from twin families in which neither twin reported a history of the disorders or divorce.

The average age of the offspring was 25.1 years (range = 14–39 years); 50.6% were women, and 49.4% were men. Of the 2,554 offspring in the study, approximately 77% (*n* = 1,959) were from intact families, 17.3% (*n* = 442) experienced the separation of their parents before the age of 16, and 6% (*n* = 153) experienced the separation of their parents after the age of 16. The offspring also reported on their current marital status: 28.3% were married, 3.8% were divorced or separated, and 68.4% had never been married. A subsample of the offspring (*n* = 176) completed the interview a second time to establish the reliability of the instrument. They were reinterviewed on average 1.08 years (range = 0.51–1.62 years) after initial assessment.

Measures of Parental Characteristics

Marital instability—The Canberra study included questions about current marital status and number of years in present marital state. The questionnaire for the Alcohol Cohort Follow-up I study included a detailed history of marriage and marriage-like unions. Questions ascertained current marital status and the length, in years, of the current marital status. The respondents then provided information on up to three spouses or de facto partners, including date of birth of the spouse, date the couple married or started living together, how the relationship ended, and the year the relationship ended. The SSAGA study included questions on current marital status, number of years in current marital state, and lifetime history of cohabitation. On the basis of these questions, the lifetime history of divorce or marital separation, including separation from a cohabiting relationship, was calculated for each participant (cohabitation was defined as living with someone for over 6 months). Divorce and separation were combined for a few reasons, including the substantial number of married couples who separate without legally divorcing (Bramlett & Mosher, 2001); the recent research illustrating that parental separation is associated with problems similar to parental divorce (e.g., Ackerman, Brown, D'Eramo, & Izard, 2002); the growing number of children who experience the separation of cohabiting, but never married, parents (Bumpass & Lu, 2000); and because a grouping of parental separation with divorce is consistent with other genetically informed studies of parental divorce (Cadoret et al., 1995; O'Connor, Caspi, DeFries, & Plomin, 2003; O'Connor et al., 2000).

Psychopathology, drug and alcohol problems, and demographic characteristics—The SSAGA (Bucholz et al., 1994), an assessment of physical, psychological, and social manifestations of alcohol abuse or dependence and related psychiatric disorders, was administered to the twins and their spouses. The SSAGA is based on previously validated research interviews and demonstrates moderate to high interrater reliability across disorders and dimensions examined. Cohen's kappa ranges from .72 to .95 for substance abuse or dependence, and from .42 to .70 and .65 to .74 for antisocial personality and lifetime depression, respectively (Bucholz et al., 1994). The SSAGA was originally developed for the Collaborative Study on the Genetics of Alcoholism but has been adapted for use as a diagnostic telephone interview in Australia (e.g., Slutske et al., 1998).

The number of lifetime symptoms of *Diagnostic and Statistical Manual of Mental Disorders* (3rd ed., rev.; American Psychiatric Association, 1987) diagnoses for conduct disorder, alcohol abuse, and major depression were calculated for each twin and his or her spouse. The lifetime history of ever using an illegal drug (24.67%) was also included. The twin's and spouse's history of suicidality was calculated with a 5-point Likert scale (1 = *no thoughts or plans of suicide*, 2 = *transitory thoughts of plan or attempt*, 3 = *persistent thoughts about suicide*, 4 = *plan for suicide or minor attempt*, 5 = *serious suicide attempt*; Statham et al., 1998). Each adult also reported the dates of birth of all of their children. On the basis of the information, each parent's age at the birth of their first child was calculated. Finally, the twins and their spouses reported their highest level of education on a 7-point Likert scale (1 = *less than 7 years' schooling*, 2 = *8–10 years' schooling*, 3 = *11–12 years' schooling*, 4 = *apprenticeship, diploma, and so forth*, 5 = *technical or teachers' college*, 6 = *university first degree*, and 7 = *university postgraduate training*).

Spousal information was included in the analyses if the spouse was the biological parent of all of the offspring in the nuclear family. We converted the twin and spousal information to maternal and paternal variables to explore whether the association between parental characteristics and offspring relationship instability was dependent on gender of the parent.

Offspring of twins study—All offspring from the three at-risk and control samples were given the same assessment, which included the version of the SSAGA adopted for interviews in Australia. The version of the SSAGA used for the offspring of adult twins included retrospective recall of *Diagnostic and Statistical Manual of Mental Disorders* (4th ed.; *DSM–IV*; American Psychiatric Association, 1994) items for oppositional-defiant disorder, attention-deficit/hyperactivity disorder, and conduct disorder. It also included lifetime history measures of cigarette use, regular smoking (smoking cigarettes daily for a period of 3 weeks), alcohol use, regular alcohol use (drinking once a month for 6 or more months), ever becoming drunk, frequent bingeing, frequent drunkenness, frequent consumption, *DSM–IV* alcohol abuse items, *DSM–IV* alcohol dependence items, arrests for drunk driving, drug use (including sedatives, stimulants, opiates, marijuana, cocaine, hallucinogens, PCP, solvents, and inhalants), heavy drug use (use of illicit drugs more than 11 times), use of drugs in larger amounts than initially intended, developed tolerance to illicit drugs, drug use leading to dangerous situations, drug use interfering with work or household responsibilities, work causing emotional problems, desire to reduce drug use three or more times in lifetime, *DSM–IV* items for major depressive episode, suicidal ideation, plan for committing suicide, suicide attempt, and self-injury.

One child per twin family was initially selected for an exploratory factor analysis. We did not analyze all children at once to avoid correlated responses that were due to the relatedness of the offspring in the same nuclear and twin family. An exploratory factor analysis of the 81 dichotomous variables was conducted with Mplus (Muthén & Muthén, 2002). Because we were unable to incorporate missing values with an analysis of categorical variables, individuals with missing values were dropped from the analysis. Of the original 889 selected offspring, 811 with complete data were included. The seventh *DSM–IV* conduct disorder item (force someone to have sex with you) had to be dropped because of its low-response frequency. The exploratory factor analysis resulted in a three-factor solution, and the factors were rotated with Promax rotation.

The first factor, referred to as the Drug and Alcohol factor, includes cigarette use, alcohol use, alcohol abuse, alcohol dependence, drug use, and problems associated with drug use. Items from the conduct disorder criteria, including deliberately destroying property, breaking into a house, stealing nontrivial items, and serious violations of rules (such as staying out despite parental prohibitions, running away from home twice, and truancy) also loaded on the factor. The second factor is referred to as the Behavioral Problems factor and includes retrospective reports of oppositional defiant behaviors, attention problems, hyperactivity, *DSM–IV* conduct disorder items (excluding serious violations of rules), and report of recurrent legal problems due to alcohol use. The third factor includes depressive episode criteria and suicidal items; it is referred to as an Internalizing factor. Two items—being physically cruel to animals (fifth conduct disorder item) and self-harm—did not load on any factor. An exploratory factor analysis of all offspring records using Mplus, ignoring the correlated structure of the data, resulted in the same three-factor structure with similar factor loadings.

Each factor showed high internal consistency (Factor 1 α = .90, Factor 2 α = .87, Factor 3 α = .91).[1] We calculated factor scores for each child by summing the items that loaded on each factor. We then completed a square root transformation on each factor to reduce the skew in the variables. Finally, the variables were converted to *Z* scores so that the units of measurement would be standard deviations. The Drug and Alcohol (r = .89), Behavioral Problems (r = .78), and Internalizing (r = .74) factors exhibited high test–retest correlations in the sample of offspring who were reinterviewed, on average, 1 year later.

Analyses

Univariate twin analysis of marital instability—To explore genetic variation in marital instability, we completed a univariate twin analyses on the entire cohort of twins. The tetrachoric correlations and concordance rates are presented for the MZ and DZ twins from the ATR (for a review of how to interpret these statistics, see Neale & Cardon, 1992; Plomin, DeFries, McClearn, & McGuffin, 2001). Individual twins who had never been married or in a cohabiting relationship were not included in the analyses. We based estimates of the proportion of variation that were due to additive genetic (A), shared environmental (C), and nonshared environmental (E) factors on a maximum-likelihood analysis of the raw data to allow the inclusion of twin pairs in which one twin had missing data (Neale, Boker, Xie, & Maes, 2002). The heritability is the proportion of the total variance that is due to genetic factors. Shared environmental influences are environmental factors that make twins similar, whereas the nonshared environmental factor represents the proportion of the total variance that is due to environmental factors that make twins dissimilar (the variation also includes measurement error). Confidence intervals around the variance components from the full ACE model were provided.

Comparison of psychopathology level by age of parental separation—We conducted analyses of covariance (ANCOVAs) to determine whether age of divorce was related to psychopathology in the young adult offspring using the SAS Mixed Procedure (Littell, Milliken, Stroup, & Wolfinger, 1996), which accounted for multiple children per family. The offspring were divided into three groups: those who never experienced the

[1]The three factors exhibited moderate to large intrafactor correlations ($r_{F1–F2}$ = .49, $r_{F1–F3}$ = .41, $r_{F2–F3}$ = .39). Complete results of the exploratory factor analysis, including eigenvalues and factor loadings, are presented elsewhere (D'Onofrio, in press; Lynch et al., 2005).

separation of their parents, those who experienced the separation of their parents before the age of 16, and those who experienced the separation of their parents after the age of 16. If the separation groups were related to the psychopathology factors, two specific comparisons were made. The separation before the age of 16 and the separation after the age of 16 groups were individually compared with the offspring who never experienced a separation.[2]

Means for offspring in concordant and discordant twin families—The means of the three outcome factors in the offspring are presented for children in eight groups. The means were calculated separately for offspring in the following four groups for MZ and DZ families: (a) the children from twin families concordant for being married, (b) the children of married twins in twin families discordant for divorce, (c) the children of divorced twins in twin families discordant for divorce, and (d) the children from twin families concordant for divorce. Figure 2 is a graphical representation of the four groups of families. A comparison of the means provides an initial glimpse into competing environmental and genetic explanations for offspring difficulties associated with parental divorce (see D'Onofrio et al., 2003;Gottesman & Bertelsen, 1989). In discordant MZ families, if children of the divorced co-twin have more problems than do children of the married co-twin, this supports a causal explanation. In contrast, finding no difference between the offspring of discordant MZ twins would support a selection effect. If differences between the children of discordant DZ twins are larger than between children of MZ twins, genetic factors contribute to the selection effect. However, if differences between the offspring of discordant twins are equivalent for MZ and DZ twins, environmental factors in the twins' family of origin (e.g., poverty, parental divorce) account for the selection effect.

HLMs for comparison of the magnitude of the divorce effects from various family designs—We conducted the HLMs using SAS Mixed Procedure to calculate the divorce effects for children of concordant and discordant MZ and DZ twins, provide appropriate tests of significance, and control for measured covariates (Littell et al., 1996). Previous analyses of CoT data have shown that this analytic strategy involves a nested three-level model: the individual level, the nuclear-family level, and the twin-family level (Nance, 1976; Nance & Corey, 1976).[3] The first level, the individual level, includes the offspring alone (see Figure 3). The second level includes nuclear families, which, in turn, are nested under the third level of twin families. Whereas earlier analyses used nested analyses of variance (ANOVAs) to test effects at these three levels, the current analyses employed three-level HLMs (review in Raudenbush & Bryk, 2002). The approach can be used to analyze regression problems with nonindependent observations (i.e., multiple offspring per family).

Five HLMs were fit for each outcome: a baseline model (Model 1), a traditional between-families model (Model 2), a within-twin-families model (Model 3), a within-twin-families model including the interaction with zygosity (Model 4), and a within-twin-families model including both the zygosity interaction and several measured covariates (Model 5). (See the Appendix for a full description of the rationale and the algebraic representations for each model). Model 1 fit an unconditional model to the data, which simply estimated the variance of the offspring outcome attributable to each of the three levels discussed above: individual, nuclear family, and twin family. The model provided information on how the variability in the child outcome variable is distributed between and within families and is similar to a nested ANOVA.[4] Model 2 included the influence of parental divorce (a nuclear-family level variable)

[2]Thirty-four offspring reported that one of their parents had died before the offspring reached the age of 16, but the offspring did not differ from the offspring in the never separated group on the three psychopathology factors. Therefore, children who lost a parent because of death were combined with the never separated group for the analyses.

[3]The three levels of the CoT Design have also been referred to as the *within sibships*, *between sibships within twin families*, and *among twin families levels* (e.g., Magnus, 1984).

and the offspring's age, age^2, and gender (individual level variables).[5] The model provided a typical divorce analysis that compares children of divorced families with unrelated children from intact families.

Model 3 is similar to a sibling-control design because it enabled the influence of divorce to be separated into between- and within-twin-family estimates. The total number of divorces in a twin family was broken into (a) the average number of divorces in the twin family and (b) the deviation of each nuclear family from their twin family average. The average of the divorces in the two twin families (0, .5, or 1) was included as a variable at the third level (twin-family level) because it is a characteristic that all cousins (children of both twins) share, regardless of the marital status of their parents. The regression weight associated with the variable is a rough estimate of the between-twin-families association with divorce (a comparison of unrelated families). The deviation of each twin's divorce status from the family mean is a second-level variable. If both twins are divorced, or neither has separated, the score is 0 for both nuclear families because there is no variability in divorce within the twin family. For discordant twins, the score is −.5 if the twin parent never divorced and .5 if the twin parents had divorced. Therefore, this second-level variable estimates the within-twin-family effect (a comparison of offspring of discordant twins), regardless of the twins' zygosity. The most important parameter in Model 3 is the within-twin-family estimate because it is free from all confounds related to divorce that vary between unrelated families.

Model 4 explored whether the within-twin-family estimate (the comparison of the offspring of discordant twins) is different for MZ and DZ families. In addition to all of the variables from the third model, the model included the interaction between the within-twin-family divorce variable and zygosity (MZ = 0 and DZ = 1). As a result, the model estimated the within-twin-family estimate for MZ families and the difference between the within-twin-family estimates for DZ and MZ families (DZ – MZ). The latter value is the value associated with the interaction term and provided information about the statistical precision of the difference between these two divorce effects. A larger divorce effect in discordant DZ families would suggest some genetic mediation (passive rGE). We also included the main effect of the zygosity in the model to determine whether offspring from MZ families had different levels of psychopathology from offspring from DZ families.

Finally, Model 5 added measured covariates of parental characteristics to Model 4 to statistically control for possible confounds. We also added these measures to help statistically control for the fact that offspring were chosen, in part, because of the characteristics of the twins. Covariates included lifetime history of maternal and paternal conduct disorder, alcohol abuse, major depression, drug use, smoking, suicidality, education level, and age at birth of first child. Because there was some incomplete data on the parental measures, the HLMs were based on five data sets in which the missing scores were estimated through multiple imputation (reviews in Little & Rubin, 1987; Rubin, 1987; Schafer, 1997). As a result, the estimates of the parameters and the standard errors, by use of multiple imputation, reflect the uncertainty that is due to the missing values.

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[4]Similar to the estimation of the biometric parameters in the standard twin design (h^2, c^2, and e^2) from the between and within variance components of MZ and DZ twins (e.g., Jinks & Fulker, 1970), the variance components at the three levels of analysis using offspring of MZ twins (Nance, 1976; Nance & Corey, 1976) and a combination of MZ and DZ twins (Magnus, 1984) can be used to estimate various genetic and environmental influences on the offspring trait. For simplicity, the three variance components were the only random effects estimated in the subsequent models because the parameters helped account for the nested nature of the data.

[5]Because of the small number of families in which there was variability in the age of parental separation among siblings (i.e., some siblings experienced parental divorce before age 16, and other siblings experienced it after the age of 16), the age of parental divorce was considered a nuclear-family level variable and was based on the average of all siblings in the few instances when there were differences (see D'Onofrio, in press, for more details).

Unstandardized coefficients are reported for the analyses instead of standardized estimates. Standardized estimates are not parameters describing invariant causal processes because they are influenced by many factors unrelated to the causal relationship being studied, especially the variance of the independent variable (Kim & Ferree, 1981, p. 195). Furthermore, the variance of the other predictive variables in the model, the covariances of the variables in the model, and the variance of related variables that were excluded from the analyses also influence the standardized variable (Kim & Mueller, 1976). The unstandardized coefficient, in contrast, is not confounded by these factors. To place the unstandardized estimates on an interpretable scale, we standardized the offspring variables before conducting the analyses using unstandardized coefficients (see Kim & Ferree, 1981, for an explanation of the distinction between standardizing variables and using standardized coefficients).

Results

Univariate Twin Analysis of Marital Instability

Table 1 lists the prevalence, proband concordance rates, tetrachoric correlations, and sample size for marital instability in the five zygosity and gender groups. The estimates suggest genetic variation in marital instability because the MZ concordance rates are higher than the DZ rates. However, the overwhelming source of variation is in the nonshared environment because the concordance rates of the MZ and DZ twins are so low. There is little evidence for shared environmental influences. A full ACE model indicated that the proportion of variance in marital instability attributable to additive genetic factors was 15% (95% confidence interval [CI] = 5%–19%). Environmental influences that made twins more similar accounted for little variance (0%; 95% CI = 0%–7%). The nonshared environment accounted for approximately 85% of the variance (95% CI = 81%–90%).

Comparison of Psychopathology Level With Age of Parental Separation

We used ANCOVAs to compare the three separation group (never separated, parental separation before the age of 16, and parental separation after the age of 16), controlling for gender, age, and age^2 of the offspring. The means of the psychopathology factors, by separation group, are presented in Table 2. The Drug and Alcohol factor was related to the three separation groups, $F(2, 186) = 18.47$, $p < .01$. Offspring in the early separation group reported more problems than the never separated group, $F(1, 1628) = 36.93$, $p < .01$, but offspring in the never and the late separation groups did not differ, $F(1, 1628) = 1.03$, $p = .31$. Behavioral problems were also related to the three separation groups, $F(2, 186) = 15.33$, $p < .01$. Offspring in the separation before, $F(1, 1629) = 26.21$, $p < .01$, and after the age of 16, $F(1, 1629) = 9.16$, $p < .01$, groups reported more behavioral problems. A post hoc comparison revealed no difference in behavioral problems between the early and late separation groups, $F(1, 186) = 0.04$, $p = .84$. The Internalizing factor was also related to the three separation groups, $F(2, 184) = 16.56$, $p < .01$. However, only offspring who experienced early separation, $F(1, 1624) = 29.65$, $p < .01$, reported more problems than the offspring who never experienced a separation; for the late separation group, $F(1, 1624) = 2.75$, $p = .10$. As a result of the ANCOVAs the association between parental divorce before the age of 16 and the Drug and Alcohol and Internalizing factors was further explored, and the relation between parental divorce, regardless of the timing, and the Behavioral Problems factor was examined.

Means for Offspring in Concordant and Discordant Twin Families

The means and regression analyses were performed with 2,527 of the offspring with complete data on parental divorce, avuncular (parent's co-twin) divorce, twin zygosity, and measures of psychopathology. The offspring who were not used in the analysis did not differ from the offspring included with respect to parental divorce, twin zygosity, drug and alcohol use, behavioral problems, or internalizing. The majority of the offspring (*n* = 25) were dropped from the analyses because there was no information about their aunt or uncle’s marital status.

Table 3 contains the means (in *Z* scores) and standard deviations for the three outcome factors in the offspring of the concordant and discordant twin families by the zygosity of the twins. The most telling comparison is between offspring from discordant MZ twin families because the difference is not confounded by genetic or environmental factors shared by the twins. The differences between offspring from the intact and the divorced MZ families on the Drug and Alcohol (−.12 vs. .22), Behavioral Problems (−.05 vs. .10), and Internalizing factors (−.04 vs. .23) suggest that parental divorce and environmental factors specifically related to divorce account for some of the association between parental marital instability and psychopathology in young adult offspring. The differences in the means of the children in the discordant DZ families are similar to those in the discordant MZ families, although the difference appears to be smaller for the Drug and Alcohol factor (counter to what would be expected for shared environmental or genetic influences) and slightly larger for the Internalizing factor (consistent with a partial influence of genetic factors). We conducted hierarchical analyses to provide appropriate statistical tests of the effect sizes, consider the clustered nature of the data, and control for measured confounds.

HLMs for Comparison of the Magnitude of the Divorce Effects From Various Family Designs

The results of the HLMs for the Drug and Alcohol factor are presented in Table 4. The unconditional model indicates that most of the variation in the factor is due to differences within nuclear families (the individual level). Model 2 indicates that parental divorce before the age of 16 is associated with a .32 difference in the Drug and Alcohol factor when children from intact families are compared with unrelated children (i.e., not cousins) in divorced families. Model 3 delineates the divorce effect into a between-(.31) and within-twin-family (.28) effect, and the results suggest that comparing offspring of discordant twins (ignoring the zygosity of the twins) does not substantially decrease the effect size. The fourth model estimated the within-twin-family divorce effect for MZ twins and the difference between the within MZ and DZ twin-family effects. The model suggests that the within-twin-family estimate for MZ families is .40. The parameter associated with the interaction of the within-family divorce effect and zygosity (−.20) suggests that the effect size associated with divorce may be smaller in DZ families. A lower DZ than MZ estimate is counter to what would be expected if shared environmental or genetic factors confounded the intergenerational relation, but the estimate is not statistically significant. Model 5 suggests that even when we controlled for parental psychopathology and life course characteristics, the MZ within-twin-family estimate associated with early divorce was significant (.37) and comparable with the phenotypic estimate obtained in Model 2. The parameters for the parental psychopathology covariates are difficult to interpret because they are estimates from a simultaneous regression model. The MZ estimate in Model 5 provides the strongest test for the association between early parental divorce and offspring alcohol and drug problems because the parameter is free from genetic and shared environmental factors from the twin parent as well as covariance due to the measured covariates of both parents, including maternal and paternal history of conduct disorder, alcohol abuse, and illicit drug use.

The parameter estimates from the HLMs for the Behavioral Problems factor are presented in Table 5. Model 1, the unconditional model, suggests that the majority of the variance in the factor is due to variation at the individual level. Parental divorce at any age is associated with a .26 increase in behavioral problems in Model 2. When the influence of parental divorce is separated in Model 3, the within-family estimate (.21) is somewhat smaller than the between-families estimate (.32) but is still statistically significant. The results from Model 4 show that the within-MZ family effect (.18) is still sizable, and there was only a small difference in the within-family estimate for MZ and DZ twin families (.05). Model 5 illustrates that the within-MZ family estimate (.17) associated with divorce was not influenced by measures of parental psychopathology. An additional model (not shown) indicated that the within-family estimate (.18) was statistically significant ($p < .05$) when the interaction of the within-family estimate with zygosity was removed from the equation.

The results for the Internalizing factor are presented in Table 6. Similar to the first two factors, the majority of the variance in the factor is attributable to variation at the individual level. The association of parental divorce before the age of 16 and the factor in Model 2 suggests that the difference between offspring in intact and divorced families is statistically significant (.29). Model 3 suggests little difference amid the between- (.27) and within-twin-family (.31) effects. The within-twin-family estimate for MZ twin families in Model 4 (.27) was sizable. The within-family estimate for DZ families (.35 = .27 + .08) is slightly larger than the MZ estimate, although no statistically significant difference was found. The results for Model 5 suggest that parental psychopathology slightly reduced the association with early divorce (within-MZ twin family estimate = .20).

Figure 4 provides a graphical representation of the effect sizes obtained from the HLMs for each offspring measure of psychopathology.[6] The graph illustrates how the association between parental divorce and each factor remained robust, although somewhat reduced in some cases, when different methodological and statistical controls were used to account for possible confounds. The bars show that the small to medium effect size associated with parental divorce remained after we controlled for shared environmental and genetic confounds associated with the twin parent, as well as measured characteristics of both parents.

Discussion

A comparison of the offspring of discordant twins and a series of HLMs suggested that environmental influences specifically associated with divorce, especially before the age of 16, account for most of the relation between parental divorce and offspring psychopathology. The results of the modeling indicated that parental divorce was associated with young-adult offspring psychopathology, even when we controlled for genetic and common environmental factors related to the twin parent, in addition to measures of psychopathology, substance use, and demographic characteristics of both parents. Although genetic factors influence marital instability, little evidence was found for genetic confounds (passive rGE). Shared environmental confounds were also negligible, indicating a limited role of environmental factors that make twins similar. Therefore, the findings are consistent with longitudinal research indicating that predivorce behavior problems and other selection factors do not account for psychological problems among young-adult offspring of divorced parents (A. J. Cherlin et al., 1998). The extent to which selection versus causation contributes to the well-being of offspring during childhood could not be addressed in the current study, although some research suggests that selection effects may be stronger during childhood than during adult life (J. C. Cherlin et al., 1991; Emery, 1999).

The magnitude of the association between parental marital instability and abnormal behavior in the offspring, in addition to the limited role of selection factors, suggest that intervention efforts should be targeted at reducing the prevalence of divorce or separation in families with children or should focus on risk factors that typically follow a divorce. These include

[6]Because differences in family contact among MZ and DZ twins can influence the within-family effect sizes (D'Onofrio et al., 2003), the amount of contact between the twins, amount of time the offspring spent with their aunt or uncle while growing up, distance between the two families, and a measure of closeness between the offspring and their aunt or uncle were included in the hierarchical regressions for each factor, but the variables did not alter the estimates.

deleterious parenting practices, conflict between parents after the divorce, loss of contact and inadequate parenting by noncustodial fathers, economic pressures, increased stressful life events, and reduced social capital available to children after a divorce or separation (reviews in Amato, 2000; Emery, 1999; Hetherington et al., 1998; Simons, 1996). Prevention services aimed at reducing these risks have been found to result in fewer symptoms and diagnoses of psychological disorders, externalizing behaviors, and drug and alcohol use (e.g., Wolchik et al., 2002).

The use of a semistructured interview for the offspring allowed us to investigate whether parental divorce was associated with *DSM–IV* criteria for psychological and substance use disorders. The results from the exploratory factor analysis are also consistent with previous research. An exploratory factor analyses of *DSM–IV* items and measures of drug use, alcohol use, tobacco use, and suicidality yielded three factors, Drug and Alcohol Use, Behavioral Problems, and Internalizing, a finding similar to other factor analyses of adult psychopathology (e.g., Krueger, 1999). Furthermore, the factors exhibited high reliability when offspring were reinterviewed approximately 1 year later.

The concordance rates and heritability of divorce in the sample of Australian twins were lower than in studies from the Minnesota Twin Registry (Jockin et al., 1996; McGue & Lykken, 1992). However, the proportion of variation in marital instability due to additive genetic factors was similar to smaller heritability estimates from the Vietnam Twin Registry (Trumbetta & Gottesman, 1997), the Finnish Twin Registry (Koskenvuo, Langinvainio, Kaprio, Rantasalo, & Sarna, 1979), and a small sample from Australia (Heller et al., 1988). In fact, an analysis of divorce in a population-based sample from Virginia (Corey, 2000) reported no genetic variation in divorce. Therefore, the heritability estimate from the Australian twin sample appears to be consistent with the overall literature, although future research is needed to explore the differences among the discrepant estimates. Cross-cultural differences in the acceptability of divorce, variation in laws governing marital separations, or cohort effects may account for some differences among the heritability estimates. The general conclusion of the twin research on marital instability to date is that environmental influences that make twins dissimilar account for most of the variation. Future twin studies that focus on divorce will need to explore the nature of these environmental influences and will greatly benefit by including assessments of the twins’ spouses, an important part of the twins’ nonshared environment that may influence divorce.

A number of limitations of the findings should be noted. The analyses do not prove that divorce causes the higher levels of psychopathology in young adults. The results can only be considered to be consistent with a causal hypothesis that will remain difficult to definitively prove, given the lack of experimental control. There are inherent limitations to all nonexperimental family designs of this kind. First, the CoT analyses conducted here, as is the case with almost all family analyses, cannot control for reciprocal influences (e.g., child behavior problems influencing their parent’s decision to divorce; D’Onofrio et al., 2003; Rutter et al., 2001). However, the design has the potential to capture such influences, given certain assumptions (Silberg & Eaves, 2004). Second, environmental risk factors, such as family conflict and socioeconomic conditions, which correlate with divorce within twin families, may actually be responsible for the association. Future genetically informed designs that depict the family environment more accurately will help to more precisely specify the salient environmental risk factors.

Third, the findings could be confounded by nonmeasured characteristics of the twins and their spouses. As highlighted above (see Figure 1), using the CoT Design by itself does not control for genetic and environmental influences of the spouses of the twin. Measured characteristics of both parents were included in the HLM to account for potential confounds, and the results of the HLM suggest that the association between parental divorce and psychopathology in

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young adulthood is not accounted for by the measures of either parents' psychopathology, substance use problems, and life course variables. However, we are unable to determine whether every salient confound was measured. The sample of offspring was also selected, in part, on the basis of parental psychopathology, and there may be characteristics of the families in the sample that were not accounted for by the measured covariates used in the HLMs. Assortative mating may also increase the environmental and genetic risks that covary with parental divorce. For example, individuals with higher rates of antisocial behavior are more likely to marry someone with similar traits (e.g., Krueger, Moffitt, Caspi, Bleske, & Silva, 1998), and the presence of two antisocial parents could increase adjustment problems through environmental (e.g., modeling) or genetic processes (D'Onofrio et al., 2003). Yet, statistically controlling for characteristics of both parents represents a major advantage over most previous research on parental divorce. A majority of the studies of divorce that have included measures of parental psychopathology have relied solely on maternal characteristics (e.g., Capaldi & Patterson, 1991;Emery, Waldron, Kitzmann, & Aaron, 1999;Simons, 1996).

Fourth, the CoT Design has limited statistical power to distinguish different intergenerational patterns of association compared with other behavior genetic designs (Heath, Kendler, Eaves, & Markell, 1985). Given the limited statistical precision of some of the estimates, we did not analyze moderators of the influence of divorce, such as gender of the offspring. Certainly, future studies will need to investigate how parental divorce interacts with individual characteristics within a genetically informative context. Subsequent research will also benefit from structural equation approaches to the CoT Design that can more readily quantify the magnitude of the underlying processes (Turkheimer et al., 2005). Finally, the results are based on data from Australia, and although research suggests that findings from Australia are consistent with studies in the United States and other western countries (Pryor & Rodgers, 2001; Rodgers, 1996), the findings may not generalize to other populations. Therefore, CoT studies of marital instability in other countries are needed.

The findings reiterate the fact that behavior genetic research illustrating genetic variation in environmental risk factors, such as divorce, merely suggests the possibility that shared genetic factors may account for the association between the environment and children's adjustment because the source of a risk variable is separate from the mode of risk mediation (Kendler & Karkowski-Shuman, 1997; Rutter, Silberg, & Simonoff, 1993). However, only genetically informed designs that explore intergenerational relationships can discriminate between direct environmental processes, shared environmental confounds, and genetic risk mediation. There are a number of behavior genetic models that can be used (review in Rutter et al., 2001). Yet, twin studies that include a measure of the shared environment, such as parental divorce (Kendler et al., 1992), are unable to explore genetic and environmental confounds (review in Turkheimer, D'Onofrio, Maes, & Eaves, in press).

Applications of the CoT Design have shed light on the importance of the family environment, including parental alcohol abuse and dependence (Jacob et al., 2003) and abusive parenting practices (Lynch et al., in press). In contrast, studies using the CoT design suggest that some intergenerational associations, such as the intergenerational transmission of schizophrenia (Gottesman & Bertelsen, 1989) and the stepfather presence–early menarche relation (Mendle et al., in press), may not be due to direct environmental causation. CoT analyses have also shown that the causal processes associated with parental divorce vary depending on the outcomes being explored (D'Onofrio et al., in press). Future CoT research using more precise measurements of the environment and statistical approaches quantifying the importance of environmental and genetic processes will provide unparalleled insight into the causes of offspring psychopathology and life course patterns. The current project used a genetically informed design, and the results suggest that environmental processes specifically associated with a common family risk factor—parental marital instability—account for higher levels of psychopathology in young-adult offspring.

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Appendix

Algebraic Representations of Hierarchical Linear Models

A series of hierarchical linear models (HLMs) were fit to test differences among effect sizes from different family designs. HLMs can be used to analyze regression problems in which the observations are nested and not independent, a required assumption for standard regression models. For a complete review of HLMs, see Raudenbush & Bryk (2002). For the analyses presented in the current article, HLMs were used to conduct analyses in which variables from three levels were included (see Figure 3 for a graphical representation of the three levels). As a result, the analyses provided the appropriate standard errors and significance values for the parameter estimates. The models use the general notation used by Raudenbush and Bryk (2002), but we have changed some of the subscripts to make them more applicable for the Children of Twins (CoT) Design. Below, a general overview of HLMs with the CoT Design is presented, followed by the exact models fit in the manuscript.

Review of HLMs

Unconditional Model

Overall, two general types of HLMs can be used. The first, the unconditional model separates the total variance of the outcome variable into variance components at each of the three levels. Let Y_{int} be the outcome for the *i*th offspring, in the *n*th nuclear family, in the *t*th twin family. The unconditional model includes one fixed effect, the grand mean (γ_{000}), and three random effects. The first is the deviation of the offspring from the nuclear-family mean; the parameter estimates the variance at the offspring level (e_{int}, $M = 0$, variance = σ^2). The second random effect is the nuclear-family effect and assesses the deviation of the nuclear family from the twin family mean (r_{0nt}, $M = 0$, variance = $\tau_\pi{}^2$). Finally, the twin-family level calculates the deviation of each twin family from the grand mean (u_{00t}, $M = 0$, variance = $\tau_\beta{}^2$).

$$Y_{int}=\gamma_{000}+e_{int}+r_{0nt}+u_{00t}. \tag{1}$$

Conditional Model

The second general type of HLM is the conditional model, which uses predictor variables at any of the levels as well as estimates the residual variances at the three levels. In the first level of the conditional model, p is the number of individual characteristics that predict Y_{int}, and π_{pnt} is the regression weight associated with each predictor variable a_{pnt}. Examples of Level 1 variables are the offspring's age and gender. These are fixed effects in the model.

$$Y_{int}=\pi_{0nt}+\pi_{1nt}(\alpha_{1nt})\ldots\pi_{pnt}(\alpha_{pnt})+e_{int}. \tag{2}$$

Each regression weight in the first level can be the dependent variable of a model at the second level. For the nuclear-family predictors to be included in the equation as fixed effects, the intercept in the first level (π_{0nt}) is the dependent variable, and the nuclear-family level variables are the independent variables. For simplicity, only random effects that account for the correlated structure of the data (the variance components at the three levels) will be incorporated into the models (see Raudenbush & Bryk, 2002, for an explanation of other random effects). In the second level, the regression weights for the nuclear-family level are represented by β_{0qt}, where q is the number of nuclear-family variables (χ_{0qt}). An example of nuclear-family predictors is parental psychopathology, because all of the children in a nuclear family share the characteristic.

$$\pi_{0nt}=\beta_{00t}+\beta_{01t}(\chi_{01t})\ldots\beta_{0qt}(\chi_{0qt})+r_{0nt}. \tag{3}$$

Finally, variables in the third level (w_{st}) can be included in the model as independent variables predicting the nuclear-family intercept (β_{00t}), with s being the number of variables. An example of a twin-family variable is zygosity type of the twins, because all cousins in the family share this characteristic.

$$\beta_{00t}=\lambda_{000}+\lambda_{001}(w_{1t})\ldots\beta_{00s}(w_{st})+u_{00t}. \tag{4}$$

The models of the three levels can be placed into the same equation by substitution.

$$Y_{int}=\lambda_{000}+\lambda_{001}(w_{1t})\ldots\beta_{00s}(w_{st})+u_{00t}+\beta_{01t}(\chi_{01t})\ldots\beta_{0qt}(\chi_{0qt})+r_{0nt}+\pi_{1nt}(\alpha_{1nt})\ldots\pi_{pnt}(\alpha_{pnt})+e_{int}. \tag{5}$$

HLMs Used in the Study

Model 1 fit an unconditional model to the data to determine how the overall variance of the outcome is allocated across the individual, nuclear-family, and overall twin-family levels (see Figure 3 for a graphical representation and Equation 1 for the algebraic model). Along with the three random effects, the model also includes an estimate of the grand mean (see Equation 1). Model 1 is similar to a nested analysis of variance.

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Model 2 included the nuclear-family level variable of parental divorce (*pa_div*) and estimated the variance components at the three levels (see Footnote 3). The model provided an example of a typical divorce analysis that compares children of divorced families with children from intact, unrelated families. The model also included individual-level variables that controlled for characteristics of each offspring; these include age, age^2, and gender of the offspring.

$$Y_{int}=\gamma_{000}+\beta_{01t}(pa\_div_{nt})+\pi_{1nt}(age_{int})+\pi_{2nt}(age^2_{int})+\pi_{3nt}(gender_{int})+u_{00t}+r_{0nt}+e_{int}. \quad (6)$$

Model 3 is similar to a sibling-control design because it enabled the influence of divorce to be separated into between- and within-twin-family estimates. The total number of divorces in a twin family was broken into (a) the average number of divorces in the twin family and (b) the deviation of each nuclear family from the twin family average. The average of the divorces in the two twin families (0, .5, or 1) was included as a variable (*tfamdiv*) at the third level because it is a characteristic that all cousins within a twin-family share, regardless of the marital status of their parents. The regression weight associated with the variable is a rough estimate of the between-families association with divorce (see Turkheimer et al., in preparation). The deviation of each individual twin's divorce status from the twin-family level divorce variable was included as a second-level variable (*nfamdiv*). If both twins are divorced or neither has separated, the *nfamdiv* score is 0 for both nuclear families because there is no variability in divorce within the twin family. In discordant twins, *nfamdiv* score will be −.5 for the nuclear families in which the parents were never divorced and .5 for the nuclear family in which the parents had been divorced. Therefore, the parameter associated with *nfamdiv* provided an estimate of the within-family effect. The most important parameter in Model 3 is the *nfamdiv* variable because it compared offspring of twins discordant for divorce (i.e. cousins), regardless of the twins' zygosity; the parameter is free from all confounds related to divorce that vary between unrelated families.

$$Y_{int}=\gamma_{000}+\gamma_{001}(tfamdiv_t)+\beta_{02t}(nfamdiv_{nt})+\pi_{1nt}(age_{int})+\pi_{2nt}(\mathrm{age}^2_{int})+\pi_{3nt}(gender_{int})+u_{00t}+r_{0nt}+e_{int}. \quad (7)$$

Model 4 explored whether the within-family estimate (the comparison of the offspring of discordant twins) is different for monozygotic (MZ) and dizygotic (DZ) families. In addition to all of the variables from the third model, the model included the interaction between the within-family divorce variable (*nfamdiv*) and zygosity (*ttype*, where MZ = 0 and DZ = 1). As a result, Model 4 estimated the within-family estimate for MZ families (the parameter associated with nfamdiv) and the difference between the within-family estimates for DZ and MZ families (DZ – MZ). The latter is the value associated with the interaction term (*nfamdiv* × *ttype*) and calculates the difference between the within-family MZ and DZ divorce effect. Furthermore, the interaction term provided information about the statistical precision of the difference between these two effect sizes. We also included the main effect of the zygosity, or twin type, of the twins in the model to determine whether offspring from MZ families had different levels of psychopathology from offspring from DZ families.

$$\begin{aligned} Y_{int}=&\gamma_{000}+\gamma_{001}(tfamdiv_t)\\ &+\gamma_{002}(ttype_t)\\ &+\gamma_{010}(nfamdiv_{nt})\\ &+\gamma_{011}(nfamdiv_{nt})(ttype_t)\\ &+\pi_{1nt}(age_{int})\\ &+\pi_{2nt}(age_{int}^2)\\ &+\pi_{3nt}(gender_{int})\\ &+u_{00t}+r_{0nt}+e_{int}. \end{aligned} \tag{8}$$

Finally, Model 5 included all of the variables from Model 4 and added measured covariates of parental characteristics to statistically control for these possible confounds. The measures included the maternal and paternal variables (c is the number of measured parental covariates), including conduct disorder, alcohol abuse, major depression, drug use, smoking, suicidality, education level, and age at birth of first child. The paternal characteristics were not separated into the three levels because they are the subject of future analyses.

$$\begin{aligned} Y_{int}=&\gamma_{000}+\gamma_{001}(tfamdiv_t)\\ &+\gamma_{002}(ttype_t)\\ &+\gamma_{010}(nfamdiv_{nt})\\ &+\gamma_{011}(nfamdiv_{nt})(ttype_t)+\sum\beta_{0ct}(maternal_{ct})\\ &+\sum\beta_{0ct}(paternal_{ct})\\ &+\pi_{1nt}(age_{int})\\ &+\pi_{2nt}(age_{int}^2)\\ &+\pi_{3nt}(gender_{int})\\ &+u_{00t}+r_{0nt}+e_{int}. \end{aligned} \tag{9}$$

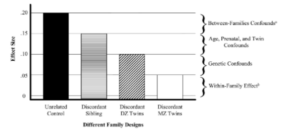

Figure 1.

Exposition of differences in the magnitude of the divorce effect using various family designs. [a]Includes both environmental and genetic confounds. [b]Differences between offspring in divorced and intact families are due to factors within twin families that are associated with divorce. This also includes genetic and environmental confounds from the spouses of the twins. DZ = dizygotic; MZ = monozygotic.

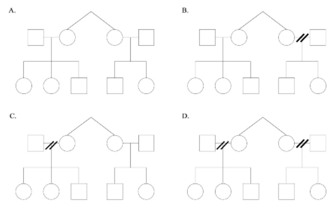

Figure 2.

Family structures in the Children of Twins Design. A: A twin family concordant for no marital instability. B: A twin family discordant for divorce with offspring in the first family living in an intact household. C: A twin family discordant for divorce in which offspring in the first family experienced the separation of their parents. D: A twin family in which both twins experienced marital instability.

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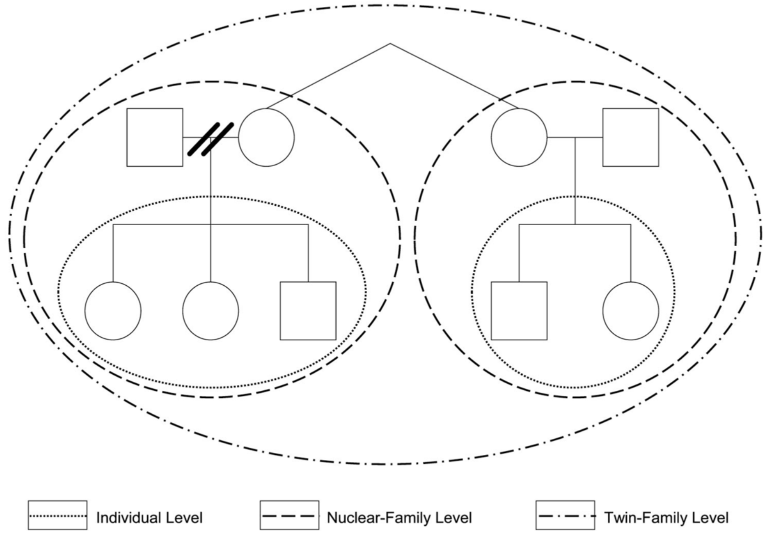

Figure 3.
Nested levels in the Children of Twins Design. The ellipses represent the three levels in the design.

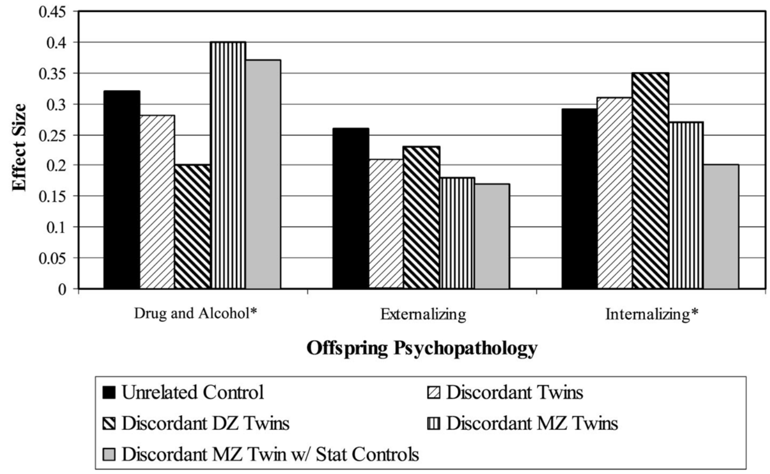

Figure 4.

Effect sizes between parental marital instability and offspring psychopathology using different methodological and statistical (stat) controls. The discordant twin method includes both monozygotic (MZ) and dizygotic (DZ) twins. The effect sizes using twin controls are within-family estimates. *Parental divorce before the age of 16.

Table 1

Twin Correlations for Marital Instability

Zygosity	Prevalence	Concordance rate[a]	Tetrachoric correlations	*N* (pairs)
MZ female	17.71	.31	.32	1,026
MZ male	14.17	.24	.24	416
DZ female	17.70	.23	.11	601
DZ male	14.39	.20	.15	235
DZ male–female	16.13	.20	.09	614

Note. Marital instability includes divorce and separation from a cohabiting relationship. MZ = monozygotic; DZ = dizygotic.

[a]Proband concordance rates are presented.

Table 2

Mean of Offspring Psychopathology by Age of Parental Separation

	Parental separation					
	Never		Before age 16		After age 16	
Psychopathology	***M***	***SE***	***M***	***SE***	***M***	***SE***
Drug and alcohol	−.06	.02	.28	.05[a]	.01	.08
Behavioral problems	−.06	.02	.21	.05[a]	.22	.07[a]
Internalizing	−.07	.02	.24	.05[a]	.11	.08

Note. The influence of age, age^2, and gender were partialed from the means, which are presented as *Z* scores.

[a]Statistically different from the never group ($p < .05$).

Table 3

Means of Offspring Psychopathology by Zygosity and Family Structure

	Drug and Alcohol[a]		Behavioral Problems		Internalizing[a]	
Family structure	***M***	***SD***	***M***	***SD***	***M***	***SD***
Dizygotic twin families						
Concordant–intact	−0.08	0.98	−0.07	0.97	−0.02	0.96
Discordant–parents married	0.00	0.96	−0.01	0.93	−0.08	0.96
Discordant–parents divorced	0.14	1.00	0.17	0.97	0.26	1.02
Concordant–divorced	0.40	1.13	0.15	1.07	0.28	0.99
Monozygotic twin families						
Concordant–intact	−0.04	0.93	−0.07	0.92	−0.11	0.96
Discordant–parents married	−0.12	0.88	−0.05	0.90	−0.04	0.90
Discordant–parents divorced	0.22	0.99	0.10	0.97	0.23	1.02
Concordant–divorced	0.38	1.02	0.32	0.92	0.19	0.98

Note. Concordant–intact represents families in which neither twin has been divorced. Discordant–parents married are offspring from the nondivorced co-twin in discordant pairs. Discordant–parents divorced are offspring from the divorced co-twin in discordant pairs. Concordant–divorced are offspring of families in which both twins are divorced. The influence of age, age^2, and gender were partialed from the means, which are presented as *Z* scores.

[a]Represents parental divorce before the age of 16.

Table 4

Parameter Estimates of Hierarchical Regression Analyses of the Drug and Alcohol Factor

	Model									
	1		2		3		4		5	
Parameter	**Parameter estimate**	***SE***	**Parameter estimate**	***SE***	**Parameter estimate**	***SE***	**Parameter estimate**	***SE***	**Parameter estimate**	***SE***
Random effects (variance components)										
Individual (σ^2)	0.81*	0.03	0.75*	0.03	0.75*	0.03	0.75*	0.03	0.75*	0.03
Nuclear-family level (τ_π^2)	0.18*	0.04	0.18*	0.04	0.18*	0.04	0.18*	0.04	0.16*	0.02
Twin-family level (τ_β^2)	0.01	0.03	0.01	0.03	0.00	0.03	0.00	0.03	0.00	0.03
Fixed effects										
Intercept (γ_{000})	0.00	0.02	−0.38	0.37	−0.36	0.38	−0.37	0.37	−0.51	0.44
Divorce (before the age of 16)										
Parental divorce (β_{01t})			0.32*	0.06						
Between-families (γ_{001})					0.31*	0.07	0.31*	0.07	0.18*	0.07
Within-family (β_{02t})					0.28*	0.08				
Within-family MZ (γ_{010})							0.40*	0.11	0.37*	0.11
Within-family DZ–MZ (γ_{001})							−0.20	0.15	−0.21	0.15
Level 1 variables										
Age (π_{1nt})			0.03	0.03	0.02	0.03	0.02	0.03	0.04	0.03
Age^2 (π_{2nt})			0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.01
Gender (π_{3nt})			0.41*	0.04	0.41*	0.04	0.41*	0.04	0.41*	0.04
Twin type (γ_{002})							−0.03	0.04	−0.04	0.04
Parental characteristics: Maternal										
Conduct (β_{03t})									0.11*	0.03
Alcohol abuse (β_{04t})									0.11*	0.04
Depression (β_{05t})									0.02*	0.01
Drug use (β_{06t})									−0.01	0.07

Parameter	Model									
	1		2		3		4		5	
	Parameter estimate	***SE***	**Parameter estimate**	***SE***	**Parameter estimate**	***SE***	**Parameter estimate**	***SE***	**Parameter estimate**	***SE***
Smoking (β_{07t})									0.10*	0.05
Suicidality (β_{07t})									0.01	0.03
Education (β_{08t})									0.00	0.02
Age at first birth (β_{09t})									0.01	0.01
Parental characteristics: Paternal										
Conduct (β_{010t})									0.06*	0.02
Alcohol abuse (β_{011t})									0.03	0.05
Depression (β_{012t})									0.00	0.01
Drug use (β_{013t})									0.08	0.07
Smoking (β_{014t})									0.05	0.06
Suicidality (β_{015t})									0.00	0.04
Education (β_{016t})									0.02	0.02
Age at first birth (β_{017t})									0.00	0.01

Note. MZ = monozygotic; DZ = dizygotic.

* $p < .05$.

Table 5

Parameter Estimates of Hierarchical Regression Analyses of the Behavioral Problems Factor

	Model									
	1		2		3		4		5	
Parameter	**Parameter estimate**	***SE***	**Parameter estimate**	***SE***	**Parameter estimate**	***SE***	**Parameter estimate**	***SE***	**Parameter estimate**	***SE***
Random effects (variance components)										
Individual (σ^2)	0.72*	0.03	0.64*	0.03	0.64*	0.03	0.64*	0.03	0.64*	0.03
Nuclear-family level (τ_π^2)	0.13*	0.04	0.13*	0.03	0.13*	0.03	0.13*	0.03	0.14*	0.03
Twin-family level (τ_β^2)	0.16*	0.04	0.12*	0.03	0.13*	0.03	0.13*	0.03	0.08*	0.03
Fixed effects										
Intercept (γ_{000})	−0.01	0.02	−4.93*	0.37	−4.93*	0.37	−4.93*	0.37	−5.20*	0.42
Divorce (at any age)										
Parental divorce (β_{01t})			0.26*	0.05						
Between-families (γ_{001})					0.32*	0.07	0.32*	0.07	0.23*	0.08
Within-family (β_{02t})					0.21*	0.07				
Within-family MZ (γ_{010})							0.18*	0.09	0.17	0.10[a]
Within-family DZ–MZ (γ_{001})							0.05	0.13	0.01	0.14
Level 1 variables										
Age (π_{1nt})			0.36*	0.03	0.36*	0.03	0.36*	0.03	0.36*	0.03
Age^2 (π_{2nt})			−0.01*	0.00	−0.01*	0.00	−0.01*	0.00	−0.01*	0.00
Gender (π_{3nt})			0.41*	0.04	0.41*	0.04	0.41*	0.04	0.41*	0.04
Twin type (γ_{002})							0.01	0.05	−0.02	0.05
Parental characteristics: Maternal										
Conduct (β_{03t})									0.05	0.03
Alcohol abuse (β_{04t})									0.09	0.06
Depression (β_{05t})									−0.01	0.02
Drug use (β_{06t})									0.10	0.08
Smoking (β_{07t})									0.14*	0.06

Parameter	Model 1		Model 2		Model 3		Model 4		Model 5	
	Parameter estimate	*SE*	Parameter estimate	*SE*	Parameter estimate	*SE*	Parameter estimate	*SE*	Parameter estimate	*SE*
Suicidality (β_{07t})									0.04	0.03
Education (β_{08t})									0.01	0.02
Age at first birth (β_{09t})									−0.01	0.01
Parental characteristics: Paternal										
Conduct (β_{010t})									0.07*	0.03
Alcohol abuse (β_{011t})									0.06	0.05
Depression (β_{012t})									0.00	0.01
Drug use (β_{013t})									0.04	0.06
Smoking (β_{014t})									0.13*	0.06
Suicidality (β_{015t})									−0.01	0.03
Education (β_{016t})									0.03*	0.01
Age at first birth (β_{017t})									−0.01	0.01

Note. MZ = monozygotic; DZ = dizygotic.

[a]The within-family estimate was significant ($p < .05$) in the last model without the interaction with twin type.

Table 6

Parameter Estimates of Hierarchical Regression Analyses of the Internalizing Factor

	Model									
	1		2		3		4		5	
Parameter	**Parameter estimate**	***SE***	**Parameter estimate**	***SE***	**Parameter estimate**	***SE***	**Parameter estimate**	***SE***	**Parameter estimate**	***SE***
Random effects (variance components)										
Individual (σ^2)	0.88*	0.03	0.83*	0.03	0.82*	0.03	0.83*	0.03	0.82*	0.03
Nuclear-family level (τ_{π}^2)	0.07*	0.03	0.07*	0.03	0.08*	0.03	0.07*	0.03	0.06*	0.03
Twin-family level (τ_{β}^2)	0.05*	0.03	0.04	0.03	0.03	0.03	0.04	0.03	0.03	0.03
Fixed effects										
Intercept (γ_{000})	0.00	0.02	−1.37*	0.38	−1.35*	0.38	−1.39*	0.38	1.83*	0.43
Divorce (before the age of 16)										
Parental divorce (β_{01t})			0.29*	0.05						
Between-families (γ_{001})					0.27*	0.07	0.27*	0.07	0.17*	0.08
Within-family (β_{02t})					0.31*	0.07				
Within-family MZ (γ_{010})							0.27*	0.10	0.20	0.10[a]
Within-family DZ–MZ (γ_{001})							0.08	0.14	0.02	0.14
Level 1 variables										
Age (π_{1nt})			0.10*	0.03	0.10*	0.03	0.10*	0.03	0.10*	0.03
Age^2 (π_{2nt})			−0.01*	0.00	−0.01*	0.00	−0.01*	0.00	−0.01*	0.00
Gender (π_{3nt})			−0.38*	0.04	−0.39*	0.04	−0.39*	0.04	−0.39*	0.04
Twin type (γ_{002})							0.05	0.04	0.02	0.04
Parental characteristics: Maternal										
Conduct (β_{03t})									0.03	0.03
Alcohol Abuse (β_{04t})									0.06	0.05
Depression (β_{05t})									0.03*	0.01
Drug Use (β_{06t})									0.04	0.07
Smoking (β_{07t})									0.03	0.06

	Model									
	1		2		3		4		5	
Parameter	Parameter estimate	*SE*	Parameter estimate	*SE*	Parameter estimate	*SE*	Parameter estimate	*SE*	Parameter estimate	*SE*
Suicidality (β_{07t})									0.01	0.03
Education (β_{08t})									0.04*	0.01
Age at First Birth (β_{09t})									−0.01	0.01
Parental characteristics: Paternal										
Conduct (β_{010t})									0.01	0.03
Alcohol abuse (β_{011t})									−0.02	0.04
Depression (β_{012t})									0.03	0.01
Drug use (β_{013t})									−0.02	0.06
Smoking (β_{014t})									0.05	0.06
Suicidality (β_{015t})									−0.01	0.04
Education (β_{016t})									0.02	0.02
Age at first birth (β_{017t})									0.00	0.01

Note. MZ = monozygotic; DZ = dizygotic.

[a]The within-family estimate was significant ($p < .05$) in the last model without the interaction with twin type.