Causation versus Selection: A Genetically Informed Study of Marital Instability and its Consequences for Young-Adult Offspring

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ABSTRACT

Most studies of the consequences of parental divorce have used statistical controls of measured covariates to account for selection factors, characteristics that influence both parental divorce and the offspring well-being. However, unmeasured characteristics may still confound the association between parental divorce and offspring adjustment. In particular, genetic factors that influence both generations could explain the intergenerational relations. To date, few behavior genetic studies have investigated the underlying mechanisms responsible for adjustment problems associated with parental marital instability. The current project used a genetically informed approach, the Children of Twins Design, to explore the genetic and environmental processes responsible for the higher rates of psychopathology, deleterious life course patterns, and relationship instability in the offspring of divorced families. The analyses utilized samples from Australia and the United States that include adult twins and their young adult offspring.

Two general conclusions about divorce can be drawn from the results. First, the amount of variation in marital instability attributable to genetic factors is small. Analyses of the adult twins indicated that environmental factors that make twins dissimilar account for most of the variance in divorce. Second, the risk mechanisms responsible for the associations between parental divorce and offspring adjustment vary across the measures of young adult functioning. Environmental risk factors specifically associated with parental divorce were responsible for the associations between parental marital instability and externalizing problems, substance use and abuse, educational problems, and earlier onset of sexual intercourse and depressive episodes. These findings are consistent with a

causal theory of the consequence of divorce. Analyses of the intergenerational transmission of relationship instability also underscored the importance of environmentally mediated risk particularly related to parental divorce, but the magnitude of the association was lower than initially estimated because of unmeasured confounds. In contrast, higher rates of depression, earlier onset of drug use, and a greater likelihood to form cohabitating relationships among offspring from divorced families were completely due to selection factors, including genetic confounds.

Overall, the results highlight the importance of using genetically informed designs to study environmental risk factors and the need for greater collaboration among behavior genetic, psychological, and sociological researchers.

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DEDICATION

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I. GENERAL INTRODUCTION

The environment in which children are being raised has changed dramatically over the past few decades (Weissberg, Walberg, O'Brien, & Kuster, 2003). One of the most striking changes has been in family structure (reviews in Casper & Bianchi, 2002; Hobbs & Stoops, 2002; Teachman, Tedrow, & Crowder, 2000). Whereas 85% of children in the United States were raised by two parents in 1970, 69% of children lived in such a family in 2002 (U.S. Department of Health and Human Services, 2002). The drop was more significant for certain racial groups—the percentage of African American children living with two parents dropped from 58% to 38% during that time. Furthermore, these estimates include families in which one adult is not the biological parent of the children (Fields, 2001), underestimating the percentage of children that experience family transitions. When biological relatedness is considered, only 56 percent of children lived in "traditional" households in 1996 (Fields, 2001)

The change in family structure has been due to many factors, including the increase in the divorce rate and the rise in births to single mothers. The increase in the divorce rate in the second half of the 21st Century was dramatic. In 1960, 9.2 of every 1000 women were divorced. The rate peaked around 1980 at 22.6 and declined to 19.8 in 1997 (Casper & Bianchi, 2002). Current estimates of the percentage of first-time marriages that will end in divorce range from 43-50% (Krieder & Fields, 2002; Bramlett & Mosher, 2001). With respect to the impact of divorce rates on children, over one million children experience parental divorce every year (US. Bureau of the Census, 1998, Table 160). However, official divorce statistics do not accurately reflect marital separations, especially in minority families where individuals are more likely to legally separate but not divorce (Bramlett & Mosher, 2001). Therefore, separations must also be included when studying the influence of marital instability. In 2002, approximately 9,850,000 children (under the age of 18), were living in a single family due to divorce or separation (US Census Bureau, 2002) [1].

The increase in births to single mothers has also resulted in a greater number of children experiencing the separation of their parents. The rise in unmarried childbearing between the early 1980's and mid 1990's was due primarily to an increase in births to women in cohabiting relationships (review Bumpass & Lu, 2000). Since cohabiting relationships are less stable than marriages, especially when a child was born before the couple lived together (Bramlett & Mosher, 2002), an increasing number of children are also experiencing the dissolution of their parents union when cohabiting relationships end. Overall, 34% of children in the United States born into unions, either cohabiting or married, will experience the disruption of their parents' relationship before they reach the age of 16 (Bumpass & Lu, 2000).

The increase in divorce rates in the last half Century has also occurred in other Western countries, including Australia, Canada, England/Wales, and New Zealand (Pryor & Rodgers, 2001). For example, the divorce rate has increased three to four-fold in Australia in the past 30 years, and current estimates indicate that 32% of marriages in Australia will now end in divorce (Australian Bureau of Statistics, 2001). Comparisons between Western countries indicate that the United States has had a much higher rate of divorce over the past 50 years. There were also short-term fluctuations in each country's divorce rate due to legal changes in divorce laws. Despite these differences there was a "remarkably similar" trend across the Western countries. Overall, there was a substantial increase in divorces during the 1960's and 1970's, with the rates leveling off during the 1990's (Pryor & Rogers, 2001).

The high numbers of single-parent households 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, some 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 and society at large continue to be heavily debated in the academic and popular press (e.g. Hetherington & Kelly, 2002; Wallerstein, Lewis, & Blakeslee, 2000; review in Thompson & Wyatt, 1999).

Associations between Parental Divorce and Offspring Adjustment

Numerous studies have found that divorce is associated with problems for younger children across various domains including academic difficulties, externalizing behaviors, depressed mood, lower social competence, lower self esteem, and sub-clinical distress (reviews in Amato, 2000; Emery, 1999; Hetherington & Stanley-Hagan, 1999a). Although the effect sizes for divorce for children are small to medium (Amato & Keith, 1991a), parental separation is linked with a two-fold increase in many problems, including dropping out of school and seeking mental health services. Parental divorce is also associated with negative outcomes and earlier life transitions as offspring enter young adulthood and later life. Socioeconomic status, educational attainment, subjective well-being, early sexual activity, non-marital childbirth, earlier marriage, cohabitation, marital discord, and divorce are all associated with the separation of one's parents (reviews in Amato, 1999; Furstenberg & Teitler, 1994). A meta-analysis has found that effect sizes associated with parental divorce are larger in late adolescence and young adulthood than at earlier ages (Amato & Keith, 1991b).

Recent empirical studies of the differences between offspring from stable and divorced families have underscored the need to explore the relationship between marital instability and offspring difficulties. A meta-analysis of studies from 1960 to 2000 indicated that the effect sizes associated with parental divorce increased during the 1980's and 1990's (Amato, 2001). Although divorce has become more prevalent and socially accepted (e.g. Thornton & Young-DeMarco, 2000), the difference between children from intact and divorced families for outcomes such as academic difficulties, externalizing behaviors, psychological problems, and lower self-concept have not decreased; rather they have increased. Furthermore, longitudinal research has indicated that the magnitude of emotional problems associated with divorce increases when offspring reach young adulthood (Cherlin, Chase-Lansdale, & McRae, 1998). The emotional problems could also not be explained by pre-divorce behavior problems.

Competing Explanations

The associations between marital instability and outcomes in offspring have been and continue to be well documented, but all discussions and debates about the consequences of divorce are based on strong assumptions regarding causation. The adage that correlation does not equal causation is crucial for the understanding of the role of divorce in the lives of children and society at large. The social sciences have generally held strong "causal" assumptions concerning the importance of psychosocial influences, such as divorce (review in Rutter, 2000). However, there are two main, competing explanations for the increase in adjustment problems associated with parental divorce (review in Amato, 2000). The first, referred to as the divorce-stress-adjustment hypothesis, considers the subsequent outcomes to be consequences of divorce (i.e. divorce causes emotional and behavior problems) (e.g. Hetherington, 1999a). Divorce leads to a series of harmful events, and problems in the offspring associated with these stressors are considered to be caused by divorce (the hypothesis will be referred to as the *causal* hypotheses throughout this paper)[2]. In contrast, the *selection* hypothesis emphasizes that divorced adults are different than non-divorced parents and that these differences lead to both marital disruptions and later adjustment problems in the offspring (e.g. Emery, Waldron, Kitzmann, & Aaron, 1999; McGue & Lykken, 1992). Either divorce sets into motion a series of events (e.g. early childbearing or educational difficulties) that influence adult functioning, or parental divorce is a "marker" for individual characteristics that influence adjustment in the offspring (Cherlin, Chase-Lansdale, & McRae, 1998). Certainly, both of these mechanisms may be operating simultaneously or to different degrees, depending on the outcome.

Given high percentage of children who will experience their parents' separation, the consistent research documenting problems associated with divorce, an increase in problems associated with divorce in the past 20 years, and a particular vulnerability to parental divorce when offspring reach young-adulthood, the search for the underlying mechanisms responsible for differences between offspring from intact and divorced families represents a critical research endeavor. Delineating between the causal and selection processes will help guide policy decisions and intervention efforts.

Methodological Requirements for Inferring Causal Relationships

Determination of underlying mechanisms is a crucial research goal and one of the central concepts in developmental psychopathology (Cicchetti, 1993; Rutter & Sroufe, 2000; Sroufe & Rutter, 1984). One of the difficulties with studying family relations is the reliance on correlational studies because of the lack of experimental control (researchers cannot assign children to different family environments). As a result, 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, Pickles, Murray, & Eaves (2001) outlined seven key needs for the study of environmental causal effects on behavior: (1) clear exposition of alternative hypotheses, (2) reliable measurement of the environmental risk factor and alternative sources of mediation, (3) strategies that delineate the influence of environments on people from the effects of people on the environments, (4) statistical methods to distinguish change from measurement error, (5) quasi-experimental designs to differentiate between environmental mediation from alternative forms of risk mediation, especially genetic influences, (6) assumptions in each design must be acknowledged and tested, and (7) a combination of samples and strategies to ensure adequate variation are necessary [reordered for ease in presentation]. In order to assess the strengths and weaknesses of the research on the causal mechanisms responsible for the association between parental divorce and offspring adjustment, the literature will be reviewed with respect to each of these needs.

(1) Clear Exposition of Alternative Hypotheses

Initial research on the influence of parental divorce focused solely on family composition (for a review of the history see Hetherington & Stanley-Hagan, 1999a). The early divorce research, referred to as "father absence" studies, was based on the assumption that the loss of a father would have serious consequences for the children. Typical studies relied on a comparison of means between children from intact and divorced families. However, more recent research has focused on the mediators between divorce and child outcomes; interactions among risk and protective factors at multiple levels of analysis (including individual, family, and community); and the multiple transitions that most children experience after the separation of their parents. Researchers now typically test many possible risk factors and alternative explanations (these will be outlined in the next section). In fact, it can be argued that the study of parental divorce represents one of the most advanced topics within developmental psychopathology.

(2) Reliable Measurement of the Environmental Risk Factor and Alternative Sources of Mediation

More Reliable Measurement of Risk Factor

The study of marital instability has benefited greatly by more accurate measurement of children's family experiences. More comprehensive indices of the multiple transitions that many children face after a separation, such as the period of living in a single-parent household and the transition to a new household(s) formed by the remarriage or cohabitation of one's parent(s), have provided a more precise picture of the environmental stressors associated with family transitions (e.g. Cherlin & Furstenberg, 1994; Coleman, Ganong, & Fine, 2000; Hetherington & Stanely-Hagan, 1999b). The understanding that marital separations are a process rather than one stressful life event have also provided greater understanding about the difficulties that arise before the actual physical separation of one's parents. Furthermore, recent studies have also examined the impact of maternal relationship instability (including separation but not legally divorced from a spouse, separation from a cohabitating relationship with the children's biological father, and separation from cohabitating relationship with a male not biologically related to the children). Research has shown that such separations are related to offspring externalizing (Ackerman, Brown, D'eramo, Izard, 2002; Ackerman, D'Eramo, Umylny, Schultz, & Izard, 2001; Ackerman, Kogos, Youngstrom, Schoff, & Izard, 1999; Adam & Chase-Lansdale, 2002), internalizing (Ackerman, Brown, D'eramo, Izard, 2002), and premarital childbirth (Wu, 1996; Wu, & Martinson, 1993). Overall, children who experience more family transitions, including remarriage and multiple separations, have poorer outcomes (e.g. Capaldi & Patterson, 1991).

Measures of Environmental Mediators Consistent with the Causal Hypothesis

Research on the influence of divorce has underscored the role of multiple mediators of the relationship between parental divorce and offspring difficulties (reviews in Amato, 2000; Hetherington, Bridges, & Insabella, 1997; Simons & Associates, 1996). One of the most consistent mediators in the literature is parenting practices. Custodial parents exhibit more punitive discipline, provide less consistency enforcing rules, monitor children less, and engage in more negative conflict with their children compared to parents in intact families (Astone & McLanahan, 1991; Forgatch, Patterson, & Ray, 1996; Hetherington, 1993; Hetherington & Clingempeel, 1992; Hetherington, Cox, & Cox, 1985; Martinez & Forgatch, 2002; Simons & Associates, 1996). General measures of parent-child relationships have also been found to mediate the relationship between divorce and adult offspring difficulties (O'Connor, Thorpe, Dunn, Golding, & ALSPAC Study Team, 1999). With respect to specific environmental sources of mediation, Martinez & Forgatch (2002) illustrated how parental encouragement of academic skills specifically mediates the relationship between parental divorce and offspring academic functioning.

Conflict between parents after divorce is also associated with more behavior problems in the offspring. Marital conflict has been found to influence child adjustment through multiple pathways (review in Cummings & Davies, 2002), and divorce does not typically end acrimonious relationships between parents (e.g. Maccoby & Mnookin, 1992). Lack of cooperation and conflict between parents after the divorce (Buchanan, Maccoby & Dornbusch, 1996; Simons & Associates, 1996), especially overt conflict to which the children are exposed (Hetherington, 1999b), predicts more behavior problems and adjustment difficulties in the offspring. Consistent with an attribution theory (Grych & Fincham, 1992), the influence of parental conflict after divorce on children's adjustment is mediated with feelings of being caught in the middle (Buchanan, Maccoby, & Dornbusch, 1991). Similarly, the fear of abandonment has also been found to mediate the relationship between poor parent-child relationships after divorce and later internalizing and externalizing problems (Wolchik, Tein, Sandler, & Doyle, 2002).

The loss of a contact with the nonresidential father has also been implicated in the difficulties children of divorce face after the separation, especially given the limited contact that most nonresidential fathers have with their children (e.g. Seltzer, 1991). Although earlier analyses suggested that contact with noncustodial fathers was not associated with children's adjustment (Amato, 1993; Amato & Keith, 1991a), a recent meta analysis illustrated how authoritative parenting by a noncustodial fathers is linked with greater academic competence and lower externalizing and internalizing behaviors (Amato & Gilbreth, 1999). The literature has generally concluded that the quality of the contact between noncustodial fathers and their children is more important than the number of visits or amount of time together.

Large scale samples in the US (McLanahan & Sandefur, 1994) and England (Rogers & Pryor, 1998) have also reported that economic pressures account for some (and upwards of 50%) of the association between divorce and childhood offspring problems. Some of the influence of economic pressures is mediated through diminished parenting (e.g. Conger et al., 1990; Simons & Associates, 1996). However, the drop of income that occurs in many custodial families, usually headed by mothers (Bianchi, Subaiya, & Kahn, 1999), also increases the number of stressful life events for children (e.g. Hetherington, Cox, & Cox, 1985). For example, children divorced families are 5 times more likely to move to a different home (Simons & Associates, 1996), and residential mobility accounts for some of the association between family transitions and offspring school dropout (Astone & McLanahan, 1994). Children and their custodial parent (typically the mother) are also more likely to move to more disadvantaged neighborhoods, with higher incidents of crime and poorer schools. The relocation weakens the ties between the families and neighborhoods, and the reduced social capital available to children has also been found to mediate the relationship between parental separation and childhood problems (McLanahan & Sandefur, 1994; Teachman, Paasch, & Carver, 1996).

In summary, the causal hypothesis emphasizes that divorce leads to poorer parenting practices, weaker parent-child bonds, economic strains, more stressful life events, less social capital, continued (and perhaps greater) parental conflict, and frequently the loss of contact with the noncustodial parent. These factors have been found to mediate the relationship between parental divorce and offspring behavior and adjustment problems. Furthermore some outcomes of divorce, such as life course patterns, subsequently represent mediators for later difficulties (Amato, 2000). Lower educational attainment, early childbearing, and leaving home early account for some of the differences between older adults who grow up in intact and separated families (O'Connor, Thorpe, Dunn, Golding, & ALSPAC Study Team, 1999).

Measures of Alternative Environmental Mediators Consistent with Selection Hypothesis

Whereas much of the literature on parental divorce has focused on mediators, with strong assumptions concerning causality, the differences between children from intact and divorced families could also be due to "third variables" (selection factors) that cause both divorce and the outcomes in the offspring.

One important methodological advance in the study of parental divorce was the use of prospective, longitudinal designs, and a number of 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; Hetherington, 1999b; Sun, 2001). Statistically controlling for predivorce functioning sharply reduces the association between divorce and behavior problems and achievement during childhood and adolescence (e.g. Cherlin et al., 1991; Hetherington, 1993). Obviously, children's psychological problems cannot be consequences of divorce if they precede divorce in time.

Although it is still unclear what is responsible for the problems before the divorce, maladaptive processes that precede the separation may account for the pre-divorce behavioral problems in the offspring (Hetherington, Bridges, Insabella, 1998). Many factors, such as poverty (Hernandez, 1993), marital conflict (Amato, Loomis, & Booth, 1995), psychological problems (Hope, Power, & Rodgers, 1999), and stressful life events (Karney & Bradbury, 1995) increase both the likelihood of divorce and adjustment problems in children. Furthermore, offspring have fewer problems in low-conflict divorced families than in high-conflict intact families (Hetherington, 1999b). Following the logic of the selection hypothesis, it may be that poverty, parenting problems, marital conflict, or similar difficulties that precede divorce are environmental mediators of the psychological problems found among children after divorce.

Even more distal factors, such as parental personality characteristics, may likewise account for the adjustment problems in the offspring of divorced parents. Utilizing a nationally representative, longitudinal study of families, Emery, Waldron, Kitzmann, & Aaron (1999) found that maternal history of delinquency predicted later marital status and much of the association between parental divorce and child behavior problems, measured 14 years later. These results are consistent with studies using community (Capaldi & Patterson, 1991) and clinic samples (Lahey et al., 1988). Although the exact mechanisms between maternal personality characteristics and offspring behavior problems are unknown, Capaldi and Patterson (1991) reported that parenting behaviors mediated the relationship. Maternal antisocial behavior may be a confound that accounts for most of the divorce-externalizing behavior association in children. The findings suggest that the relationship between divorce and child outcomes may be spurious—the difference between children from divorced and intact families is explained by the personality characteristics and behaviors of divorcing parents and not the separation.

In contrast, studies have found a robust relationship between marital instability and child behavior problems even after controlling for maternal antisocial traits (Simons & Associates, 1996). Also, pre-divorce measures of adjustment cannot explain the differences between young adults from married and divorced families (Cherlin, Chase-Lansdale, & McRae, 1998). Thus, longitudinal studies that control for pre-divorce functioning and those that include measures of maternal personality provide mixed support for both the stress and the selection hypotheses. The mechanisms accounting for the differences between offspring from intact and married families may depend on the age of the offspring and the specific outcome measure.

In summary, researchers have identified various environmental risk mechanisms associated with divorce, but a number of studies have suggested that the consequences of marital separation are due to nonrandom selection into divorce. Findings that support the selection hypothesis have undermined the causal connection between divorce and later behavior problems in children. However, in summarizing the literature on causal versus selection hypotheses, Amato (2000) concluded that the weight of the literature supported the notion that divorce brings about new conditions and events that influence children's adjustment, even if there are some factors that predispose children to have adjustment problems.

(3) Strategies Which Delineate Environment-Person from Person-Environment Influences

Although the higher levels of behavior and adjustment problems in children before the divorce may be due to deleterious family processes, an alternative explanation may be that raising difficult children makes it more likely for couples to separate (Hetherington, Bridges, & Insabella, 1998). Under such conditions, the differences between children from divorced and intact families would not be the result of divorce causing the difficulties in the offspring; rather the children's behavior problems would increase the probability of parental separation. Similar arguments have been made to explain the association between harsh parenting and offspring behavioral problems (e.g. Bell & Harper, 1977; Lytton, 1990).

Cross-sectional studies (review in Karney & Bradbury, 1995) and longitudinal analyses (e.g Karney & Bradbury, 1997; Kurdek, 1999) of families have found the presence of children is associated with lower marital quality and marital satisfaction. In spite of the decrease in marital quality, demographic studies have generally concluded that children act as a barrier to divorce, effectively reducing the probability that married (Cherlin, 1977; Lillard & Waite, 1993; Waite & Lillard, 1991) and cohabiting couples (Wu, 1995) will separate. However, age of the children, timing of the birth, and medical conditions in the offspring moderate the protective association between the presence of children and parental separations. The presence of younger children in the house is related to lower levels of divorce, but adolescent offspring have been associated with a greater risk for separation (Waite & Lillard, 1991). The timing of the pregnancy is also important as the presence of a child before the start of a cohabiting relationship or marriage increases the likelihood of separation (Bramlett & Mosher, 2002). Parents with children who experience certain medical conditions, including congenital heart disease, cerebral palsy, and blindness, are more likely to separate, although other medical conditions have a negative association with parental divorce (Joesch & Smith, 1997). Despite demographic studies that suggest that the presence of children reduces the probability of divorce, the stresses associated with raising adolescents, children born before the start of a union, and offspring with some serious medical conditions, increase the likelihood that parents will separate.

To the best of my knowledge, no prospective, longitudinal study has been conducted looking at the influence of child behavior and internalizing problems on the subsequent marital status of parents. However, results from longitudinal studies suggest that reverse causation cannot completely account for the association between parental divorce and behavior problems in offspring. Many of the problems associated with divorce were not evident before the separation, externalizing and internalizing problems increase after the separation, and controlling for pre-divorce functioning does not account for all post-divorce adjustment (review in Amato, 2000). However, future longitudinal research is needed to explore the possibility that raising children, especially under stressful conditions, may make it more likely that parent will separate.

(4) Statistical Methods to Distinguish Change from Measurement Error

Research into the association between parental divorce and offspring adjustment originally relied solely on single measures of the outcome variable. However, single measures include an estimate of the underlying latent construct *and* measurement error. As a result, the estimate of the association may be attenuated (See Heath et al., 1993 for a specific description of the impact of measurement error on behavior genetic studies). In order to account for this limitation, multiple measures of each construct can be utilized. Including multiple measures of the offspring outcome enables an estimate of the relationship between divorce and a latent variable that is free from measurement error. The technique is now widely used in the divorce literature (e.g. Hetherington 1999a; Simons & Associates, 1996), although some longitudinal studies and secondary data analyses are limited by the measurement strategies employed in the studies. When the research is taken as a whole, the differences between offspring from divorced and intact families cannot be attributable to measurement error. Future research, though, must continue to include appropriate statistical and methodological techniques to estimate accurate associations.

(5) Quasi-experimental Designs to Differentiate Environmental Mediation from Alternative forms of Mediation, Especially Genetic Influences

The research on divorce has become quite sophisticated—studies typically statistically control for many variables (e.g. family income, maternal personality characteristics, etc.) that may confound the association between divorce and offspring outcomes (review in Amato, 2000). However, typically epidemiological studies can only control for variables that are measured and included in regression or structural equation models. The analyses assume that all unmeasured differences between divorced and intact families do not account for the associations with parental divorce. Therefore, research efforts must focus on quasi-experiments that "pull apart" risk variables that typically co-occur, especially genetic factors. As outlined above, most of the research on the effects of parental divorce has explored alternative environmental explanations, but these studies have been unable to delineate between environmental and genetic processes.

What appears to be an "environmental" family influence on children may actually be due to genotypic factors. Behavior genetic analyses of "environmental" risk factors (reviews in Plomin, 1995; Plomin & Bergemen, 1991) have indicated that genetic factors influence variation in what were originally believed to be purely environmental measures. Specifically, twin studies have shown that genetic factors influence divorce (McGue & Lykken, 1992; Trumbetta & Gottesman, 1997). Researchers have been quick to point out that there were not genes that code for divorce; rather genetic factors influence intermediate characteristics or endophenotypes (Gottesman & Gould, 2003), such as personality traits (Jockin, McGue, Lykken, 1996), that influence the probability of getting divorced.

Because parents provide both the environment for their children and transmit their genes to their offspring, environmental and genetic factors are correlated. Thus, genetic factors that influence parental divorce can be passed to the offspring and subsequently influence the offspring's behavior. One possibility is that that personality characteristics that influence divorce (Jockin, McGue, & Lykken, 1996), are transmitted to the offspring and influence their actions. Under such conditions, the relationship between parental divorce and the offspring outcomes would be spurious, with parental divorce being an epiphenomena representing genetic risk for the outcome (Rutter et al., 1997). The situation in which a common genetic component influences a parental characteristic or behavior (measured as the environment) and outcomes in the offspring is referred to as a passive gene by environment correlation (rGE) (Eaves, Last, Martin, & Jinks, 1977;

Plomin, DeFries, & Loehlin, 1977; Scarr & McCartney, 1983). The role of passive rGE has not been received much attention in the scientific literature and is an important research priority in the field of developmental psychopathology (Rutter et al., 1997).

However, it is important to remember that the behavior genetic research that illustrates genetic variation in divorce only suggests the possibility that shared genetic factors may be responsible for the intergenerational associations (passive rGE). Hypothetically, if genetic influences completely accounted for all of the variation of divorce (which obviously isn't true) the influence of parental divorce on offspring could still be purely environmentally mediated because the source of a risk variable are separate from the mode of risk mediation (Kendler & Karkowski-Shuman, 1997; Rutter, Silberg, & Simonoff, 1993). The presence of genetic variation in divorce only provides the *prima facie* grounds for the possibility of genetic risk mediation, and only behavioral genetic methods that explore intergenerational relationships can delineate between or "pull apart" the environmental and genetic risk mediation.

Only a few genetically informed studies of children's adjustment associated with divorce have been conducted, and the findings have been limited by the methodological assumptions inherent in the designs. O'Connor, Caspi, DeFries, and Plomin (2000) utilized the Colorado Adoption Project to study the mechanisms that account for the increased difficulties in 12 year-old offspring of divorced families. In biological families, children who experienced the divorce of their parents showed higher rates of externalizing behavior, more substance use, poorer academic achievement, and lower social competence compared to children in intact families. These findings are consistent with the existing divorce literature. Adopted children in divorced families reported more behavior problems and substance use than adopted children in intact families, suggesting an environmental mediation of these outcomes. In contrast, the results suggest that passive rGE accounted for the association between divorce and school achievement and social adjustment because adopted children in divorced families did not differ from adopted children in intact families on these measures. 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, weak power to detect differences among families, and the assumption that divorce influences biological and adoptive children similarly (Rutter, Pickles, Murray, & Eaves, 2001).

Kendler and his colleagues (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. The statistically significant finding reinforces the importance of including direct measures of shared environmental risk factors into genetic models instead of only considering the environment to be a “black box” (Wachs, 1983). However, as the authors noted, the analyses are hindered by the assumption that parental separation is a “pure” environmental risk factor (no passive rGE), the assumption made by divorce research focused on environmental mediators. Therefore the design does not test alternative forms of mediation between parental divorce and offspring psychopathology.

In contrast, extended twin-family models account for this limitation. The model adds measures of family-level environments and parental phenotypes to the standard univariate twin design in order estimate both direct (environmental) and indirect (genetic) pathways from the family-level risk factors to offspring outcomes. An extended-twin family study of early parental loss, which included both death of a parent and absence due to marital separation, suggested that environmental mechanisms accounted for most of the association (Kendler et al., 1996). Although not a study of divorce per se, Meyer et al. (2000) utilized the extended twin-family model to study the association between two family-level risk factors, marital discord and family maladaption, with adolescent conduct disorder. The results suggest the statistical association between marital discord and 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 methodological assumptions and restrictions that limit the interpretation and generalizability of the results (D'Onofrio et al., 2003; Rutter, Pickles, Murray, & Eaves, 2001). Most importantly, the extended twin-family models assume that the same underlying biometric models (e.g. the same genes and environments) influence both the child and parent generation.

Behavior genetic analyses of divorce have suggested the possibility that passive rGE accounts for some of the elevated risk of offspring maladjustment in divorced families. These findings are consistent with the research indicating that antisocial characteristics in mothers account for the intergenerational association between parental divorce and offspring externalizing (e.g. Capaldi & Patterson, 1991; Emery, Waldron, Kitzmann, & Aaron, 1999; Lahey et al., 1988). However, the existing behavior genetic research is limited and has provided somewhat conflicting results. Therefore, more genetically informed studies of divorce, especially those with fewer and different methodological limitations, need to be conducted in order to pull apart the correlated environmental and genetic family processes.

(6) Assumptions in Each Design must be Acknowledged and Tested

Each study must identify its strengths and weaknesses, especially with respect to sample selection, measurement, statistical analyses, and methodological assumptions, so that the results can be placed in context. A few general assumptions, particularly those that influence claims of a causal connection between divorce and offspring functioning, will be addressed here. Large-scale survey studies provide insight into general patterns and provide the opportunity to make comparisons between different demographic groups. However, large demographic studies sometimes lack the specificity found in studies that incorporate multiple measures of mediating mechanisms (e.g. Hetherington, 1993). Smaller studies are also able to rely on multiple raters to provide a more comprehensive view of family dynamics and the individuals' behaviors. However, in-depth studies are typically limited by their ability to obtain representative samples, and the generalizability of the findings must be considered.

Most studies on the effects of parental divorce assume that child characteristics do not influence parental divorce (reverse causation), an assumption that may be warranted but which is rarely acknowledged (see discussion above). Although studies now frequently include measured covariates to control for selection factors, such as maternal personality characteristics (e.g. Simons & Associates, 1996), many researchers do explicitly state the logical assumption that they are making—all family characteristics that have not been measured do not to account for the remainder of the association between divorce and offspring adjustment problems. In particular, most studies assume that risk is mediated via environmental pathways (review in Rutter, 2000) and do not acknowledge the possibility of genetic factors could account for the difference between children from intact and divorced families. This represents one of the major limitations of the research on marital instability.

Studies that have included measures of parental characteristics as selection factors have highlighted an important caveat to the divorce literature, but they have primarily relied only on measures of maternal antisocial behavior (e.g. Capaldi & Patterson, 1991; Emery, Waldron, Kitzmann, & Aaron, 1999; Simons & Associates, 1996). This may be a serious limitation, given that spouses are highly correlated for such traits (e.g. Krueger, Moffitt, Caspi, Bleske, Silva, 1998). Paternal characteristics such as intelligence, personality traits, and psychopathology may be crucial in our understanding of the mechanisms that underlie the association between parental divorce and offspring difficulties. The intergenerational associations with parental divorce may be due to pathways related to personality traits in both parents, including genetic mechanisms.

A similar assumption has also been made by behavior genetic analyses of divorce. Namely, standard twin models assume that there is no assortative mating for the phenotype being analyzed. However, the wealth of literature on marriage is that spouses are similar in many respects, including age, education, religion, social attitudes, and alcohol and drug use (e.g. DeGenova & Rice, 2002). Therefore, studies designed to delineate the mechanisms, both environmental and genetic, associated with parental divorce will benefit greatly by including measures of both parents in order to test alternative models. Another assumption made by behavior genetic researchers is the equal environments assumption. A full description of this and other assumptions in twin studies is described in detailed elsewhere (e.g. Plomin, DeFries, McClearn, & McGuffin, 2001), but concordance rates of divorce may be influenced by different interactions between identical and fraternal twins. Consequently, twin studies of divorce must determine whether identical twins share more environmental similarities than fraternal twins and test whether these similarities influence the concordance rates of divorce. Future studies, whether by sample design or measurement strategy, can provide tests for these assumptions.

(7) Combination of Samples and Strategies to Ensure Necessary Variation

Because no single study can answer every question multiple approaches that utilize various methodologies and their associated assumptions, are needed to understand the risk mechanisms associated with divorce. The study of divorce has benefited greatly by the insights of researchers from many fields, including psychology, sociology, demography, economics, law, and anthropology. For example, comparisons of divorce rates in countries around the world have also shed light on the historical, political, and cultural factors that influence the stability of marriages (e.g. Goode, 1993). The research on the causes of divorce have also highlighted a number of individual characteristics, dyadic interactions, community factors, and stressful life events that serve as risk and protective factors for marital stability (review in Karney & Bradbury, 1995). Research on the different risk factors for divorce has documented many factors that may confound the association between parental divorce and offspring functioning.

The study of parental divorce on children has benefited greatly by the use of multiple nationally representative samples in the United States (McLanahan & Sandefur, 1994) and England (Rogers & Pryor, 1998). Reviews of the research in various Western countries (Pryor & Rogers, 2001), including Australia (Rodgers, 1996), have also shown that the offspring from divorced families exhibit a higher levels of behavioral, academic, social, and interpersonal problems compared with offspring from intact families. The literature includes in-depth studies utilizing multiple raters and observational methods (e.g. Hetherington, 1993; Simons & Associates, 1996). Furthermore, causal models are not based purely on cross-sectional data; rather, longitudinal, prospective studies have greatly enhanced our knowledge of the underlying mechanisms responsible for associations with parental divorce. The decades of research have also enabled researchers to explore how the effects of divorce have changed over time (e.g. Amato, 2001), but separating cohort effects from period trends has been difficult (e.g. Cherlin, 1992). The specific study of marital instability in minority populations has surprisingly received little research, but recent studies have provided more information concerning the outcomes associated with parental divorce in different racial groups (e.g. Chase-Lansdale, Gordon, Coley, Wakshlag, & Brooks-Gunn, 1999; Shaw, Winslow, & Flanagan, 1999). Research on relationship instability is also shedding light on the effects of family transitions, such as the end of cohabiting relationships, that more children are experiencing (e.g. Ackerman, Brown, D'eramo, Izard, 2002).

Overall, the advances in the study of divorce have illustrated that various environmental processes may mediate the association between parental divorce and offspring adjustment, but genetic confounds have also been implicated. There have been a few genetically informed studies of divorce (e.g. O'Connor, Caspi, DeFries, & Plomin, 2000), but the lack of quasi-experiments that pull apart correlated genetic and environmental processes remains a serious limitation in the research. Therefore more studies that pull apart environmental and genetic processes are required, a need echoed by family researchers (e.g. Booth, Carver, & Granger, 2000).

Quasi-Experiments for Studying Causal Relations

Rutter, Pickles, Murray, & Eaves (2001) discussed a number of methodologies that are capable of delineating risk factors that typically go together, a crucial step in trying to determine whether parental divorce actually "causes" the differences between children from intact and non-intact families. This paper will focus on the advantages of using various family designs to investigate causal relations between parental divorce and family outcomes (Turkheimer, D'Onofrio, Waldron, Mendle, Lynch, & Emery, in preparation).

Sibling and Co-Twin Controls

The research on divorce has primarily relied on studies of unrelated parents. As a result, the relation between parental divorce and offspring outcomes are between-family effects. Because of the non-experimental nature of the studies, between-family effects include the influence of the risk factor (e.g. divorce) *and everything that is correlated with the risk between families* (Turkheimer, D'Onofrio, Waldron, Mendle, Lynch, & Emery, in preparation). As discussed above, statistical controls can be applied, but it is impossible to determine whether all salient confounds have been included in the analyses. One methodological approach to account for between-family confounds is to study related individuals, such as siblings. Since siblings share many family-wide variables (e.g. family income, growing up in the same family, etc.), using siblings as the comparison group (instead of unrelated individuals) controls for these factors. Using siblings enables the estimation of within-family effects. Within-family estimates are free from confounds that vary between families and effectively pull apart the environmental risk factor from correlated between-family confounds.

Sibling controls have been utilized to study many risk factors. For example, the use of the sibling control design has helped to elucidate the relation between teenage pregnancy and later negative consequences for the mother (Geronimus & Korenman, 1992; Hoffman, Foster & Furstenberg, 1993). Instead of comparing teenage mothers to unrelated individuals (and estimating a between-family effect) researchers compared women who gave birth when they were teenagers to their sister who did not. The sibling-control design provided a within-family effect that was smaller than between-family estimates, even those where known confounds were statistically controlled. The results suggest that studies that only use statistical controls overestimate the influence of teenage pregnancy on subsequent outcomes in the mothers.

The co-twin control design is special case of the sibling-control design and provides additional advantages. Because twins are born at the same time the co-twin control design controls for age effects. Certain gestational influences are also held constant (Davis, Phelps, Bracha, 1995: Phelps, Davis, Schartz, 1997). As a result, when discordant dizygotic (DZ), or fraternal twins, are included in a design, the within-family estimate is not confounded with age effects or some prenatal experiences. However, DZ twins are similar to siblings in that they share only 50% of their genes and cannot account for any selection confounds that are caused by shared genetic factors that may influence exposure to the risk factor and likelihood of the outcome. On the other hand, the use of monozygotic (MZ), or identical twins, discordant for a risk factor controls for possible genetic confounds since MZ twins share all of their genes (e.g. Gesell, 1942). Thus, discordant MZ twins represent an excellent control group for studying the effects of an environment risk factor because the “matching” controls for between-family differences, age differences, certain gestational influences, and genetic confounds. In short, a within-family effect using MZ discordant twins is consistent with a causal association between the risk factor and the outcome. It must be noted that studies that report differences between MZ twins discordant for a risk factor are only consistent with causal hypotheses. The findings do not prove causation since there are many confounds that vary within twins as well.

When both MZ and DZ discordant twins are included, selection factors can be separated into shared family environmental and genetic factors (see Kendler et al., 1993 for a graphical representation and explanation of differences in effect sizes consistent with different causal mechanisms). With respect to family-level risk factors, co-twin control studies have helped distinguish between causal and selection hypotheses for a number of associations, including the relations between loss of a spouse and mortality (Lichtenstein, Gatz, and Berg, 1998) and marital status with personal alcohol use (Prescott & Kendler, 2001).

Co-twin control studies are able to control for unmeasured confounds that have typically plagued studies which rely solely on statistical controls. In spite of the many advantages of estimating within-family effects using discordant twins, the design has a number of limitations (see D’Onofrio et al., 2003; Rutter, Pickles, Murray, & Eaves, 2001). With respect to marital instability, the main limitation is that the design cannot include environmental experiences that both twins experience (twins raised in the same house are concordant for their parents’ marital status). The co-twin control design is an excellent design to study the influence of marital instability and outcomes in the adults, but other genetically informative designs must be utilized to study the relation between divorce and characteristics in the offspring.

Children of Siblings and Twins Designs

A number of researchers have noted that an extension of the co-twin control design, the Children of Twins (CoT) Design, may be helpful to study environmental risk factors for offspring (D'Onofrio et al., 2003; Labuda, Gottesman, & Pauls, 1993; Rutter, Pickles, Murray, & Eaves, 2001). The CoT Design includes adult twins that are discordant for a behavior that is considered to be an environmental risk factor. Measures of their offspring are also included. With respect to marital status, the design includes twins discordant for divorce in order to determine whether genetic (e.g. passive rGE) or shared environmental factors are confounds in the intergeneration associations. The CoT Design follows similar logic to the sibling and co-twin control design in that it controls for unmeasured factors and delineates between environmental and genetic confounds. The design can initially be considered an extension of the sibling or co-twin design but the outcome is a characteristic of the offspring, not the siblings themselves.

Effect Size Analyses

Estimates of effect sizes can be considered to be the difference in means between the two groups (e.g. regression coefficient for continuously distributed variables that have been converted to Z scores and coefficients that are distributed as logits for categorical outcomes). See Figure 1 for a graphical representation of how the differences in estimates of effect sizes from various family designs can help account for correlated confounds. The first bar represents the hypothetical effect size associated with parental divorce, measured as an effect size, when children of divorced families are compared to children of unrelated, intact families. The second bar represents the effect size when comparing children of discordant siblings. In the design, the offspring of divorced parents are compared to their cousins whose parents remained married. If factors that vary between sibling families (perhaps poverty) account for some of the problems associated with parental divorc the within-family effect size using discordant siblings will be smaller than the effect size from unrelated controls. The between-family confound could be either environmental or genetic in origin because unrelated individuals differ in both respects. The comparison of offspring of discordant siblings controls for environmental confounds that make siblings similar. To our knowledge, the use of discordant adult siblings to control for unmeasured between-family factors has not been used to study the relationship between parental divorce and child outcomes. Certainly, use of the design is encouraged in datasets with related adults.

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

The final bar in the graph represents the effect size comparing offspring of discordant MZ twins. If the effect size using discordant MZ twin families is less than the effect size in DZ discordant twin families, genetic factors account for some of the association between offspring adjustment and parental divorce. Children of MZ twins share 50% of their genes with their parents *and* with their parent's co-twin; however, only the children's parents provide the environment. Therefore, all of the offspring in discordant MZ families receive the same genetic and environmental risk from the twins associated with divorce, but only the offspring of the divorced twin would experience a change in family structure. The within-family effect size in discordant MZ twins is free of genetic confounds from the twins and all of the factors that twins control, such as the effects of between-family environmental variables, age differences, and certain prenatal experiences. Similar to the co-twin control design, caution must be taken when equating the effect size from families of discordant MZ twins with a causal relationship because within nuclear family environmental factors could account for the association. Furthermore, the genetic and environmental factors related to the spouses of the twins confound the effect sizes. However, statistical controls for characteristics of both parents may be added to the analyses to help account for these influences (Jacobs et al., 2003; Rutter, Pickles, Murray, & Eaves, 2001). In summary, the effect size estimate from MZ families is consistent with environmental effects within families that are correlated with divorce.

The difference between the effect sizes in MZ and DZ discordant families is not a measure of the magnitude of the genetic confounds because genetic factors vary both within and between families. Instead, the comparison between offspring of discordant MZ and DZ twins enables the confounds to be delineated into genetic and shared environmental factors (see D'Onofrio et al., 2003; Gottesman & Bertelsen, 1989; Rutter, Pickles, Murray, & Eaves, 2001 for additional descriptions of the rationale). Figure 2 provides the hypothetical estimates of effect sizes for between-family, within-family DZ, and within-family MZ effect sizes that correspond to three contrasting mechanisms which could explain the association between parental divorce and offspring adjustment (see D'Onofrio et al., 2003 and Gottesman & Bertelsen, 1989 for descriptions using mean and rates of disorders in the offspring).

The first set of expectations (Example A) is consistent with a causal model of parental divorce. Since the effect size from discordant MZ twin families is as elevated as the effect size using unrelated controls, genetic and between-family environmental confounds do not confound the relation between divorce and the child outcome. The effect size in this example means that even when compared to children with the same genetic risk for the disorder from the twins and whose twin parents share similar environmental experiences, offspring from divorced families have more problems than those from intact families. This pattern is consistent with the causal theory of outcomes association with divorce but does not prove causation.

If the effect size in families of discordant MZ twins is zero (Example B and C), then selection factors are responsible for the association. Under both of these conditions, it does not matter whether a child's parents were married or divorced—children in the intact and divorced twin families had the same level of behavior problems, making the effect size zero. Both of these patterns would support the selection hypothesis.

The comparison of MZ and DZ within-family effect sizes separates selection factors into genetic and environmental confounds. In example B, the pattern of effect size indicates that genetic confounds account for the association between divorce and the outcome because the effect size for MZ discordant twins is zero and the effect size in DZ discordant twins is larger. If genetic factors completely explained all of the association then all offspring in MZ families would receive the same genetic risk from the twins, regardless of whether the offspring's parents are divorced or intact. The risk of adjustment problems would be the same for offspring in both families. However, in DZ discordant families, the offspring of the divorced parent would share 50% of genetic risk associated with divorce (from their parents), whereas offspring from the intact family would only share 25% of their genes with the divorced twin (their aunt or uncle). The differences in genetic risk associated with divorce would put offspring of the divorced twin at more risk for adjustment problems than offspring from the intact family, making the difference between the two families (and the effect size) larger. Example B is an illustration of passive rGE.

If the effect size is zero in discordant MZ and DZ twins, as in Example C, then shared environmental factors would account for the confound. Under this scenario the risk would be shared among offspring in both families, regardless of genetic relationship to the divorced twin. Offspring in divorced and in intact twin families would receive the same environmental risk, making the differences between the offspring in the intact and divorced families zero.

Caution must be taken in order to ensure that the statistical methods are appropriate for the types of "causal" analyses being employed. When comparing different regression weights (or path coefficients), especially across samples, unstandardized coefficients must be used. The debate over the use of standardized and unstandardized coefficients has a rich history (e.g. Tukey, 1954). Using standardized coefficients has the benefits of placing estimates on a recognizable scale that is easily interpretable. However, standardized estimates are not "structural 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, 1976, 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. With respect to the use of coefficients in family models, including the sibling control and children of twins models, using standardized coefficients confounds the estimates of variances and the underlying, structural relationship (Turkheimer, D'Onofrio, Waldron, Mendle, Lynch, & Emery, in preparation). The importance of genetically informed studies of intergenerational relationships is to delineate the source of the risk from the underlying mechanisms of the risk (Rutter et al., 1997), and the use of unstandardized coefficients statistically separates these two factors.

If variables in the offspring are not on an interval scale, the variable of interest may be standardized before conducting the analyses using unstandardized coefficients (see Kim & Ferree, 1981 for an explanation of the distinction between standardizing variables and using standardized coefficients). However, the standardization must be completed across all of the subjects, not within each group. In summary, unstandardized coefficients are more appropriate for family models because they are not influenced by the variance of the independent variables and can be compared across samples with different variances.

Structural Equation Modeling

The analysis of children of twin data using effect sizes, or a comparison of means, provides an initial description of the data, but the analytical approach is somewhat limited. A comparison of effect size estimates relies purely on significance testing (e.g. Kringlen & Cramer, 1989), requires subjective judgments on whether the estimates fit certain patterns, and excludes concordant twins from the analyses. Most importantly, the approach does not provide estimates of the different underlying processes, a limitation that may be especially important if more than one mechanism underlies the association between divorce and offspring adjustment (D'Onofrio et al., 2003). Therefore, an analytical approach is needed that estimates the magnitude of the genetic transmission, between family confounds, and within-family environmental effects. Previous studies have utilized structural equation models to analyze the children of twin data that estimate these processes (D'Onofrio et al., 2003; Heath, Kendler, Eaves, & Markell, 1985). A series of structural equation models with children of twins data will be described here which correspond to the effect size analyses described earlier but rectify a number of inherent limitations.

The first structural equation model (Figure 3), referred to as the phenotypic model, is an example of the use of unrelated controls and provides a between-family path estimate. Only divorce in one twin (Div T1) from each twin pair and the children of the twin (Out 11, Out 12, Out 13) are included in the analysis (the first number refers to the twin family and the second refers to the order among siblings). Only one twin family is included so that no families in the analyses will be related. The model estimates the variance of divorce (V) in the sample and the unstandardized path (b_b) from divorce to the offspring (see explanation above for the rationale supporting the use of unstandardized estimates). The path will estimate the difference in outcomes between offspring from intact and divorced families and is equivalent to the effect size associated with unrelated controls described earlier. The variance of the outcome in offspring that is not accounted for by parental divorce is estimated by u_1. Since the offspring are members of the same family, the covariance of the offspring, not due to sharing the same family status, is also included in the model (u_2). The model is equivalent to drawing a "causal" or one headed arrow from divorce directly to the outcome measure in the offspring. In this and the subsequent models, the magnitude of the intergenerational association, will be reduced due to the measurement error of the adult characteristics. Therefore, when possible, researchers should incorporate multiple measures of the parent characteristics or include measurement error estimates into the structural equation models (e.g. Neale and Cardon, 1992).

Figure 4 represents the use of the sibling control design with the data. Divorce in sibling one (Div S1) and sibling two (Div S2) are now included in the analyses. This enables the variance of divorce to be separated into shared and unshared variance components. The variances of each component are estimated instead of estimating the path coefficients (the standard deviations) and setting the variance of latent constructs to equal 1.0. The covariance between the shared variance latent variables is given the value of the variance of the shared variance so that the correlation between the two latent variables will equal 1.0. As a result, the shared variance represents factors that make siblings similar. Factors that make twins dissimilar are included in the unshared variance. The (u_B) covariance is now estimated between each cousin to account for any covariance not accounted for by the marital status of the parents.

Two sets of offspring are included in the analysis, one for each twin family. Instead of measuring one path from divorce to the offspring outcomes as in the phenotypic model, two paths can be estimated, a between (b_b) and within-family (b_w) estimate. Again, because the variances are estimated, the b weights are unstandardized which allows them to be directly compared. The within-family path is a measure of the effect size when cousins of discordant siblings are compared. When the between and within-family paths are equivalent (i.e. the within path is as large as the between path), the model supports the causal hypothesis. If the paths are equal, the model can be drawn with a "causal" path from divorce to the offspring [see Turkheimer, D'Onofrio, Waldron, Mendle, Lynch, & Emery (in preparation) for an algebraic proof]. The strength of the sibling control model is that two unstandardized estimates, the within and between paths, can be compared to see if between-family confounds are responsible for part or all of the risk associated with parental divorce.

The children of twins model in Figure 5 utilizes the strength of including MZ and DZ twins to explore the relationship between parental divorce and measures of child adjustment. First, the variance in divorce is separated into three components—an additive genetic effect (A), a shared environment factor (C), and a nonshared environmental factor (E). See Plomin, DeFries, McClearn, & McGuffin, 2001 for a description of standard twin analyses. The twin model presented here may appear to be different from the typical univariate twin models that estimate the path coefficient from the three latent variance components that are standardized to equal 1.0. The twin model here estimates the variance components instead, and is merely a reparamaterization of the model. In order to estimate the variances, the covariance between the additive genetic factors is set to equal the [variance of (A)] in MZ twins and [.5 * variance in (A)] for DZ twins. This corresponds to correlations of 1.0 in MZ twins and .5 in DZ twins, the standard relationships based on genetic theory. Similarly, the covariance between the shared environmental components is set to the [variance of (C)] so that the correlation between the two latent variables equals 1.0. By definition, there is no covariance between the E variables in the twins. The covariance between the cousins is now estimated separately for the different twin families (u_{3MZ} / u_{3DZ}) because cousins in MZ twin families are correlated .25 and cousins in DZ families are correlated .125. Specifying two covariances for the offspring generation accounts for any genetic influence on the child outcomes which are not related to genetic risk associated with divorce. More complex biometric models for the offspring level can be specified, but the parameterization here (which accurately accounts for the genetic and environmental influences) is used for the sake of simplicity.

Because the variance in divorce can now be separated into three variance components, three path estimates, one from each variance component to the child outcomes, can be estimated (b_a, b_c, and b_e). The path from the nonshared environment variance (b_e) represents the effect size comparing offspring of discordant MZ twins described earlier and is a measure of the within-family environmental path from divorce to the child offspring. Using a similar rationale to the sibling control design, if the three paths are equal, then the model supports a “causal” connection between divorce and the outcomes. Setting the three paths to be equal is the equivalent model of drawing a direct path from parental divorce to the child offspring [see Turkheimer, D'Onofrio, Waldron, Mendle, Lynch, & Emery (in preparation) for the algebraic proof].

The model is capable of including three paths between parental divorce and the child outcomes. Therefore, children of twins models can be specified that include a “causal path” directly from divorce to offspring and from two of the latent variance components. For an example, a model can be specified that includes a “causal” pathway and the additional influences from additive genetic and shared environmental influences (D’Onofrio et al., 2003). Such a model would be warranted if the effect size analysis and/or full children of twins model indicated that more than one pathway was significant. For example, the effect size in discordant MZ twins could be greater than zero (a within family environmental effect) and the DZ effect size could be greater than the MZ effect size (supporting a partial mediating influence of genetic factors).

Overall, the children of twins design represents a genetically informative approach to the study of parental divorce that can pull apart factors which typically co-occur, such as shared environmental and genetic confounds. Furthermore, the design is not plagued by the assumptions required in adoption studies and extended twin-family studies (see. D’Onofrio et al., 2003 for a comparison of the designs and Rutter, Pickles, Murray, & Eaves, 2001 for a detailed description of limitations in each design).

Summary of Analyses

In light of the high percentage of children who will experience the separation of their parents, the consistent finding of differences in adjustment between offspring in intact and separated families, and the increasing risks associated with parental divorce in the past few decades, the exploration of the underlying mechanisms responsible for the elevated risk for adjustment problems in children of separated parents is an important research endeavor. The research on the consequences of parental divorce represents one of the most advanced areas of study in the field of developmental psychopathology, with sophisticated sampling strategies, longitudinal designs, and assessments of potential selection processes. A review of the research of the mechanisms underlying the association between parental divorce and offspring adjustment suggests that divorce leads to a series of harmful events that *cause* negative outcomes in the children, even if the children of divorced families have underlying predispositions for adjustment problems (Amato, 2000). However, the research literature is hindered by the lack of genetically informed studies that explore the possibility of passive rGE and unmeasured environmental selection factors.

Because of the limited behavior genetic research on the associations between parental separation and offspring the CoT Design was utilized to study outcomes in young-adult and adult offspring associated with parental marital instability. Focusing on measures of adjustment in this age group is of particular importance because the magnitude of the problems associated with parental divorce increases as offspring reach young adulthood and cannot be accounted for by pre-divorce functioning in the children (Cherlin, Chase-Lansdale, & McRae, 1998).

The analyses focused on three primary domains of adult functioning. First, the relation between parental marital instability and offspring psychopathology, including measures of externalizing, internalizing, and substance abuse, was explored. Chapter II includes analyses of the covariation between parental divorce and psychopathology using a sample of twins and their offspring from Australia. Chapter III explores the intergenerational association between parental marital instability and offspring substance problems and internalizing difficulties using a sample of twins and offspring from the United States.

The second major domain included life course patterns and demographic outcomes associated with parental divorce. Chapter IV presents analyses of the relation between parental divorce and measures of offspring adjustment, including educational achievement, sexual development and living arrangements, initiation of substance use, and age of onset for emotional problems, in the sample from Australia. Because various research methods have suggested that the mechanisms responsible for the intergenerational associations may be age specific, the analyses explored the age at which the offspring experienced their parents' separation.

The last major domain explored in the analyses is offspring relationship/marital instability. Chapter V explores the underlying mechanisms for the intergenerational transmission of relationship instability in the Australian sample. The investigation of the association between parental and offspring relationship instability in the United States sample is presented in Chapter VI. Finally, a summary of the results and future directions for studies of divorce are presented in Chapter VII.

II. AUSTRALIAN - OFFSPRING PSYCHOPATHOLOGY

Abstract

Experiencing parental divorce is associated with a number of 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 utilizes 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 three factors of abnormal behavior, including drug and alcohol, externalizing, and internalizing problems, suggest that environmental influences associated with divorce account for the higher rates of psychopathology. The results are consistent with a quasi-causal connection between marital instability and psychological problems in young-adult offspring.

Introduction

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 necessary nurturance and guidance (Silverstein & Auerbach, 1999). Overall, the consequences of marital instability for children and society at large continue to be heavily debated in the academic and popular press (e.g. 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 sub-clinical distress (reviews in Amato, 2000; Emery, 1999; Hetherington & Stanley-Hagan, 1999a). Although the effect sizes for the association between divorce and outcomes in children are small to medium (Amato & Keith, 1991a), marital disruption is linked with a two-fold 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, non-marital childbirth, earlier marriage, cohabitation, marital discord, and divorced are all associated with parental separation (reviews in Amato, 1999; Amato & Keith, 1991b; Furstenberg & Teitler, 1994). Although divorce has become more prevalent and socially accepted (Thornton & Young-DeMarco, 2000), 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 (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 offspring and 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* hypotheses throughout this paper because the higher rates of psychological and behavioral problems in the offspring of divorced parents are considered to be consequences of the marital disruption. The hypothesis is also known as the divorce-stress-adjustment hypothesis (e.g. Amato, 2000).

In contrast, the *selection* hypothesis emphasizes that divorced adults are different from non-divorced parents and that these differences lead both to marital disruptions and 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; Hetherington, 1999b; Sun, 2001). Statistically controlling for pre-divorce functioning sharply reduces the association between divorce and behavior problems and achievement during childhood and adolescence (e.g. Cherlin et al., 1991). Family and parental characteristics that precede the separation, such as marital conflict (Amato, Loomis, & Booth, 1995) and parental psychopathology (Hope, Power, & Rodgers, 1999), may also account for the post-divorce 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 provide both 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 in the offspring (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) utilized 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 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, weak power to detect differences among families, and the assumption that divorce influences biological and adoptive children similarly (Rutter, Pickles, Murray, & Eaves, 2001).

Kendler and colleagues (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 "pure" 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 which limit the interpretability and generalizability of the results (D'Onofrio et al., 2003; Rutter, Pickles, Murray, & Eaves, 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 (review in Amato, 2000) and is especially important because the findings will help guide public policy decisions and intervention efforts. Therefore, genetically informed studies of divorce with fewer and different methodological limitations are required, a need echoed by family researchers (e.g. Booth, Carver, & Granger, 2000).

Methodological Requirements for Inferring Causation

Researchers obviously cannot 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, Pickles, Murray, & Eaves (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 paper focuses on the advantages of using the CoT Desing to investigate the association between parental divorce and family outcomes.

Figure 1 portrays a graphical representation of how differences among effect sizes from a few family designs can help account for correlated confounds (Turkheimer, D'Onofrio, Waldron, Mendle, Lynch, & Emery, in preparation; 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 to children of unrelated, intact families. Because of the non-experimental nature of the studies, between-family effects include the influence of the risk factor (e.g. divorce) *and everything that is correlated with the risk between families* (Turkheimer, D'Onofrio, Waldron, Mendle, Lynch, & Emery, in preparation). Regression-based statistical controls can be applied for measures 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-family confounds is to study the children of related individuals, such as siblings. The second bar in Figure 1 represents the effect size when children of siblings discordant for divorce are compared. In the design, the offspring of divorced parents are compared to their cousins whose parents remained married. This comparison enables the estimation of a within-family effect free from between-family 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 between-family confounds, which can be either environmental or genetic in origin because unrelated individuals differ in both respects. To our knowledge, the use of discordant adult siblings to control for unmeasured between-family factors has not been used to study the relationship between parental divorce and child offspring.

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

The final bar in the graph represents the effect size comparing offspring of discordant MZ twins. 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 to DZ twins), genetic factors 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 (see discussion for a review of the implications of the genetic and environmental influence of the twins' spouses on the offspring). In comparison, children of the intact DZ twin only share 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; whereas offspring of discordant MZ twins only differ with respect to the environmental risk.

If the within-family estimate in MZ families is zero, then divorce does not cause the problems in the offspring. Such a finding would not explain whether shared environmental or genetic factors account for the overall correlations between parental divorce and child adjustment, but a comparison of the within-family estimates from MZ and DZ twin families can delineate the underlying mechanisms. If the within-family effect size from DZ discordant twins is larger than for MZ discordant twins, genetic factors must account for the 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-family estimate from both MZ and DZ twin families is zero, 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.

This paper 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 utilized genetically informative designs that require major methodological assumptions. First, the heritability of marital instability was estimated to determine whether genetic factors influenced this trait in Australia. A series of hierarchical linear models were then performed that compared effect sizes from multiple family designs, including children of discordant twins. Comparisons of within-family estimates from offspring of DZ twins and MZ twins highlight whether genetic and environmental confounds account for part of the association between parental marital instability and abnormal behavior in young-adult offspring. Measures of parental psychological and behavioral problems were also included in the models to statistically account for these possible confounds.

Methods

Samples

Longitudinal Adult Twin Study

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 ATR. All twins in these samples were born between 1893 and 1965 (25^{th} % = 1939 and 75^{th} % =1958). The first survey, referred to as the Canberra Study, was a mailed questionnaire 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 (ALC1), 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. The third survey (SSAGA1) consisted of a telephone interview for twins in 1992-1993 (N = 5,889 individual twins; 86% response rate) (Heath et al., 1997). The Australian Twin Registry 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 only includes 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: (1) twins with a history of alcohol dependence and/or conduct disorder, (2) twins with a history of depression, and (3) twins with a history of 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). The average age of the offspring is 25.1 years (Range: 14 – 39) and 50.6% are female. Approximately 23% of the offspring report that their parents are divorced, with 74% of those offspring indicating that the separation occurred before they reached the age of 17. The offspring also reported on their current marital status: 28.3% are married, 3.8% are divorced or separated, and 68.4% have 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 re-interviewed on average 1.08 yrs (range .51-1.62 yrs) after initial assessment.

Measures

Adult Characteristics

Marital Instability.

The Canberra study included questions about current marital status and number of years in present marital state. The questionnaire for the ALC1 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/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 SSAGA1 study included questions on current marital status, number of years in current marital state, and lifetime history of cohabitation. Based on 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 six 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, 2000; O'Connor, Caspi, DeFries, & Plomin, 2003).

Abnormal Behavior, Behavioral Problems, and Psychological Problems.

The Semi-Structured Assessment for the Genetics of Alcoholism (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 (e.g., DIS, CIDI, HELPER, SAM, SADS, and SCID) and demonstrates moderate to high inter-rater reliability across disorders and dimensions examined. Cohen's kappa ranges from .72-.95 for substance abuse or dependence, and .42-.70 and .65-.74 for ASP and lifetime depression, respectively (Bucholz et al., 1994). The SSAGA was originally developed for the Collaborative Study on the Genetics of Alcoholism (COGA) but has been adapted for use as a diagnostic telephone interview in Australia (e.g., Slutske, Heath, Dinwiddie, Madden, Bucholz, Dunne, Statham, & Martin, 1998).

The number of lifetime symptoms of DSM-III-R diagnoses for *conduct disorder, alcohol dependence, alcohol abuse, and major depression* were calculated for each adult twin. The lifetime history of ever using an illegal drug (24.67%) was also included. Finally, the twin's history of suicidality was calculated based on 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).

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 DSM-IV 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 three 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 3 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 the correlated responses 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 using Mplus (Muthen & Muthen, 1998-2004). Due to the inability 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 Conduct Disorder 7 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 using Promax rotation.

The first factor, referred to as Alcohol and Drug Factor, includes all of the cigarette, 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 will be referred to as an Externalizing Factor and includes retrospective reports of oppositional defiant behaviors, attention problems, hyperactivity, 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 will be referred to as an Internalizing Factor. Two items, being physically cruel to animals (Conduct Disorder 5) and Self Harm did not load on any factor. An exploratory factor analysis of all 2,508 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 (alpha factor 1 = .90, alpha factor 2 = .87, alpha = .91). Factor scores for each child were calculated by summing the items that loaded on each factor. A square root transformation was then completed 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), externalizing (r=.78), and internalizing (r=.74) factors exhibited high test-retest correlations in the sample of offspring who were re-interviewed, on average, one year later. Complete results of the exploratory factor analysis, including eigenvalues, factor loadings, and factor correlations, are available upon request from the first author (also see Appendix A).

Analyses

Univariate Twin Analysis of Marital Instability

To explore whether there is genetic variation in marital instability, a univariate twin analyses was completed on the entire cohort of twins. The tetrachoric correlations are presented for the MZ and DZ twins from the twins in the ATR (Neale & Cardon, 1992; Plomin, DeFries, McClearn, & McGuffin, 2001). Individual twins who had never been in married or in a cohabitating relationship were not included in the analyses. Estimates of the proportion of variation due to additive genetic (e.g. heritability), shared environmental, and nonshared environmental factors were based on a maximum likelihood analysis of the raw data in order to allow twin pairs in which one twin had missing data to be included (Neale, Boker, Xie, & Maes, 2002). Confidence intervals around the parameters from the full ACE model were provided.

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: twin families concordant for being married, twin families discordant for divorce where the offspring's parents remained married, twin families discordant for divorce where the offspring's parents were divorced, and twin families concordant for marital instability. Figure 6 presents a graphical representation of the four groups of families. A comparison of the means among the groups provides an initial glimpse into the underlying processes responsible for the intergenerational associations (for a complete explanation of the rationale see D'Onofrio et al., 2003; Gottesman & Bertelsen, 1989). Comparisons of the offspring in the discordant MZ families suggest whether selection factors account for the intergenerational association. If children of the divorced co-twin reported higher levels of behavior problems than offspring of the intact co-twin, the results are consistent with a quasi-causal association because the comparison is free of genetic confounds associated with divorce and environments that the twins share. However, no difference in the offspring would discount a causal theory and suggest that selection factors are responsible for intergenerational relation of marital instability and the offspring outcome. A comparison of the differences in the offspring of MZ and DZ twin pairs discordant for divorce highlights the nature of the selection factors. If the difference in the offspring of discordant DZ twins is larger than the difference between offspring of MZ twins, genetic factors account for part of the association. If the difference between the offspring of discordant twins is equivalent in each type of twin family, environmental factors would account for the selection factors.

Hierarchical Linear Models to Compare Effect Sizes from Different Family Designs

To provide tests of significance and to control for measured confounds while using the genetically informative design, hierarchical linear models (HLM) were conducted. Previous analyses of children of twins data have illustrated that the design is a three-level model: the twin-family level, the nuclear-family level within the twin-level, and the individual level within the nuclear family level (Nance, 1976; Nance and Corey, 1976). Whereas earlier analyses utilized traditional nested analyses of variance, the current analyses will use three-level HLM (Raudenbush and Bryk, 2002) to obtain estimates of the influence of parental divorce and compare the between and within-family estimates obtained from the CoT Design. The models will be summarized below (see Appendix B for a full description and algebraic rationale for each model).

The analyses presented in the paper will include five HLM for each outcome. Model 1 fit an unconditional model to the data, a model that estimated the variance of the offspring outcome attributable to the three levels: the twin-family level, the nuclear-family level, and the individual level. The model provided information on how the variability in the child outcome variable is distributed between and within families. For simplicity, the three variance components that accounted for the nested nature of the data were the only random effects estimated in the subsequent models.

Model 2 included the fixed effect of parental divorce (a nuclear-family level variable) and the offspring's age, age^2, and gender. The analysis provided an example of typical divorce analysis that compares children of divorced families to children from intact families. Model 3 is similar to a sibling-control design because it enabled the estimation of the within-family estimates. The total number of divorces in a twin family was broken into the average number of divorces in the twin family and the deviation of each nuclear family from the twin family average. The average of the divorces in the two twin families (0, 0.5, or 1) was included as a variable at the third level (twin-family level) because it is a characteristic that all cousins within a twin-family share, regardless of their marital status of their parents. The regression weight associated with the variable is a rough estimate of the between-family association with divorce (Appendix B). The deviation of each twin's divorce status from the twin-family level divorce variable was included as a second-level variable. The variable is zero for twin families where either both or neither of the twins are divorced. In discordant twins, the variable will be -.5 for the children those parents were never divorced and .5 for the children whose parents had been divorced. Therefore, the second-level divorce variable compares families of discordant twins, and provides an exact estimate of the within-family effect.

Model 4 explored whether the within-family estimate is different for MZ and DZ families. In addition to all of the variables from the third regression model, the model estimated the within-family estimate for MZ families and the difference between the within-family estimates for DZ and MZ families (DZ-MZ). The main effect of the zygosity, or twin type, of the twins was also included in the model. Finally, model 5 utilized the methodological controls inherent in Model 4 and added measures of adult psychopathology to statistically control for these possible confounds. The measures included the adult twin's history of conduct disorder, alcohol dependence, alcohol abuse, depression, drug use, and suicidality. The measures of psychopathology were not separated into the three levels because they are the subject of future analyses.

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, 1976, 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. In order to place the unstandardized estimates on an interpretable scale, the offspring variables were standardized 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, but the overwhelming source of variation is in the nonshared environment. 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 = 05 - .19). Environmental influences which made twins more similar accounted for little variance (.00, .00 - .07). The nonshared environment accounted for approximately 85 % of the variance (.81 - .90).

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, externalizing, 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 2 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 shared environmental confounds shared by the twins. The difference between offspring from the intact and the divorced MZ families on the drug and alcohol (-.10 vs .14), externalizing (-.05 vs .10), and internalizing factors (-.03 vs .13) suggest that twin pair nonshared environmental influences associated with 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 influences) and larger for the internalizing factor (consistent with a partial influence of shared genetic factors). Hierarchical analyses were conducted to provide appropriate statistical tests of the effect sizes, considering the clustered nature of the data, and control for measured confounds.

Hierarchical Linear Models to Compare Effect Sizes from Different Family Designs

The results of the regression models for the Drug and Alcohol Factors are presented in Table 3. 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 divorce is associated with a .23 difference in the drug and alcohol factor when children from intact families are compared to unrelated children in divorced families. Equation 3 delineates the divorce effect into a between-family (.25) and within-family (.20) effect. The fourth equation suggests that within-family estimate for MZ families is .26 with no statistically significant difference between the MZ and DZ within-family effects. The fifth equation suggests that even when controlling for parental psychopathology, the MZ within-family estimate associated with divorce was significant (.24) and comparable to the first estimate (model 2).

The hierarchical regression equations for the Externalizing Factor are presented in Table 4. The unconditional model suggests that the majority of the variance in the factor is due to variation at the within the nuclear family level. Parental divorce is associated with a .25 increase in externalizing in model two. When the influence of parental divorce is separated in model three, the within-family estimate (.20) is somewhat smaller than the between-family estimate (.31), but still statistically significant. The results from model four show that there is no difference in the within-family estimate for MZ and DZ twin families. Model five illustrates that the within-family estimates associated with divorce are not influenced by measures of parental psychopathology. An additional model (not shown) indicated that the within-family estimate (.17) was statistically significant ($p < .05$) when the interaction of the within-family estimate with zygosity was removed from the equation.

The results of the series of equations for the Internalizing Factor are presented in Table 5. Similar to the first two factors, the majority of the variance in the factor is attributable to differences within nuclear families. The association of parental divorce and the factor in model 2 suggests that the difference between offspring in intact and divorced families is statistically significant (.23). Model three suggests little difference amid the between (.21) and within-family (.24) effects. When the within-family estimate is calculated separately for MZ and DZ families in model four, no statistically significant difference was found, although the within-family estimate for DZ families is larger than the MZ estimate. The results for model five suggest that parental psychopathology had little effect on the within-family divorce estimates, although the between-family estimate was reduced.

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 (results available upon request).

Figure 7 provides a graphical representation of the effect sizes obtained from the HLM for each offspring measure of psychopathology. 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 utilized to account for possible confounds. The bars shows that the small to medium effect size associated with parental divorce remained after controlling for shared environmental and genetic confounds, as well as measured characteristics of the adult twins.

Discussion

A comparison of the offspring of discordant twins and a series of HLM suggested that environmental influences associated with divorce within families may account for most of the association between parental divorce and offspring psychopathology. The results of the modeling indicated that parental divorce was associated with young-adult offspring psychopathology even when controlling for twin pair shared environmental and genetic confounds, in addition to measures of parental psychopathology. Although genetic factors influence marital instability, little evidence was found for genetic confounds (e.g. passive rGE). The absence of shared environmental confounds are consistent with twin analyses indicating a limited role of environmental factors that make twins similar. Therefore, the findings are consistent with the findings from longitudinal studies indicating that pre-divorce behavior problems and other selection factors cannot account for the higher incidents of psychological problems for young-adult offspring of divorced parents (Cherlin, Chase-Lansdale, & McRae, 1998). The extent to which selection versus causation contributes specifically 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 (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 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, Bridges, & Insabella, 1997; Simons & Associates, 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 semi-structured interview in the study 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, Externalizing, 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 re-interviewed approximately one 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, McGue, Lykken, 1996; McGue & Lykken, 1992). However, the magnitude 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 the differences among the heritability estimates.

A number of limitations of the findings must be addressed. 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 "prove," given the lack of experimental control. There are other inherent limitations to uncontrolled family designs of this kind. First, the children of twins 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). However, the design has the potential to capture such influences, given certain assumptions (Silberg & Eaves, 2004). Second, environmental risk factors, such as family conflict, which correlate with divorce within nuclear families, may actually be responsible for the association. Future genetically-informed designs that depict the family environment more accurately will help to specify the salient environmental risk factors.

Third, our findings could be confounded by the influence of the twins' spouses and the role of assortative mating. Children from divorce-discordant MZ pairs will differ in terms of the overall genetic and environmental risk associated with divorce through the influences of the spouse. The influence of the twins' spouses confounds the analyses presented here, even under random mating. Assortative mating could also increase the environmental and genetic risks that covary with parental divorce. For example, twins 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). The genetic and environmental influence of the twins' spouses can be statistically controlled (e.g. Jacob et al., 2003). However, given the complexities of the analyses already presented and the complications inherent in analyzing family data with extensive patterns of incompleteness, we are reserving for future analyses to explore whether environmental or genetic influences associated with the twins' spouses confound the findings presented here. Additional analyses that included measures of psychopathology and personality characteristics of the twins and their spouses did not alter the findings (see Appendix C).

Fourth, the children of twins design has limited statistical power to distinguish different intergenerational patterns of association compared with other behavior genetic designs (Heath, Kendler, Eaves, & Markell, 1985). There are structural equation approaches to the design that can more readily quantify the magnitude of the underlying processes (Turkheimer, D'Onofrio, Waldron, Mendle, Lynch, & Emery, in preparation), but to date, most structural equation software packages have difficulties efficiently analyzing models with both dichotomous (e.g. parental divorce) and continuous variables with missing data. Finally, the results are based on data from Australia, and although research suggests that findings from Australia are consistent with studies in the US and other Western countries (Pryor & Rogers, 2001; Rodgers, 1996), the findings may not generalize to other populations. Therefore, children of twin 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 a number of behavior genetic models that can be used (review in Rutter, Pickles, Murray, & Eaves, 2001), but the children of twins design contains the fewest methodological assumptions in the study of parental divorce (D'Onofrio et al., 2003).

Applications of the 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 preparation). In contrast, studies using the children of twins suggest that some risk factors, such as parental psychopathology (Bertelson & Gottesman, 1986; Gottesman & Bertelson, 1989) and the presence of a stepfather (Mendle et al., in preparation), are probably not causally related to offspring outcomes. Future research on the children of twins utilizing 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 utilized a genetically informed design to study parental marital instability, and the results indicate that environmental factors associated with parental divorce within nuclear families account for higher levels of psychopathology in young-adult offspring.

III. UNITED STATES - OFFSPRING PSYCHOPATHOLOGY

Abstract

We used the Children of Twins Design to explore whether genetic or environmental factors confound the association between parental divorce and offspring adjustment. The results indicate that environmental processes specifically related to parental divorce were responsible for the higher levels of substance use problems in young adult offspring whose parents divorced. In contrast, genetic confounds accounted for the all of the increased risk for emotional problems in offspring from divorced families. The study illustrates that unmeasured genetic and environmental processes must be considered when studying environmental risk factors.

Introduction

Parental divorce is correlated with behavior problems and psychological difficulties, but why or even whether parental marital instability causes these problems continues to be debated (Amato, 2000; Emery, 1999). Most researchers assume that parental divorce causally influences offspring (Rutter, 2000), but characteristics of parents or families that lead both to divorce and difficulties in the offspring, commonly referred to as selection factors, may account for the documented correlations (Cherlin, et al., 1991; Emery, Waldron, Kitzmann, & Aaron, 1999). Family environmental factors that lead to both parental divorce and difficulties in the offspring may account for the intergenerational associations. Furthermore, twin studies show genetic contributions to divorce risk (e.g. McGue & Lykken, 1992). Because parents provide their children with both their genes and family environment, genetic factors transmitted from divorce-prone parents to their children could also account for the divorce-offspring associations, a phenomenon referred to as passive gene-environment correlation (rGE) (Scarr & McCartney, 1983). Indeed, the results of many twin studies have led prominent researchers to suggest that the family environment in general (Harris, 1998a; Rowe, 1994), and divorce in particular (Harris, 1998b), has no lasting effects on children at all.

The role of passive rGE with parental divorce was explored in one adoption study with young children (O'Connor, Caspi, DeFries, Plomin, 2000). However, the limitations and assumptions of adoption studies (Rutter, Pickles, Murray, & Eaves, 2001) and evidence that divorce-offspring relations are greater among young-adult children (Cherlin, Chase-Lansdale, McRae, 1998) suggest the need for a new approach. The environmental and genetic confounds inherent in intergenerational relations require that research take advantage of natural quasi-experiments that untangle co-occurring genetic and environmental risk processes (Rutter, Pickles, Murray, & Eaves, 2001). Relying on using statistical controls for measured covariates may not account for all possible confounds. We used the Children of Twins (CoT) Design, an approach that can delineate between specific environmental processes associated with divorce, shared environmental confounds, and genetic confounds (Rutter, Pickles, Murray, & Eaves, 2001; D'Onofrio et al., 2003; Gottesman & Bertelsen, 1999; Heath, Kendler, Eaves, & Markell, 1985). Adult identical twins discordant for divorce offer the best available control group for children who experience their parent's separation—the cousins of the non-divorced twins share the same genetic and common environment as the children of the divorced twins, but not the divorce itself. In contrast, children of fraternal twins discordant for divorce share environmental experiences common to the twin parents, but vary with respect to both the genetic risk associated with divorce and the specific effects of divorce. Therefore, the comparison of offspring from discordant fraternal twins is free from environmental risk factors that make the adult twins similar, and the comparison of offspring from identical twins is free from shared environmental confounds *and* genetic confounds from the twins related to divorce.

Methods

Samples

Adult Twins

The Virginia 30,000 contains 14,763 twins who were ascertained from two sources. First, public birth records and other public records from the Commonwealth of Virginia were utilized to obtain addresses for twins born between 1915 and 1971.

Second, a group of twins were recruited by their response to an advertisement in the newsletter of the American Association of Retired Persons (AARP). A "Health and Lifestyle" questionnaire was sent to the participating twins that asked them to provide the names and addresses of family members, including spouses, siblings, parents and children. The response rate for the twin questionnaires was 69.8%. The average age of the twins was 51.8 (range 14-94); 63.9% were female. The sample was exclusively Caucasian.

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 (Prob.=.44, .43-.46) is consistent with estimates of relationship disruption for women in the United States (Bramlett & Mosher, 2002). 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 was 45%.

Offspring of Twins

A modified version of the "Health and Lifestyle" questionnaire was then sent to the family members. The response rate for all of the relatives was 44.7%. The offspring sample included 4,800 responses. The average age of the offspring was 35.5 (range 16-79), and included more females (60.6%) than males. Of the offspring, 22.1% reported a history of parental divorce. With respect to the marital status in the offspring, 17.4% were single, 56.9% were married, 12.2% were remarried, .8% were widowed, 4.3% were cohabitating, and 8.4% were currently separated or divorced. More specifics concerning the samples and methods can be found elsewhere (Truett et al., 1994).

Measures

The mailed survey included questions about twinning, demographic information, lifestyle, health, personality, social attitudes, and emotional problems. Questions concerning marital instability included current marital status (seven categories), date of separation (if divorced/separated), years together with current spouse/partner, and number of times married. Based on these responses, a lifetime history of marital instability, which included both divorce and separation, was calculated for each individual. In the adult sample 18.4% reported a lifetime history of divorce or marital separation.

Emotional difficulties were measured by the Symptom Checklist (SCL) (Derogatis, Lipman, & Covi, 1973). The SCL included 30 items that measured emotional difficulties on a five-point Likert scale. The total SCL score was calculated as the total number of responses divided by the number of non-missing items. A dichotomous measure of emotional difficulties was defined as a score in the top 20%.

Personality variables were based on short scales of the Eysenck Personality Questionnaire (EPQ) (Eysenck, 1967). The revised EPQ included 54 yes/no items, and included extraversion, neuroticism, and psychoticism dimensions. Each measure was calculated as the proportion of positive responses over the total number of non-missing items for the scale. The personality variables were transformed by taking the inverse trigonometric sine in order to remove skew in the distributions. Offspring with scores on the SCL and EPQ that were four standard deviations above or below the mean for continuous variables were deleted in order to reduce the influence of outliers on the analyses. For continuously distributed outcomes the variables were transformed into Z scores so that the scale could be more easily interpreted.

Lifetime diagnoses of medical problems were based on a list of common health problems on which respondents were asked to indicate whether they had ever been diagnosed or treated by a physician. The list included alcohol problems and depression. Respondents were also asked to indicate whether they had an alcohol problem in the previous 12 month period. The questionnaire also included items concerning lifetime cigarette use.

Zygosity determination was based on questions concerning childhood similarity and recognition confusion. The method has been validated against blood-typing in numerous studies, and has been found to be over 95% accurate (Kasriel & Eaves, 1976). Twin contact was based on two items answered by both twins measuring the frequency of seeing and contacting (e.g. by telephone) each other on six-point Likert scales. The average response for each twin pair on the four items was based on the non-missing values.

Analyses

Univariate Twin Analysis of Marital Instability

Univariate twin analyses were conducted to determine the biometric structure of 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 (Neale & Cardon, 1992). 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 that were attributed to additive genetic, shared environmental, and nonshared environmental factors. Twin models were based on a) the entire sample of child bearing age and b) the twins pairs in which offspring of at least one of the twins participated.

Risks of Offspring Variables by Zygosity and Family Structure

The risks for each categorical variable were calculated separately by zygosity and family structure. The risks based on Kaplan-Meier nonparametric survival analysis to control for the age of the offspring (Allison, 1995). Family structure was broken into four categories: offspring from families in which neither twin was divorced, offspring from the non-divorced co-twin in discordant pairs, offspring from the divorced co-twin in discordant pairs, and offspring from families that were concordant for divorce. Comparing the risk in these groups separately for MZ and DZ twins suggests which processes are responsible for the association parental characteristics and offspring variables (Rutter, Pickles, Murray, & Eaves, 2001; D'Onofrio et al., 2003; Gottesman & Bertelsen, 1999; Heath, Kendler, Eaves, & Markell, 1985). In brief, if offspring from the divorced co-twin in MZ twins discordant for divorce have a higher risk for relationship instability than their cousins (from intact households), the findings would be consistent with a causal hypothesis. However if there is no difference among the offspring of the MZ twins discordant for divorce the results would suggest that selection factors completely account for the relation between offspring and parental divorce. If the intergenerational transmission of divorce is 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. This is because offspring from discordant MZ families receive the same genetic and shared environmental risk associated with divorce from the twins, but offspring in discordant DZ families only share environmental risk associated with divorce that make the twins similar.

Hierarchical Linear Models Utilizing Methodological and Statistical Controls

Figure 2 provides the hypothetical patterns of odds ratios when comparing offspring from divorced families to 1) unrelated controls, 2) cousins from discordant DZ twin-families, or 3) cousins from discordant MZ twin-families that correspond to three contrasting mechanisms for the association between parental divorce and offspring characteristics (D'Onofrio et al., 2003). The first set of expectations (Example A) is consistent with a quasi-causal model of parental divorce. Because the odds ratio from discordant MZ twin families is as elevated as the odds ratio using unrelated controls, genetic and between-family environmental factors do not confound the relation between divorce and the child outcome. The odds ratio in the MZ discordant twins in this example suggests that even when compared to children with the same genetic and family environmental risk for divorce, offspring from divorced families have more problems than those from intact families.

If the odds ratio in families of discordant MZ twins is one (Example B and C), selection factors are responsible for the association. Under both of these conditions, it does not matter whether a child's parents were married or divorced—children in the intact and divorced twin families had the same level of behavior problems, making the odds ratio one. Both of these patterns would suggest that selection factors account for the association between parental divorce and the characteristic in the offspring. The comparison of MZ and DZ within-family odds ratios separates selection factors into genetic and environmental confounds. In example B, genetic confounds account for the association between divorce and the outcome, because the odds ratio for MZ discordant twins is one and the parameter in DZ discordant twins is larger. If genetic factors completely explained all of the association then all offspring in MZ families would receive the same genetic risk, regardless of whether the offspring's parents are divorced or intact. As a result, the risk of adjustment problems would be the same for offspring in both families, and the odds ratio would be one. However, in DZ discordant families, the offspring of the divorced parent would share 50% of genetic risk associated with divorce (from their parents), whereas offspring from the intact family would only share 25% of their genes with the divorced twin (their aunt or uncle). The differences in genetic risk associated with divorce would put offspring of the divorced twin at more risk for adjustment problems than offspring from the intact family, making the difference between the two families larger. Example B is an illustration of passive rGE.

If the odds ratios are one in discordant MZ and DZ twin families, as in Example C, then shared environmental factors would account for the confound. Under this scenario the risk would be shared among offspring in both families, regardless of genetic risk associated with divorce. Offspring in divorced and in intact twin families would receive the same environmental risk, making the differences between the offspring in the intact and divorced families zero.

The magnitude of the associations between parental marital instability and each offspring variable were estimated with Hierarchical Linear Models (HLM) (Raudenbush & Bryk, 2002). There are three nested levels of analysis in the CoT Design: the individual level, the nuclear-family level, and the twin-family level (Nance & Corey, 1976). Therefore, three-level HLM models were used to analyze the influence of parental divorce while estimating the residual variance attributable to the three levels (random effects). The fixed effects of gender were included in each model and the parameters were estimated with variable exposure of risk for the outcome based on the age of the offspring. Logistic regressions were conducted with categorical variables with the parameters distributed as logits.

A series of HLM models were fit to the data to utilize the methodological controls inherent in the CoT Design and to statistically control for measures of parental psychopathology. Each HLM model 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 results compare children of divorced families to unrelated offspring of intact families and provide a parameter referred to as the phenotypic association.

Model two estimated the same comparison, a phenotypic association, but also included measures of adult substance use problems, emotional problems, depression, and personality characteristics. The measures of parental psychopathology include parental emotional difficulties as measured by the SCL, extraversion, neuroticism, psychoticism, lifetime history of alcohol problems, alcohol problems in the past year, lifetime history of smoking cigarettes, and lifetime history of depression. These variables were added to statistically control for characteristics of the parents that 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. Furthermore, measures of neuroticism, extraversion, and psychoticism in the twins were added because previous research had demonstrated that personality characteristics mediated part of the genetic influence on marital instability (Jockin, McGue, Lykken, 1996). Model two represent the traditional approach to control for confounds.

Model three compared offspring of DZ twins discordant for divorce by estimating the within-family effect of divorce in these families. 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 influence of the within-family effect was estimated by including the difference between each twin's divorce status and the between-family effect. 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).

Model four compared offspring of MZ twins discordant for divorce. The model included an approximation of the between-family effect of divorce and the within-family estimate in MZ families. The latter parameter represents the purest measure of the environmental association between marital instability and offspring characteristics 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 passive rGE mediates part of the intergenerational association.

Model five estimated the same parameters in model four, 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 found in model two. Therefore, model five combines the statistical controls found in most studies of divorce 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. (Appendix B).

Results

Univariate Twin Analysis of Marital Instability

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 that were above the age of 35. Table 6 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 (McGue & Lykken, 1992), but is generally consistent with estimates from twin studies in Australia (Heller et al., 1988), the WWII Twin Registry (Trumbetta & Gottesman, 1997), Finland (Koskenvuo, Langinvainio, Kaprio, Rantasalo, & Sarna, 1979), and an epidemiological sample of twins from Virginia (Corey, 2000).

Risks of Offspring Outcomes by Zygosity and Family Structure

For the genetically informed analyses 692 offspring were not included because of missing information about their age, their aunt or uncle's marital status, or the zygosity of the twin pair. The majority of these offspring were missing information concerning their aunt or uncle's marital status or the zygosity of the twin parents. The difference between those included in the analyses and those dropped due to missing values did not differ with respect to lifetime history of diagnosis or treatment for alcohol problems (b=-.37, SE=.37, OR = .70, p=.32), alcohol problems in the last year (b=-.17, SE= .23, p=.46), history of cigarette smoking (b=.03, SE=.09, p=.71), lifetime diagnoses of depression (b=.23, SE= .15, p=.12), and relationship instability (b=-.06, OR=.94, p=.53). Given the null findings, the data was considered to be missing at random. The sample size will be presented for each analysis because of limited missing values in each outcome variable.

The lifetime risks for the categorical offspring variables by zygosity and family structure are presented in Table 7. The risks of a lifetime history of alcohol problems in the offspring of discordant MZ twins (.04 vs .12) suggest a quasi-causal intergenerational association with parental marital instability. The results in the MZ twins for alcohol problems in the past year (.05 vs .08) also imply a direct environmental association. For lifetime history of cigarette smoking, the comparison of the offspring of the discordant MZ twins (.46 vs .68) also suggests a quasi-causal connection with parental marital instability, although there is little difference in the offspring of discordant DZ twins (.48 vs .55). The results are in contrast to the prevalence rates for lifetime history of depression. There is no difference in the offspring of discordant MZ twins (.12 vs .12), and the difference in the risks in the offspring of discordant DZ twins (.09 vs .13) suggests genetic mediation. Similar findings were found with the risks for emotional difficulties in discordant MZ twins (.32 vs .34) and DZ twins (.22 vs .29).

Hierarchical Linear Models Utilizing Methodological and Statistical Controls

A series of HLM models were fit to the data for each offspring variable to incorporate the methodological control of genetic and twin-family environmental factors from the CoT Design as well as statistical controls of parental characteristics and psychopathology. The results of the model fitting for the offspring outcomes are shown in Tables 8-10. Odds ratios for each model are presented in Figure 8.

When compared to unrelated families, offspring whose parents were separated were more likely to have ever been diagnosed or treated for alcohol problems (b=.74, SE=.15, p<.001). Parental marital instability was still associated with offspring alcohol problems (b=.56, SE=.13, p<.001) when statistical controls were utilized for measures of parental emotional problems; extraversion, neuroticism, psychoticism, frequency of alcohol consumption, quantity of alcohol consumption, lifetime history of alcohol problems and depression, and lifetime cigarette use. The association between marital instability and offspring alcohol problems was still robust when comparing offspring of fraternal twins discordant for divorce (b=.90, SE=.25, p<.001). The comparison of offspring from discordant identical twins controlled for genetic confounds, and the magnitude of the intergenerational association remained (b=.60, SE=.21, p<.01). The difference in the parameter estimates of divorce in the discordant fraternal and identical families (b=.31, SE=.32, p=.33) implied the possibility of a small influence of genetic confounds, in addition to a direct environmental influence, but the estimate is not statistically significant. The use of statistical controls did not reduce the overall magnitude of the association with divorce in offspring of discordant MZ families (b=.63, SE=43, p=.14) but slightly reduced the difference between the MZ and DZ estimates (b=.18, SE=.62, p=.78).

The phenotypic association between parental marital instability and alcohol problems in the past year (b=.39, SE=.11, p<.005) was lower than the phenotypic association with lifetime history of alcohol problems but significant. The association was somewhat reduced by the statistical controls in model two (b=.29, SE=.12, p<.05). There was no association in model three (b=-.03, SE=.23, p=.88). However, when offspring of

MZ twins discordant for divorce were compared in model four (b=.30, SE=.26, p=.24) the magnitude was similar to phenotypic associations found in model one and two. The difference in the within MZ and DZ family estimates (b=-.33, SE=.35, p=.33) indicated that the association between divorce and alcohol problems in the past year was smaller in offspring of discordant DZ twins, counter to what would be expected by genetic transmission. In model five, the magnitude of the within-family MZ estimates remained (b=.30, SE=.27, p=.27) with the within-family DZ estimate being lower (b=-.40, SE=.36, p=.27).

In the entire sample, parental marital instability was associated with offspring risk for smoking (b=.16, SE=.04, p<.001), and the magnitude of the association remained (b=.13, SE=.04, p<.005) when controlling for parental psychopathology and personality characteristics (see above). The association between parental marital instability and offspring risk of smoking was reduced in model three (b=.10, SE=.10, p=.33). However, model four suggested a small statistically significant association with lifetime history of smoking that cannot be accounted for by shared genetic or environmental confounds (b=.19, SE=.08, p=.02). The difference between the within-family MZ and DZ estimates was not statistically significant (b=-.10, SE=.13, p=.46). The MZ estimate remained robust even with statistical controls (b=.20, SE=.08, p=.02) and the difference between the MZ and DZ estimates remained small (b=-.13, SE=.13, p=.30).

In the entire sample parental marital instability was associated with emotional difficulties, as measured by the top 20% of the SCL (b=.30, SE=.07, p<.001). The association was not reduced greatly when parental variables were statistically included in the model two (b=.28, SE=.07, p<.001). The size of the association with divorce was slightly higher in model three (b=.41, SE=.15, p<.01). In contrast, no association was found when offspring of MZ twins discordant for divorce were compared in model four (b=-.01, SE=.15, p=.94). The difference between the within-family MZ and DZ associations (b=.42, SE=.20, p=.04) suggests that genetic factors may be responsible for the association between parental divorce and depression. In model five, the association with divorce in offspring of discordant MZ twins remained the same (b=-.01, SE =.15, p=.97) and the difference between the MZ and DZ within-family effect remained large (b=.41, SE=.22, p=.06), although the statistical precision to estimate the parameters was somewhat reduced. Furthermore, the main effect of zygosity and a measure of twin contact was also included in the HLM to control for these variables because they can confound the parameter estimates (D'Onofrio et al., 2003), but they did not change the parameters associated with parental divorce (results not shown).

Lifetime diagnosis of depression was associated with parental divorce in the entire sample (b=.40, SE=.10, p<.001). Statistical controls for parental confounds in model two reduced the association (b=.33, SE=.11, p<.005). Parental divorce remained significant in model three (b=.38, SE=.20, p=.04). However, there was no association when offspring of discordant MZ twins were compared in model four (b=-.01, SE=.16, p=.95) and the difference between the within MZ and DZ estimates (b=.39, SE=.25, p=.12) suggested that passive rGE accounted for the association. The same magnitude for the within MZ estimate (b=-.01, SE=.16, p=.96) and difference between the MZ and DZ within parameters (b=.40, SE=.26, p=.13) were found in model five.

The association between parental marital instability and emotional difficulties, as measured continuously was also explored. The total score for the SCL was converted to

Z scores, in order to make the parameter estimates more interpretable (effect sizes). In model one, parental divorce was associated with emotional problems (b=.10, SE=.04, $p<.05$), and the phenotypic association was only slightly reduced in model two (b=.09, SE=.04, $p<.05$). The association was larger, although the precision of the estimate is reduced, in model three (b=.15, SE=.09, p=.09). In model four, there was no within MZ family estimate (b=-.03, SE=.08, p=.71), and the difference between the MZ and DZ parameters (b=.18, SE=.13, p=.13) again suggested the presence of passive rGE. The same pattern (b=.00, SE=.08, p=.99 and b=.13, SE=.12, p=.27) was found for the continuously distributed emotional difficulties variable in model five.

Discussion

The findings suggest that offspring alcohol problems and cigarette smoking are associated with environmental factors within families specifically related to parental divorce. For substance use problems, the use of the CoT Design provides support for a causal relationship with parental marital instability and illustrates that family risk factors may influence offspring behavior even after children leave home. Furthermore, the results exemplify how the source of a risk factor is independent of the mechanisms that mediate the risk (Rutter, Silberg, Simonoff, 1993). Even though genetic factors may influence variation in marital instability, the mechanisms through which divorce influences offspring can be environmentally mediated. In contrast, the association between marital instability and offspring emotional problems is due to shared genetic factors in both generations. The importance of utilizing a genetically-informed approach is highlighted by the fact that we would have drawn false (i.e. causal) conclusions about the consequences of parental marital instability for offspring depression if we only relied on the traditional approach of statistically controlling for measured covariates. As a result, the current analyses call into question the interpretation of previous research that suggests parental divorce causes offspring emotional difficulties.

Assumptions

First, studies using the CoT Design cannot prove causation because environmental confounds that covary with divorce within nuclear families may actually account for the intergenerational associational (D'Onofrio et al., 2003). In addition, the role of the twins' spouses and assortative mating were not considered in the current analyses. Offspring of discordant MZ twins will still differ in their overall genetic and environmental risk associated with divorce because the influence of the twins' spouses. However, the difference in overall genetic risk will be lower for offspring of MZ than DZ twins. Assortative mating could also influence offspring characteristics related to divorce through environmental or genetic mechanisms (e.g. D'Onofrio et al., 2003) and remains an important research issue because accurately specifying the reasons for parental similarity can influence estimates of the processes responsible for intergenerational associations (Heath, Kendler, Eaves, & Markell, 1985). The developmental psychopathology research focusing on the influence of divorce on offspring must continue to explore the risk factors associated with divorce while considering the contributions made by both parents within a genetically informed context.

Second, the current analyses only addressed the possibility of genetic factors mediating the relationship between marital instability and offspring adjustment (passive rGE), but genetic factors may also moderate the influence parental divorce by making some offspring more susceptible—a gene-environment interaction (O'Connor, Caspi, DeFries, Plomin, 2000; review in Rutter & Silberg, 2002). The CoT Design can be utilized to explore gene-environment interaction (Jacobs et al., 2003). Ideally, future research will need to explore both gene-environment correlation and interaction simultaneously (e.g. Eaves & Erkanli, 2003). Third, the study assumes that parental divorce influenced the offspring and that offspring behaviors did not increase the risk of their parents separating, a common assumption in most studies of divorce.

However, the analyses represent the first attempt to explore genetic and unmeasured environmental confounds with adult outcomes related to divorce. More extensive research specifying the environmental risks associated with divorce and the role of both parents need to be explored, and the findings must be replicated in other samples and cultures to determine if the results generalize to other populations.

Only genetically-informed approaches and advanced research designs can pull apart risk factors that typically go together (Rutter, Pickles, Murray, & Eaves, 2001). Therefore large-scale, longitudinal, and prospective studies that use approaches such as the CoT Design are required. Because the underlying mechanisms associated with environmental risk factors may vary across outcomes, as they do with parental divorce, research must explore how genetic and environmental factors act to specifically cause all domains of adjustment and psychopathology.

IV. AUSTRALIAN - OFFSPRING LIFE COURSE PATTERNS

Abstract

Parental divorce is associated with problematic adjustment, but the relation may be due to shared genetic or environmental factors. One way to test for these confounds is to study offspring of twins discordant for divorce. The current analyses used this design to separate the mechanisms responsible for the association between parental divorce, experienced either before or after the age of 16, and offspring well-being. The results are consistent with a causal role of divorce in earlier initiation of sexual intercourse and emotional difficulties, in addition to a greater probability of educational problems, depressed mood, and suicidal ideation. In contrast, the increased risk for cohabitation and earlier initiation of drug use were explained by selection factors, including genetic confounds.

Introduction

Parental divorce and marital separation are associated with negative outcomes and earlier life transitions as offspring enter young adulthood and later life. Socioeconomic status, educational attainment, early sexual activity, non-marital childbirth, earlier marriage, and cohabitation are associated with the separation of one's parents (reviews in Amato, 1999; Amato, 2000; Emery, 1999; Furstenberg & Teitler, 1994). Furthermore, these life course patterns appear to mediate the association between parental divorce and adult psychopathology. Lower educational attainment, early childbearing, leaving home early (O'Connor, Thorpe, Dunn, Golding, & ALSPAC Study Team, 1999), and early sexual activity (Cherlin, Kiernan, & Chase-Lansdale, 1995) account for part of the statistical relation between parental divorce and adult adjustment problems. Therefore, any understanding of the mechanisms through which parental divorce influences adult offspring must consider developmental outcomes across a number of domains.

A recent meta-analysis found that effect sizes associated with divorce have increased over the past 20 years (Amato, 2001), and the effect sizes associated with parental divorce are larger in late adolescence and young adulthood than at earlier ages (Amato & Keith, 1991). Furthermore, longitudinal research has indicated that adult difficulties associated with divorce increase across the lifespan and cannot be explained by pre-divorce behavior problems (Cherlin, Chase-Lansdale, & McRae, 1998). Still, it is possible that the intergenerational association does not occur because divorce *causes* increased risk in children, but because correlated factors, including genetic or environmental correlates, account for the intergenerational association.

Research on divorce often controls statistically for many variables (e.g. family income, maternal personality characteristics, and ethnicity) that may confound the association between divorce and offspring outcomes (reviews in Amato, 2000; Hetherington, Bridges, & Insabella, 1997; Simons & Associates, 1996). However, selection on unmeasured variables may lead to both marital instability and offspring outcomes may still account for the statistical associations (D'Onofrio, et al., 2003). Furthermore, what appears to be an "environmental" family influence on children may actually be due to the gene-environment correlation (e.g. Rutter, 2000). Behavior genetic analyses of "environmental" risk factors (review in Plomin, 1995), such as divorce (McGue & Lykken, 1992; Trumbetta & Gottesman, 1997), have indicated that genetic factors influence variation in what were originally believed to be purely environmental measures. Because parents provide both the environment for their children and transmit their genes to their offspring, environmental and genetic factors are correlated. Genetic factors that influence parental divorce can be passed to the offspring and subsequently influence the offspring's behavior, a phenomenon referred to as a passive gene by environment correlation (rGE) (Eaves, Last, Martin, & Jinks, 1977; Plomin, DeFries, & Loehlin, 1977; Scarr & McCartney, 1983). Life course patterns may play a central role in understanding the genetic and environmental pathways between parental divorce and later adjustment—researchers have hypothesized that the rate at which individuals mature may be a possible genetic pathway between parental divorce and behavior problems in adult offspring (Caspi, 1998; Surbey, 1990).

A number of genetically informed methods are available for explaining associations between family life and offspring characteristics (Rutter, Pickles, Murray, &

Eaves, 2001). Only one such study has been published in relation to divorce. O'Connor and colleagues (2000) utilized 12 year old participants in the Colorado Adoption Project to explore the genetic and environmental processes responsible for the association between parental divorce and offspring adjustment. Adoption studies separate the influence of environmental and genetic factors because adoptive parents are only environmentally related to their offspring, given the assumption of no selective placement in adoption. The results suggested that passive rGE accounted for the higher risk of difficulties in school achievement in children raised by divorced parents. In contrast, risk for behavioral problems and substance use associated with parental divorce appeared to be environmentally mediated. As the authors noted, there are a number of limitations and assumptions in adoption studies that may hinder the interpretation of the results (review in Rutter, Pickles, Murray, & Eaves, 2001).

The Children of Twins (CoT) Design is an approach that has fewer methodological assumptions than other behavior genetic designs for exploring the importance of environmental risk factors that siblings in a family share (D'Onofrio et al., 2003). The CoT Design can delineate the statistical association between an "environmental" risk factor and offspring outcome into environmental processes specifically related to the risk factor, shared environmental factors, and shared genetic factors (see D'Onofrio et al., 2003; D'Onofrio et al., submitted; Heath et al., 1986; Gottesman & Bertelsen, 1989; and Rutter, Pickles, Murray, & Eaves, 2001 for summaries of the rationale of the design). The strength of the design stems from the use of different control groups for offspring in divorced families. Typical family studies of divorce use unrelated control groups (i.e. samples of non-divorced families), resulting in estimates of the influence of divorce that are confounded by all of the between-family factors related to divorce. However, comparing offspring of discordant dizygotic (DZ) twins provides a within-family estimate that is free from all between family confounds of the twins. If environmental factors that make twins similar for divorce also account for higher rates of adjustment problems in the offspring, the influence of divorce in the offspring of DZ twins discordant for divorce will be less than the phenotypic association[1]. A comparison of offspring from monozygotic (MZ) twins provides an estimate that is free from shared environmental *and* genetic confounds related to the twins because offspring from each family have the same genetic relationship with their parents and their parent's co-twin. Therefore, if the influence of parental divorce is lower in offspring of MZ twins discordant for divorce than DZ twins, genetic confounds account for part of the phenotypic relation. Overall, a comparison of the estimates of the influence of divorce using these different control groups provides the ability to distinguish between the different processes responsible for the intergenerational association (see discussion for a review of the implications of the genetic and environmental influence of the twins' spouses on the offspring).

The goal of the current analyses was to examine whether genetic or shared environment factors account for the association between parental divorce (before and after the age of 16) and offspring well-being[2]. To the extent that the association between divorce and offspring adjustment is explained by selection, we can conclude that divorce does not play a causal role. On the other hand, the argument for causality is strengthened considerably if we can rule out at least some of these potential selection effects. We used a number of approaches to explore the possibility that selection factors account for the phenotypic association between parental divorce and offspring outcomes. Because of the number of analyses presented and the fact that the CoT Design is not widely known, it is important to be clear about our methods and the logic behind them. First, the analyses explored whether parental separation was related to offspring adjustment problems across multiple domains of young-adult adjustment. Second, offspring who never experienced a separation were compared to offspring who never experienced a separation but whose parents had been separated in a previous relationship. If offspring in the latter group exhibited more adjustment problems than the previous group, selection factors would be implicated (e.g. Capaldi & Patterson, 1991). Third, offspring who experienced the separation of their parents before and after the age 16 years old were compared to unrelated individuals who never experienced a divorce. If parental divorce after the age of 16 predicted onset of a behavior that occurred before the age of 16, then family processes or other selection factors would account for association between parental divorce and the outcomes. Fourth, life course and demographic outcomes that were associated with parental divorce before or after the age of 16 were explored using the CoT Design. The association between parental divorce and each offspring outcome was estimated using unrelated controls, offspring of DZ twins discordant for divorce, and offspring of MZ twins discordant for divorce. In addition to the methodological controls in the CoT Design, the approach can also be combined with the use of statistical controls. Each comparison was also estimated while controlling for measures of psychopathology, adjustment, and demographic characteristics of the adult twins. Therefore, the analyses controlled for environmental and genetic confounds related to the twins and variability due to measured parental characteristics.

Methods

Samples

Longitudinal Adult Twin Study

Information regarding the adult twin samples included in the current study can be found in Chapter II. Adult twins were drawn from the Australian National Twin Register (ATR). Three health and behavior surveys have been conducted on the twins and their relatives in the ATR in the current cohort. All twins in these samples were born between 1893 and 1965 (25^{th} % = 1939 and 75^{th} % =1958). The Canberra Study was the first assessment (N = 8,183 individual twins; 69% response rate) (Jardine & Martin, 1984). The mailed questionnaire was completed during the early 1980's. A second mailed questionnaire, the Alcohol Cohort Follow-up I Study (ALC1), was completed in 1988-1989 (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. The third survey (referred to as the SSAGA1 study) was a telephone interview for twins in 1992-1993 (N = 5,889 individual twins; 86% response rate) (Heath et al., 1997). Tests for self-selection biases in the longitudinal sample have not found detectable differences in risk for abnormal behavior (Heath et al., 1997; Slutske et al., 1997).

Offspring of Twins

Data were collected from the offspring of adult twins in three at-risk subgroups and a control group. The three at-risk groups include: (1) twins with a history of alcohol dependence and/or conduct disorder, (2) twins with a history of depression, and (3) twins with a history of divorce. The adult twins originally had to consent for the research team to contact their children. Once parental consent was given, the offspring were contacted. If the offspring consented to participate they completed a telephone interview and were mailed a questionnaire. In total, 1,409 adult twins completed the screening interview (85% response rate) and 2,554 offspring completed the telephone interview (82% response rate). The average age of the offspring was 25.1 years (Range: 14 – 39) and 50.6% were female. Of the 2554 offspring in the study, 1876 (73.5%) were from families in which the adult twin had no history of marital instability, 83 (3.3%) had not experienced the separation of their parents but the adult twin had separated from an earlier relationship, 442 (17.3%) experienced the separation of their parents before the age of 16, and 153 (6.0%) 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 sub-sample of the offspring (n=176) completed the interview a second time to establish the reliability of the instrument. They were re-interviewed on average 1.08 yrs (range .51-1.62 yrs) after initial assessment.

Measures

Adult Characteristics

Based on marital items in each adult assessment, including a detailed history of living arrangements in the ALC1 study, a lifetime history of divorce and marital separation was calculated for each participant (see Chapter II). Marital separation included separation from a cohabiting relationship, defined as living with someone for more than six months. Approximately a quarter of the twins (23.7%) reported a lifetime history of marital separation. Previous analyses revealed that genetic factors contributed to variation in martial instability in the sample (see Chapter II). In summary, 15% (CI=5-19%) of the variation in marital instability was due to additive genetic factors. The majority of variance (85%, 81-90%) was due to nonshared environmental factors, with a limited role environmental factors that equally influenced both twins (0%, 0-7%).

Measures of the adult twins that could act as selection factors were also assessed. Parental age at birth of first child was calculated from information on the children's date of birth. The respondents also reported their highest level of education on a seven-point Likert scale: A) less than 7 years' schooling (1.0%), B) 8-10 years' schooling (32,1%), C) 11-12 years' schooling (21.7%), D) apprenticeship, diploma, etc. (16.2%), E) technical or teachers' college (14.6%), F) university first degree (8.5%), and G) university post-graduate training (5.9%).

The Semi-Structured Assessment for the Genetics of Alcoholism (SSAGA; Bucholz et al., 1994) was given to the adult twins in the early 1990's. The SSAGA is based on validated research interviews and has demonstrated moderate to high reliability (Bucholz et al., 1994). The original SSAGA was adapted for use as a diagnostic telephone interview in Australia (e.g., Slutske et al., 1998). The number of lifetime symptoms of DSM-III-R diagnoses for *conduct disorder, alcohol dependence, alcohol abuse, and major depression* were calculated for each adult twin. The lifetime history of ever using an illegal drug (24.67%) was also included. Finally, the twin's history of suicidality was calculated based on 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).

Offspring of Twins Study.

The offspring were also assessed with the SSAGA. With respect to educational outcomes, the offspring reported their years of education and whether they ever failed a grade in school. Female offspring were asked to report their age when they had their first menstrual period. All respondents were also asked whether they had ever had sexual intercourse with their consent. If so, they reported how old they were when they first had sexual intercourse with their consent. Each offspring was also asked whether they had ever lived with someone as though they were married for a period of six months or longer. The respondents were instructed not to count anyone that they later married. Therefore, the variable assesses the tendency to form cohabitating relationships that do not lead to marriage. Each responded was also asked whether they had ever consumed alcohol, been drunk (couldn’t talk clearly or it was hard to keep your balance), smoked cigarettes, and tried marijuana. If respondents answered in the affirmative, the respondents indicated when they first experienced the event. The SSAGA also included sections on depression and suicidality. The offspring were asked whether there had a) ever been two weeks or more when they were depressed or down most of the day, nearly every day or b) been two weeks or more when they were a lot less interested in most things or unable to enjoy the things they used to enjoy, most of the day, nearly every day. A positive endorsement for either was coded as depressed mood. Although the symptoms are important criteria for the diagnosis of DSM-IV major depression, the variable represents depressed mood, rather than a diagnosis, because the episodes may or may not have met all of the DSM-IV criteria. The respondents also reported the age of onset for the first depressive episode. The SSAGA also assessed lifetime presence and initiation of suicidal ideation.

Table 11 presents the means, standard errors and reliability of the outcome variables in the entire sample. Most of the variables had adequate test-retest reliability. A few of the items, such as lifetime history of intercourse, cohabitation, and intoxication, had lower reliability over time. However, this does not reflect inaccuracies in measurement; rather, the low reliability reflects the chronological development of many of the participants in the study. Most of the discrepant reporting or "unreliability" in lifetime history of intercourse (92%), cohabitation (98%), and intoxication (86%) was due to participants who originally denied these experiences but participated in these events during the period of time in between the two measurements.

Analyses

Comparison of Separation Groups

The means and prevalences of the offspring variables were calculated separately for the four separation groups: offspring whose parents never separated, offspring whose parents had separated from a previous relationship, offspring who experienced their parents' separation before the age of 16, and offspring who experienced the separation of their parents after the age of 16. All means are presented after controlling for age, age^2, and gender of the offspring. ANCOVAs were conducted using SAS Proc Mixed (Littell, Milliken, Stroup, Wolfinger, 1996) to account for the nested nature of the data, controlling for the age, age^2, and gender of the offspring. The significance testing for ANCOVAs with the dichotomous outcomes controlled for variable exposure of risk for the outcome based on the age of the offspring (a survival analysis), the fixed effects of gender, and the nested nature of the data using the software HLM (Raudenbush, Bryk, Cheong, & Congdon, 2001). For offspring variables that were related to the separation groups, comparisons among the separation groups were conducted using dummy codes, with the never separated group being the reference group.

Children of Twins Analyses Using Hierarchical Linear Models

To provide tests of significance for the various estimates of the influence of divorce and to control for measured confounds while using the CoT design, hierarchical linear models (HLM) were conducted (Raudenbush and Bryk, 2002). A series of three-level HLM were conducted with each offspring variable that was associated with the parental separation groups in the ANCOVA analyses. The three levels were the within nuclear families level, the nuclear-family level, and the twin-family level. Residual variance components, or random effects, were only included at each level to account for the nested nature of the data. Due to the small number of families with variation within the nuclear family level (e.g. siblings who differed in their experience of their parent's divorce), no definitive conclusions could be drawn from the comparison of individuals within families.[3] Therefore, nuclear-family level divorce variables were based on the average number of offspring within a nuclear family who experienced the separation of their parents either before or after the age of 16.

Model one compared offspring who experienced the separation of their parents either before or after 16 to offspring in unrelated families who had never experienced a separation. Model two made the same comparison, but also statistically controlled for characteristics of the parents that could act as selection factors. The analyses controlled for parental age at the birth of first children, parental level of education, history of parental conduct disorder symptoms, alcohol abuse symptoms, alcohol dependence symptoms, cigarette smoking, lifetime history of illicit drug use, and suicidality. Model two, thus, provides an example of the standard statistical approach of controlling for confounds.

Model three utilized the CoT Design to provide comparisons of offspring to their cousins. Table 12 presents the sample sizes for the entire dataset and for the MZ and DZ twin families by age of parental separation and the divorce status of the parent's co-twin. The design allows the influence of divorce to be separated into the effect of divorce between twin families and within twin families. The within-twin family effect compared offspring who experienced the separation of their parents (before or after the age of 16) to their cousins who had never experienced any separation—a comparison of offspring from twins discordant for divorce. Model three provided up to five divorce parameters. First, an approximation of the between-twin family estimate of divorce was calculated (see Turkheimer, et al, in preparation; Appendix B). The following two divorce parameters could be estimated for divorce before or after the age of 16: 1) a comparison of the offspring from MZ twins discordant for divorce and 2) the difference between the magnitude of the within-family estimates in MZ and DZ families (b=DZ-MZ). The first parameter, referred to as the within MZ twin-family parameter provides an estimate of the relation between parental divorce and the offspring variable free from genetic and shared environmental confounds related to the twins. Therefore, the magnitude of the within MZ estimate quantifies the influence of parental divorce, controlling for non-measured confounds in the twins. The second parameter estimates whether the within twin-family association between parental divorce and the offspring variable was different for DZ twins, compared to MZ twins. A higher within family estimate in DZ twins would suggest that genetic factors confound the intergenerational association.

Model four included all of the parameters from model three but also included the statistical controls for parental confounds. Model four represents an approach that utilizes both methodological and statistical controls. If the phenotypic association between parental divorce after the age of 16 and the offspring outcome was small, the phenotypic association was not decomposed into separate MZ and DZ estimates. Because the major focus of this paper is on parental separation, the parameter estimates, standard errors, and significance levels for the divorce variables will be provided in the text. The parameter estimates for all of the variables in the model will be presented in the Appendix D. Algebraic representations of the models can be found elsewhere (Appendix B).

Results

Comparison of Separation Groups

Table 13 presents the means and crude prevalence rates for the offspring variables by the separation groups, with the overall significance levels. The offspring in the four groups differed in years of education and failing a grade. Parental separation was not related to age of menarche or lifetime history of intercourse, but the groups differed on age at first intercourse, lifetime history of cohabitation, and having a baby before the age of 20. The separation groups did not differ on prevalence of ever drinking, being intoxicated, or trying cigarettes. However, the offspring in the four groups differed in age first drinking, age of first intoxication, and age at first cigarette use, marijuana use, and age at first marijuana use. Depressed mood, age of first depression, and suicidal ideation also differed across the separation groups.

For the variables that were associated with marital instability, three comparisons were made based on dummy codes, with the never separated group as the reference group. The first comparison contrasted the two groups of offspring who never experienced their parents' separation, the never separated and the previous separation groups. The regression weights for continuous variables are distributed in years and logits for the dichotomous variables. There were no significant differences for any outcomes: years of education [b=.04, SE=.12, p=.70], failed a grade [b=-.28, SE=.37, p=.45], age of first sex [b=.04, SE=.16, p=.81], cohabitated [b=-.17, SE=.27, p=.53], age of first drink [b=.10, SE=.13, p=.43], age at first intoxication [b=-.01, SE=.15, p=.97], age of first cigarette use [b=.21, SE=.22, p=.33], marijuana use [b=.17, SE=.10, p=.07], and age of first marijuana use [b=-.07, SE=.20, p=.74], depressed mood [b=-.09, SE=.14, p=.54], age of first depression [b=-.41, SE=.84, p=.62], and suicidal ideation [b=.06, SE=.20, p=.75]. The comparison could not be made for having a baby before the age of 20 because none of the offspring in the previous parental separation group endorsed the outcome.

For all of the outcomes associated with the separation groups, offspring who experienced a separation before the age of 16 differed from those whose parents never separated: education years [b=-.41, SE=.24, p<.001], failed a grade [b=.33, SE=.14, p=.02], age of first intercourse [b=-1.00, SE=.15, p<.0001], cohabitation [b=.70, SE=.17, p<.001], parent before the age of 20 [b=1.50, SE=.33, p<.001], age of first drink [b=-.45, SE=.12, p<.001], age of first intoxication [b=-.51, SE=.13, p<.0005], age of first cigarette [b=-.71, SE=.19, p<.0005], marijuana use [b=.19, SE=.04, p<.001], age of first marijuana use [b=-.71, SE=.19, p<.0001], depressed mood [b=.24, SE=.05, p<.001], age of first depression [b=-1.75, SE=.33, p<.005], and suicidal ideation [b=.30, SE=.08, p<.001].

The offspring who experienced their parents divorce after the age of 17 also differed from the no separation group for years of education [b=-.63, SE=.17, p<.001], age of first intercourse [b=-.72, SE=.22, p<.001], cohabitation [b=.89, SE=.21, p<.001], and becoming a parent before the age of 20 [b=1.50, SE=.33, p<.001].

Children of Twins Analyses Using Hierarchical Linear Models

Of the 2554 offspring in the study, 47 were not included in the HLM because of missing data. The majority of the missing observations were due to incomplete information regarding the marital status of the offspring's aunt or uncle. However, the offspring with incomplete data did not differ from those included in the analyses for any life course outcome.[3] Due to the fact that there were no differences between the previous and no separation groups for any of the offspring variables, the two groups were collapsed in the HLM. The prevalence and means for each life course outcome was calculated for the no separation group, divorce before the age of 16, and parental separation after 16 separately for MZ and DZ twins, conditional on the divorce status of their parent's co-twin (referred to as the avuncular relationship). The results are presented in Appendix D.

Education

The divorce parameters and standard errors from the HLM are presented in Table 14. The phenotypic, within DZ, and within MZ divorce estimates for the age of onset variables are also presented in Figure 9. The figure illustrates how the phenotypic association between divorce years of education was reduced when statistical and methodological controls for confounds were utilized. Years of education were associated with parental divorce before and after the age of 16. In each case, statistical controls for parental characteristics slightly reduced the magnitude of the association. Estimates of the association using offspring of MZ twins discordant for divorce, with and without the statistical controls, suggest that the size of the intergeneration relation is half the original phenotypic estimate. The difference between the within MZ and DZ estimates were in the opposite direction of what would be expected by genetic confounds for early divorce, and were negligible for later divorce. Therefore, the findings suggest no presence of rGE. A similar pattern was seen for the risk of failing a grade. The original phenotypic estimate associated with early divorce was reduced by approximately 50% when statistical and methodological controls were used, but there was little evidence for genetic confounds. Figure 10 presents the parameters for the dichotomous outcomes, presented as odds ratios.

Sexual Development, Living Arrangements, & Early Parenting

Age of first intercourse had a sizeable association with early parental divorce. Statistical controls and the within MZ family estimates suggest that the relation may be half of the original estimate, although early parental divorce was still associated with an onset a half year earlier. Furthermore, the associations with early parental divorce appear to be larger in DZ families, suggesting that genetic factors may account for part of the confounds of the original phenotypic association. Parental divorce after the age of 16 was also associated with age of first sexual intercourse, but the association was substantially reduced when the CoT Design was used.

The results for cohabitation are some of the most striking findings. Although early parental divorce had a large phenotypic association with cohabitation and the estimate remained robust when statistical controls were used, there was no association when offspring of MZ twins discordant for divorce were compared. The within DZ estimate appeared to be larger than the DZ estimate (b=1.09, p=.09), suggesting that passive rGE accounted for all of the phenotypic relation. The association between late divorce and cohabitation showed a slightly different pattern. The use of the CoT Design substantially reduced the estimates of the association, indicating that the relation was not causal, but there was little evidence of the role of genetic confounds.

Due to the low prevalence of endorsement for becoming a parent before the age of 20, the effects of divorce before and after age 16 could not be calculated in the genetically informed analyses.

Alcohol, Cigarette, and Drug Use

Early parental divorce was associated with age initiating drinking, but the magnitude of the relation was greatly reduced when statistical and methodological controls were used. The difference between the within MZ and DZ estimates suggest that passive rGE may partly confound the associations, but the limited statistical precision makes a definitive conclusion impossible. Similar to initiation of alcohol use, early parental divorce was associated with age of first intoxication. The association was reduced by approximately 50% in the subsequent analyses, but the results did not suggest any genetic confounds. The same overall results were obtained when exploring the relations between parental divorce before the age of 16 and initiation of cigarette smoking.

Lifetime history of marijuana use was associated with early parental divorce, and the results of the model fitting suggest that genetic and shared environmental confounds do not mediate the any of the relation. The estimates using statistical controls and comparing offspring of discordant twins were consistent with the original phenotypic relations, indicating that environmental risk factors associated with divorce account for higher rates of marijuana use in children in separated households. However, the results for age of initiating marijuana use suggest a different underlying mechanism. Early parental divorce was associated with an earlier age of onset, even when statistical controls for parental characteristics were utilized. Yet, there was no association when in offspring of discordant MZ twins. The findings discount a causal association. The larger within DZ than MZ family estimate implies that genetic factors may account for the association.

Emotional Problems

There was a phenotypic association between early parental divorce and a risk for depressed mood, and the use of statistical and methodological controls for possible confounds did not reduce the estimate. Parental divorce before the age of 16 was also associated with an earlier onset of depressed mood. The use of CoT Design slightly reduced the magnitude of the association. The difference between the within MZ and DZ estimates is also suggestive of a slight role of passive rGE. Therefore, the results suggest that environmental risks that covary with divorce account with a majority of the intergenerational association, with the possibility of a small genetic confound.

Finally, parental divorce before the age of 16 was associated with the risk of experiencing suicidal ideation. Although statistical controls for parental characteristics slightly reduced the magnitude of the estimate, the within MZ family parameters were consistent with the phenotypic association, consistent with a causal theory. Furthermore, the differences between the within MZ and DZ results are in the opposite direction of what would be expected by passive rGE.

Discussion

Summary of Results

The current analyses used a longitudinal study and genetically informed method, the CoT Design, to account for possible confounds in the putative effects of parental divorce on children. The results therefore provide a more fully informed test of the common view that parental divorce causes the well-being of offspring to decline. The findings support a few general conclusions toward that end. First, and consistent with a large body of research, parental divorce, especially when experienced before the age of 16, is associated with a number of life course patterns, including lower educational attainment, earlier initiation of sexual activity, higher rates cohabitation, earlier age of onset of alcohol and drug use, and earlier emotional problems. Second, children who had not experienced a divorce but whose parents had separated from a previous relationship did not differ from offspring whose parents have never been separated. Third, in most of the analyses, the estimates from the HLM that controlled for shared environmental and genetic factors were smaller than the original phenotypic associations and the estimates that only utilized statistical controls. Fourth, the relative contributions of genetic selection, selection due to the shared environment, and the effects of parental divorce differed across outcomes. Some apparent effects of divorce appear to be due to genetic and/or environmental selection, other apparent effects seem to be partially due to selection, and still other effects appear to be true effects of divorce, at least as inasmuch as we could not account for them using the CoT design, an approach that offers a major advantage over other methods in being able to account for selection effects. Below, we consider how these general patterns differ across various outcomes.

Education

The phenotypic associations between parental divorce and educational outcomes, such as years of education and risk of failing a grade, are consistent with previous research (e.g. McLanahan & Sandefur, 1994). However, the phenotypic associations of years of education with early and later divorce were both reduced substantially when both statistical and methodological controls were utilized. The phenotypic association between early parental divorce and failing a grade was also reduced when using the CoT Design. The findings suggest that there is a quasi-causal association between parental divorce and educational attainment, but the size of the associations was approximately half of the initial estimates.[4] The results do not replicate previous findings for the role of passive rGE in academic achievement (O'Connor, Caspi, DeFries, & Plomin, 2000), but the disparity may reflect the differences in the educational variables used in the studies. Certainly further studies are necessary to explore the underlying mechanisms responsible for educational difficulties associated with parental divorce.

Sexual Development, Living Arrangements, and Early Parenting

Although some research has found associations between parental divorce and age of menarche (e.g. Hetherington, 1993), no relation was found in the current analyses. The null findings are consistent with epidemiological studies in Britain that support the notion that age of menarche does not contribute to the differences between women of divorced and intact families on measures of sexual activity, partner formation, or childbearing (Kiernan & Hobcraft, 1997). These results do not support the possibility that sexual maturation is a genetically mediated process that accounts for higher levels of adjustment problems in divorced families (Caspi, 1998; Surbey, 1990), but the association between other family risk factors, such as stepfather presence, and sexual maturation may be the result of genetic confounds (Mendle et al., in preparation).

Findings from the current sample were consistent with previous research exploring age of first intercourse (Cherlin, Kiernan, & Chase-Lansdale, 1995; Kiernan & Hobcraft, 1997). Parental divorce, especially early parental separation, was associated with an earlier initiation of sexual activity. Although genetic factors appear to account for part of the association, the results suggest that parental marital dissolution has a sizeable impact on their offspring's sexual activity. Because of the negative health outcomes associated with early sexual activity, the results suggest that prevention efforts and sexual education targeted at children from broken households may be especially beneficial.

The relationship between parental divorce and offspring cohabitation provides an example of the complexity of studying the impact marital dissolution. Early parental divorce is associated with an increased probability of forming a cohabiting relationship in the entire sample, but the use of the CoT Design suggests that genetic factors completely account for the relation. The association between parental divorce after the age of 16 and cohabitation also appears to be mostly due to selection factors, but the results do not support the role of passive rGE. The use of the CoT Design suggests that the processes responsible for the likelihood of forming a cohabiting relationship may differ depending on the age of parental divorce; however, studies of sensitive periods are difficult to conduct with just one time point (see the limitations discussed below). Overall, the results imply that statistical associations between parental divorce and cohabitation in other studies (e.g. Cherlin, Kiernan, Chase-Lansdale, 1995; Kiernan, 1992; Thornton, 1991; Furtenberg & Teitler, 1994) may not represent causal relations.

Although having a child before the age of 20 was related to parental divorce, consistent with other studies (Wu, 1996), the low prevalence of the outcome made it impossible to explore within the current genetically informative context. Therefore, larger genetically informed samples are required to explore this intergenerational association.

Alcohol, Cigarette, and Drug Use

Parental divorce was not associated with offspring reports of ever using alcohol, being intoxicated, or trying a cigarette, but experiencing the separation of one's parents before the age of 16 was related to age of first alcohol use, intoxication, and cigarette use. In each case, controlling for parental characteristics and non-measured confounds via the CoT Design reduced the association. Again, early parental divorce appears to have a small quasi-causal influence on these developmental outcomes, but the magnitude of the effect was reduced, suggesting that divorce may not have as large of an impact as originally expected.

Early parental divorce was associated with the risk of ever using marijuana in the entire sample, and the magnitude of the association was not reduced with statistical or methodological controls for confounds. These findings suggest a quasi-causal relation between early parental divorce and offspring marijuana use. However, the sizeable association with age of first marijuana use in the entire sample appears to be entirely due to confounds because there was no association in the offspring of discordant MZ twins. Furthermore, the within family estimate in DZ families appears to be larger than the within family MZ estimate, a pattern that suggests genetic mediation.

Emotional Problems

Parental divorce before the age of 16 was associated with depressed mood and the magnitude was not reduced in the HLM, consistent with a causal association. The magnitude of the finding is commensurate with previous research on internalizing problems (e.g. Amato & Keith, 1991). Furthermore early parental divorce was associated with a much earlier age of onset of emotional problems, one of the largest phenotypic associations in the current study. The magnitude was somewhat lower in the offspring of discordant MZ twins, compared to discordant DZ twins, implying both a large quasi-causal association and some role of rGE. Lifetime history of suicidal ideation was related to early parental divorce, and similar to depressed mood, the magnitude was not reduced by the statistical and methodological controls. The finding for emotional problems are consistent with the literature that illustrates that parental divorce is a traumatic experience for many young children (e.g. Emery, 1999).

Limitations

A number of limitations of the current research need to be addressed. First, a statistical association between parental divorce and offspring life course outcomes, even with the statistical and methodological controls used in the current analyses, does not prove causation (also see D'Onofrio et al., submitted). Environmental risk factors associated with divorce within a twin family (environmental factors that only affect one twin) may actually be responsible for the outcomes. For example, the analyses were unable to control for income before and after the parental separation. However, the relation between family instability and some life course patterns, such as premarital childbirth, are independent of low income, unstable income, or changes in income after parental separation (Wu, 1996). Furthermore, the analyses presented here, consistent with most research of divorce (e.g. Capaldi & Patterson, 1991; Emery, Waldron, Kitzmann, & Aaron, 1999; Simons & Associates, 1996), only statistically controlled for measures of one of the parent's characteristics. Therefore, the associations reported here may be confounded by the environmental or genetic contributions of the spouses of the twins. Because of the complexities of the analyses presented here, further research will explore the role of the spouses of the twins. The analyses also assumed that reciprocal influences were negligible, such that offspring adjustment problems and life course patterns did not influence the probability that the parents would separate.

Second, although the comparison of offspring from MZ twins discordant for divorce provides an excellent control group, the CoT Design requires large samples to delineate between shared environmental and genetic confounds (Heath, Kendler, Eaves, & Markell, 1985). As a result, the analyses presented here that suggest genetic mediation, compared to the role of shared environmental factors, should be considered cautiously. Furthermore, the statistical power in the current project to precisely estimate all of the divorce parameters, especially when separating the effects of early and later parental divorce, was limited. The interpretation of the results relied on the magnitude of the parameter estimates instead of exclusively focusing on significant testing because we did not want to confuse statistical precision with the importance of parameter estimates.

As a result, replications of the findings will be extremely important, especially to determine whether the same patterns of results are seen in samples of the US and other cultures.

Third, it is impossible to determine whether differences in estimates for early and later parental divorce represent fundamental differences in the underlying mechanisms because an offspring's age at the time of the divorce is perfectly correlated with the time since the divorce and the outcome (see Emery, 1999 for a detailed description). This limitation may be especially salient for the results for cohabitation; the differences between the findings for parental divorce before and after the age of 16 may be due to the time since the parental divorce and not an indication of a developmental sensitive risk period.

Conclusions

The consequences for parental divorce for our society at large continue to be debated in the social science literature (see review in Thompson & Wyatt, 1999). All discourse about the consequences of divorce on offspring is predicated on a proper understanding of the causal pathways linking marital separation and offspring characteristics. If the increased rates of adjustment problems are due to selection factors interventions to reduce the prevalence of divorce will be misguided. Likewise, studies that illustrate quasi-causal associations provide further evidence that a reduction of divorce or an amelioration of the environmental risk factors associated with parental separation will result in offspring with fewer difficulties.

The findings of the current analyses provide further support for a quasi-causal association between experiencing parental divorce before the age of 16 and a) educational attainment, failing a grade, and lifetime risk for marijuana use, depressed mood, and suicidal ideation, and b) earlier onset of sexual intercourse, substance use, and age of first period of depressive symptoms. These findings, in conjunction with other studies of divorce using the CoT Design (Chapter II and III), support the causal, or the divorce stress-adjustment, hypothesis of the consequence of divorce (e.g. Hetherington, 1999). In contrast, offspring cohabitation and age of first use of marijuana do not appear to be consequences of divorce; rather factors that increase the risk for parental divorce also lead to these offspring outcomes.

Genetically informed studies of environmental variables are beginning to highlight the importance of specific environmental risk factors. Whereas some researchers have used behavior genetic results to claim that the parental behaviors (within certain limits), are not important influences on children's development or adjustment (e.g. Harris, 1998; Rowe, 1994), behavior genetic studies using the CoT Design (e.g. D'Onofrio et al., submitted; Jacob et al., 2003; Lynch et al., in preparation) and other behavior genetic approaches (e.g. Caspi, et al., 2004; Jaffee, Caspi, Moffitt, & Taylor, 2004; Kim-Cohen, Moffitt, Caspi, & Taylor, 2004) have illustrated that many family risk factors influence children and young adults. However, the findings from these studies and others (Mendle, et al., in preparation) have also illustrated that a more nuanced approach is necessary because the mechanisms through which genetic and environmental act depend on the specific environmental risk factor and developmental outcome.

V. AUSTRALIA – OFFSPRING RELATIONSHIP INSTABILITY

Abstract

Most research on the intergenerational transmission of divorce has used statistical controls of measured covariates to account for selection factors. However, unmeasured characteristics of the divorced parents could still account for the association. In particular, most studies have not explored whether psychopathology in both parents and unmeasured selection factors, such as common environmental or genetic confounds, account for the intergenerational transmission of divorce. The current analyses used the Children of Twins Design with a longitudinal study of twins, their spouses, and their young adult offspring in Australia to investigate whether selection factors account for the intergenerational association of relationship instability. The results suggest the possibility that genetic factors may partially confound the relation, but environmentally mediated risk factors specifically associated with parental marital instability appear to account for most of the transmission of divorce.

Introduction

Nationally representative studies in multiple countries have shown that parental divorce is associated with higher rates of marital instability in the offspring (e.g. Amato, 1996; Diekmann & Engelhardt, 1999; Feng, Giarrusso, Bengtson, & Frye, 1999; Greenstein, 1995; Glenn & Kramer, 1987; McLanahan & Bumpass, 1988; Mueller & Pope, 1977; Rodgers, 1994; O'Connor et al., 1999). As a result, recent research has explored the mediators of the intergenerational transmission, including offspring life course variables (age at marriage, cohabitation, and socioeconomic status), acceptability of divorce, mate selection, and interpersonal behavior problems (reviews in Amato, 1996; Furstenberg & Teitler, 1994; Hetheington, 2003; O'Connor et al., 1999; Teachman, 2002). These efforts stem from the general conclusion that parental divorce has a causal relation with offspring marital instability (e.g. Amato, 2000).

However, the statistical association between marital instability in both generations may not be due to causal processes (e.g. Emery, 1999). Rather, selection factors that lead to divorce in parents and offspring may account for the "transmission." Most studies statistically control for potential confounds, such as socioeconomic status and ethnicity, by including measured covariates in the analyses (reviews in Amato, 2000; Emery, 1999; Hetherington, Bridges, & Insabella, 1997; Simons & Associates, 1996). However, unmeasured or imperfectly measured confounds may still account for the intergenerational transmission (e.g. D'Onofrio et al., 2003). Most research on the intergenerational transmission of divorce has utilized sociological samples that do not include in-depth assessments of parental psychopathology. This is a major limitation, given that parental psychopathology is associated with changes in family functioning and the transmission of psychopathology could account for some of the intergenerational transmission of divorce (e.g. Rutter et al., 1997). Studies of the association between parental divorce and offspring adjustment that include measures of one parent's psychopathology have provided great insight into the role of selection factors (e.g. Capaldi & Patterson, 1991; Emery, Waldron, Kitzmann, & Aaron, 1999; Simons & Associates, 1996), but these studies are limited by their inability to account for characteristics of both parents.

Furthermore, genetic factors could also account for the intergenerational transmission. Twin studies have illustrated that genetic factors influence variation in divorce (e.g. McGue & Lykken, 1992; Trumbetta & Gottesman, 1997), and the genetic predisposition for relationship instability may be passed from parents to their children (Eaves, Last, Martin, & Jinks, 1977; Plomin, DeFries, & Loehlin, 1977; Scarr & McCartney, 1983). Personality characteristics that lead to a greater probability of divorce could be the mechanisms through which genetic factors influence both generations (Jockin, McGue, Lykken, 1996).

Because genetic and environmental risk associated with parental divorce are correlated within families, genetically informative research designs are required to pull apart these mechanisms (Rutter, Pickles, Murray, & Eaves, 2000). Although family researchers (Booth, Carver, & Granger, 2000) and developmental psychologists (Collins et al., 2000) have called for more integration of behavior genetics and the social sciences, no behavior genetic studies have explored the mechanisms underlying the intergenerational transmission of divorce. There are many genetically informative designs, but the Children of Twins (CoT) design may be the most appropriate approach to explore the underlying processes related to parental divorce (D'Onofrio et al., 2003). The CoT design utilizes comparison groups that differ in their genetic and environmental risks associated divorce, thus allowing researchers to separate the intergenerational association into genetic, shared environmental, and the nonshared environmental processes (reviews in D'Onofrio et al., 2003; Heath, Kendler, Eaves, & Markell, 1985; Gottesman & Bertelsen, 1989).

The current analyses used a longitudinal study of adult twins, their spouses, and their offspring from Australia to explore whether selection factors confound the association between parental and offspring divorce. The current manuscript provides a more detailed examination of selection factors by including measures of parental psychopathology and demographic characteristics for both parents. The use of the CoT Design also allowed us to explore whether unmeasured genetic and environmental characteristics of the twins account for some of the intergenerational transmission of divorce.

Methods

Samples

Longitudinal Study of Adult Twins and their Spouses

Adult twins for the current analyses were drawn from the Australian National Twin Register. The twins in the current cohort were first assessed in 1981 with a self report survey, referred to as the Canberra study (N = 8,183 individual twins; 69% response rate, Jardine & Martin, 1984). In 1988, the twins were assessed again with a mailed questionnaire, the Alcohol One (AL1) study (N = 6,327 individuals, 83% response rate, Heath & Martin, 1994). Relatives of the twins (N=14,421), including

3,318 spouses, were also assessed with a similar questionnaire (Lake et al, 2000). The study was named the Alcohol Relatives One Study (AR1). Finally, the twins and their spouses were assessed via telephone beginning in 1992 with a semi-structured diagnostic interview (86% response rate, Heath, et al., 1997). The twin study is referred to as the SSAGA study (N = 5,889 individual twins), and the spouse study was named the SSAGA-Spouse study (N=3,844). The sample is primarily Caucasian, consistent with the demographics of Australia. Tests for self-selection biases in the longitudinal sample have found few detectable differences in terms of risk for abnormal behavior (Heath et al., 1997; Slutske et al., 1997).

Offspring of Twins

Offspring of the adult twins were selected from a control group and three at-risk subgroups: 1) a history of alcohol dependence and/or conduct disorder, 2) twins with a history of depression, and 3) twins with a history of divorce. The adult twins were required to consent for the researchers to contact their children, and the offspring also had to agree to participate. Approximately 85% (N=1,409) adult twins completed the screening, and 2,554 offspring completed the telephone interview (82% response rate). The offspring ranged from 14-39 years old (M=25.1 yrs), and 51% were female. A sub-sample of the offspring (n=176) completed the interview a second time to establish the reliability of the instrument. They were re-interviewed on average 1.08 yrs (range .51-1.62 yrs) after initial assessment. See Chapter II for more details about the offspring dataset.

Measures

Characteristics of Twins and their Spouses

A lifetime history of the adult twins' living arrangements was included in the AL1 Study, and the Canberra and SSAGA studies included items on current marital status and duration of the current status. Based on these items, a lifetime history of divorce and marital separation (including separation from a cohabiting relationship longer than 6 months) was calculated for each twin. Twin analyses indicated that additive genetic factors accounted for 15% (CI=5-19%) of the variation in marital instability. Nonshared environmental factors accounted for most of the variance (85%, 81-90%), with a minimal role of environmental factors that equally influenced both twins (0, 0-7%) (see D'Onofrio et al., submitted).

The twins and their spouses reported the dates of birth of all of their children. Based on the information, each parent's age at the birth of their first child was calculated. Church attendance was based on a 5 point Likert Scale ranging from never to more than once a week. The adults also reported their highest level of education on a seven-point Likert scale; A) less than 7 years' schooling, B) 8-10 years' schooling, C) 11-12 years' schooling, D) apprenticeship, diploma, etc., E) technical or teachers' college, F) university first degree, and G) university post-graduate training.

The twins and their spouses completed the Semi-Structured Assessment for the Genetics of Alcoholism (SSAGA; Bucholz et al., 1994). The SSAGA, based on previously validated research interviews, has demonstrated moderate to high reliability (Bucholz et al., 1994), especially in Australia (e.g., Slutske et al., 1998). The number of lifetime symptoms of DSM-III-R diagnoses for *conduct disorder, alcohol abuse, and major depression* were calculated for the twins and their spouses. The lifetime history of ever using an illegal drug was also included. The individual's history of suicidality was also calculated based on 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).

The AL1 and AR1 studies included the revised Eysenck Personality Questionnaire (EPQ) (Eysenck et al., 1985). The measure assessed Neuroticism (12 items), Extraversion (12 items), Psychoticism (13 items), Impulsivity (5 items), and the Lie scale (12 items). A shortened 54-item version of the Tridimensional Personality Questionnaire (TPQ) was also included (Cloninger et al., 1991). The TPQ assessed Harm Avoidance (18 items), Novelty Seeking (18 items), Reward Dependence (18 items), and a measure of persistence (5 items). See Gillespie et al. (2001) for more details of the personality measures in the current sample. Each personality dimension was standardized (M=0, SD=1) across both the male and female parents of the offspring to make parameter estimates based on these variables more interpretable.

Spousal information was only included in the analyses if they were the biological parent of all of the offspring in the current study. The twin and spousal information was converted 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

The offspring completed the SSAGA, which included a number of items assessing current marital status and history of cohabitation. Based on the variables, a lifetime history of relationship instability was calculated. Relationship instability included individuals who had divorced, separated, had more than one marriage (excluding widowers), or who had ended a cohabiting relationship (defined as living with someone for over 6 months).

Results

The children of twins design is a three level design (Nance, 1976; Nance and Corey, 1976). The 2,554 offspring were nested into 1,296 nuclear families, which were nested in 889 twin families. In 14 of the twin families, one of the twin's divorce statuses was missing, a crucial aspect of the design. The missing information influenced 25 offspring in the study. However, the incomplete data was not associated with offspring relationship instability (OR=.89, p=.90) or parental divorce status (OR=.81, p=.66). As a result, the data were considered missing at random, and these twin families and offspring were removed from the analyses.

Intergenerational Transmission of Relationship Instability

Survival analyses were used to explore the intergenerational association of marital instability because of the right censored nature of the offspring data (all of the offspring have not lived through the "risk period" for the outcome). The offspring who experienced a divorce and separation were compared to 1) all offspring who had ever been in a relationship and 2) the entire sample, regardless of whether they had ever entered into a cohabiting or married relationship. A comparison of the patterns using these two "control groups" were conducted to see if earlier initiation of intimate relationships accounted for the higher rate of separation in the offspring from divorced families.

Offspring who reported a history of relationship instability were initially compared to a group that consisted of other offspring who had ever been in a cohabiting or married relationship. In the reduced sample, 15.55% (114/733) of individuals who had ever entered into a married or cohabiting relationship had separated or divorced (1,796 offspring were not included because they had never been in a relationship). The risk for marital instability, controlling for the gender of offspring, was estimated using Cox Regression Models (Allison, 1995). The risks are Kaplan Meier nonparametric estimates of the failure rate at the age of 33, the last age at which comparisons could be made across the groups. The risk of separation was .20 (SE=.02) in the sample of offspring who had ever entered a relationship. The association between parental marital instability and offspring relationship instability was then calculated within a survival analysis. The coefficient (b=.78, SE=.19), distributed as a logit, and the Hazard Ratio (HR=2.19) from the Cox Regression analyses suggest that parental divorce was significantly associated with offspring relationship instability. However, gender of the offspring was not related to related relationship instability (b=.12, SE=.19, HR=.89). For descriptive purposes, the Kaplan Meier risks for offspring relationship instability were calculated separately for individuals from intact (.15, SE=.02) and broken homes risk (.33, SE=.05).

The second comparison consisted of offspring who reported a separation or divorce and all of the other offspring, regardless of their history of entering into a relationship. For the entire sample, 4.5% (114/2529) of the offspring had ever separated or divorced. The risk of separating in the entire sample was .14 (SE=.02), based on a survival analysis controlling for the gender of the offspring. A Cox Regression analysis found that parental divorce was associated with their offspring's risk of divorce (b=.76, SE=.19, Hazard Ratio=2.07), but gender of the offspring was not (b=-.26, SE=.19, HR=.77). Offspring from intact families had a lower risk of separating (.11, SE=.02) than offspring from broken households (.23, SE=.04). These analyses, ignoring the nested nature of the data, were conducted to provide initial estimates of the association (see hierarchical linear models below).

Comparison of Prevalence and Risk for Relationship Instability by Family Structure

The prevalence and risk for relationship instability were calculated separately for the following four groups in MZ and DZ families: twin families concordant for being married, twin families discordant for divorce where the offspring's parents remained married, twin families discordant for divorce where the offspring's parents were divorced, and twin families concordant for marital instability. Comparison of the risks among the groups provides an initial assessment of the processes responsible for the intergenerational association between parental marital instability and offspring relationship instability (for an explanation of the rationale see D'Onofrio et al., 2003; Gottesman & Bertelsen, 1989). In brief, a comparison of the offspring of MZ twins discordant for divorce provides the strongest evidence of whether selection factors are responsible for the intergenerational relation. Offspring in both of these families receive the same genetic risk associated with divorce from the twins and share environmental experiences that make the twins similar. Therefore differences between these two groups suggest that environmental factors associated with divorce account for the association. However, no difference in the offspring of the discordant MZ twins would discount a causal theory and suggest that selection factors are responsible for intergenerational transmission of marital instability. A comparison of offspring of discordant DZ twins provides a similar comparison except that these offspring differ with respect to environmental risk associated with divorce *and* the genetic risk associated with divorce related to the twins. Therefore, a comparison of the differences in the offspring of discordant MZ and DZ twins provides the opportunity to distinguish between shared environmental and genetic factors related to the twins. If the difference in risk for relationship instability in the offspring of discordant DZ twins is larger than the difference between offspring of MZ twins, genetic factors are implicated. In contrast, if the difference between the offspring of discordant twins is equivalent in each type of twin family, environmental factors would account for the selection factors.

Table 15 presents the crude prevalence rates and risk for relationship instability across the eight separation groups. The estimates using the reduced sample that only included offspring who had ever been in a relationship were similar to the results when the entire sample was included. A comparison of the offspring from the MZ twins discordant for divorce (.14 vs .23 in those ever in a relationship and .10 vs .16 in the entire sample) suggest that parental divorce has a direct influence on the risk for relationship instability. In addition, the difference in risk in the offspring of DZ twins discordant for divorce (.19 vs .44 and .15 vs .32) also suggest that genetic factors may contribute to the risk of relationship instability in the offspring. Because similar answers were obtained when using the reduced sample of offspring ever in a relationship and the entire sample, the latter was utilized for the remainder of the analyses, with the appropriate controls for the right censored nature of the data.

Associations between Parental Characteristics and Offspring Relationship Instability

A comparison of risks in the offspring of twins provides methodological controls for genetic and shared environmental factors related to the twins. However, the design does not control for the genetic and environmental risk transmitted to the offspring from the spouses of the twins. This limitation can be remedied by including statistical controls for characteristics of the spouses (Jacob et al., 2003; Rutter, Pickles, Murray, & Eaves, 2001). Furthermore, the children of twins design controls for environmental factors that make twins similar, but environmental risk factors associated with divorce within nuclear families may also account for the intergenerational association. Therefore, the relationship between characteristics of both parents (the twins and their spouses) and offspring relationship instability was explored so that the salient variables could be included in the genetically informative analyses. Cox regression analyses with each individual parental characteristic were initially conducted to identify the characteristics of the parents that were associated with offspring relationship instability and reduce the number of variables included in the genetically informative analyses.

Due to the incomplete data on the mothers and fathers, the Cox regression analyses were based on datasets in which the missing scores were estimated through multiple imputation (MI) (Little & Rubin, 1987; Rubin, 1987; Schafer, 1997). MI assumes that the missing data are missing at random (MAR). With MAR, the probability that an observation is missing may depend on the observed values in the dataset but not the missing values. Assuming that the data are from a multivariate normal distribution, data augmentation is applied to Bayesian inference with missing data by repeating the following two steps: 1) the imputation step simulates the missing values for each observation independently from the estimated means and covariance matrix and 2) the posterior step simulates the posterior population means and covariances (e.g. Gilks, Richardson, & Spiegelhalter, 1996). Multiple imputation continues the iteration between the two steps until convergence. After the data has been imputed (m) times, the analyses are calculated on each of the (m) datasets and the parameter estimates are summarized based on the (m) analyses. As a result, the estimates of the parameters and the standard errors using MI reflect the uncertainty of the data due to the missing values.

Table 16 presents the percentages of missing parental variables. Overall, less information was missing for maternal characteristics. Furthermore, the more information was available for the demographic and psychopathology parental measures, as compared to information concerning the parental personality variables. The parental variables in the 1,282 nuclear families were imputed 5 times using SAS Proc MI. Cox regression analyses predicting offspring relationship instability were then conducted with each parental characteristic separately for each (m) imputed dataset. Proc MIANALYZE in SAS was then used to estimate the regression coefficient and calculate the appropriate standard errors. Because the nested nature of the data was ignored in the analyses, the significance levels are biased downward. Therefore, the analyses represent a liberal approach of identifying the salient variables. Variables that were marginally related to offspring relationship instability were used in the subsequent HLM. The regression coefficients and hazard rates associated with offspring relationship instability are presented in Table 17. The results suggested that parental church attendance, age of first child, history of conduct disorder, depression, illegal drug use, psychoticism, extraversion, and impulsivity were associated with offspring separation. These variables, from both spouses, were included in the subsequent genetically informed analyses.

Hierarchical Models Utilizing Methodological and Statistical Controls

Hierarchical Linear Models (HLM) were conducted to quantify the magnitude of the association between parental and offspring relationship instability using the different comparison groups within the children of twins design as well as incorporate statistical controls for parental characteristics that could act as selection factors. The use of HLM also controlled for the nested nature of the data. Extensive details and algebraic models of the approach are explained elsewhere (Appendix B). The current analyses used three-level HLM (Raudenbush and Bryk, 2002) to obtain estimates and their standard errors. In order to simplify the analyses, the variance components that accounted for the nested nature of the data were the only random effects estimated in each HLM. The fixed effect of gender was included in each model, and the right-censored nature of the data was taken into account.

All models that incorporated statistical controls were conducted on 5 multiply imputed datasets, and the standard errors of the variables reflect the uncertainty due to the incomplete data. The range of the divorce parameter estimates from the analyses of the multiply imputed datasets, in addition to the standard errors, were presented to provide further information about the stability of the estimates. Comparisons of the parameters were made with the unstandardized coefficients because standardized estimates do not describe invariant causal processes because they are influenced by factors unrelated to the specific relationship being explored (Kim & Feree, 1976; Kim & Mueller, 1976). However, the standardized estimates were also reported for descriptive purposes.

The analyses presented in the paper will include eight HLM. Model 1 included parental divorce (a second level variable), providing a comparison of offspring from divorced families to unrelated offspring in intact households. In Model 1 parental divorce was associated with offspring psychopathology (b=.69, SE=.17, HR=1.99, p<.001). Model 2 included parental divorce and measures of maternal and paternal church attendance, age at the birth of their first child, conduct disorder, depression, use of illegal substances, psychoticism, extraversion, and impulsivity. In model 2, the inclusion of the statistical controls for parental characteristics slightly reduced the influence of divorce (b=.51, SE=.20, HR=1.67, p<.01). The model provides an example of the standard approach of statistically controlling for possible confounds. The estimates of the influence of divorce in each model are presented in Figure 11, and the first two bars illustrate how using statistical controls for characteristics of both spouses reduced the intergenerational transmission. All of the parameters estimates from the models are presented in Table 18.

Model 3 separated parental divorce into between and within-family effects. The average of divorces in a twin family (0, .5, or 1) was a third-level variable and represents an approximation of the between-family effect of divorce. The difference between the individual twin's divorce status and the twin-family average (-.5, 0, .5) represents the within-family effect. The variable compares offspring from divorced families to their cousins from intact homes. The within-family effect of divorce was larger than the phenotypic association reported in the first two models (b=.82, SE=.26, HR=2.27, p<.005). Model 4 included the between and within-family estimates as well as the statistical controls for the parental characteristics, and the model illustrated that the statistical controls again reduced the association between parental and offspring relationship instability (b=.71, SE=.28, HR=2.03, p=.01).

Model 5 included the between-family estimate of divorce (the average of the number of divorces of the two twins), but the within-family estimate of divorce was calculated separately for the DZ twins and MZ twins. The interaction between the within family divorce variable (a second level variable) and zygosity type (a third level variable) enabled an estimation of the two parameters. Model 5 included a variable of zygosity type (DZ=0 and MZ=1) so that standard errors were calculated around the DZ within estimate (b=1.03, SE=.38, HR=2.80, p<.01). The difference between the DZ and MZ within estimate (DZ-MZ) (b=-.41, SE=.53, p=.44) suggests that the DZ estimate is larger than the MZ estimate, although the precision is limited by the statistical power to estimate the parameter. Model 6 estimated the divorce parameters in model 5 and added the measures of the parental characteristics. The DZ within family estimate (b=.90, SE=.39, HR=2.46, p=.02) and the difference in the two within family estimates (b=.37, SE=.54, p=.49) was slightly reduced. The bars in Figure 11 for the comparison of offspring from discordant DZ and MZ twins illustrate that the association between parental divorce is lower when the latter are compared.

Model 7 and 8 are mathematically identical to models 5 and 6, but a different coding of zygosity (MZ=0 and DZ=1) was utilized. Therefore, the standard errors around the MZ within family parameter were estimated, as well as the difference in the within family estimates based on the zygosity of the family. Conducting these models is an over-paramaterization of the data, but we felt that providing standard errors around the MZ and DZ within family parameters would provide a more detailed picture of the data and the precision of the estimates. Model 7 included the within-family estimate in MZ families (b=.62, SE=.38, HR=1.86, p=.10) and the difference between the within MZ and

DZ estimates (b=.41, SE=.53, p=.44). The within MZ family estimate suggests that environmental risks associated with divorce influence offspring relationship difficulties, and the higher DZ than MZ within-family estimates indicate that genetic factors may also account for some of the intergenerational transmission. The within MZ family estimate (b=.53, SE=.38, HR=1.70, p=.16) was slightly reduced in model 8, but the magnitude of the difference in the two estimates (b=-.37, SE=.54, p=.49) was similar to the previous model.

Discussion

The current analyses are commensurate with previous studies in the Western countries illustrating a higher rate of relationship instability in the offspring of divorced parents (review in Pryor & Rogers, 2001). Statistically controlling for measures of psychopathology and demographic characteristics of both parents slightly reduced the overall magnitude of the association, but a sizeable relation remained. The use of the CoT Design also revealed that parental divorce (or environmental risk factors associated with parental marital instability within nuclear families) accounts for a majority of the intergenerational transmission. The results also suggest that genetic factors may partially confound the relation, a role that family researchers are beginning to include in theories of the consequences of divorce (e.g. Emery, 1999; Hetherington, 2003). Overall, the results indicate that environmental factor specifically related to parental divorce account for most of the intergenerational transmission of divorce. The findings are consistent with a causal theory of the consequences of divorce (e.g. Hetherington, 1999a).

The results of the study must be interpreted cautiously. Although the approach investigated the role of many potential selection factors, the study is based on correlational data. Therefore, the results are limited by the constraints inherent in using any non-experimental design and cannot prove that parental divorce causes offspring relationship instability (e.g. D'Onofrio et al., 2003). Parental divorce could be a proxy for other environmental risk factors that actually cause the offspring to get divorced. For example, unmeasured factors, such as socioeconomic status, could be responsible for the intergenerational association. Furthermore, characteristics of the offspring that increase the likelihood of divorce in both generations could also explain the relation (i.e. reciprocal influences).

There are also a number of methodological limitations. Large sample sizes are needed to precisely estimate the parameters from the CoT Design (Heath, Kendler, Eaves, & Markell, 1985). Because the standard errors around many of the estimates in the current analyses are large, the results must be viewed carefully. The sample consisted of young adults, many of whom had not lived through the "risk period" for divorce or separation from a cohabiting. Although similar results were obtained when all offspring were compared with a sample that only included offspring that had been in a relationship, differences in the life course patterns of union formation and dissolution between offspring from intact and divorced families could alter the results. Finally, it is unclear whether the results from the current analyses, based on an exclusively Caucasian sample in Australia, will generalize to other populations.

In light of the limitation of the current analyses, a number of recommendations can be made for future studies exploring the intergenerational transmission of divorce. Large-scale genetically informed studies need to be conducted with nationally representative samples. Larger samples sizes would provide greater statistical precision around the estimates, allow comparisons among different ethnic and socioeconomic groups, enable exploration of moderators of the intergenerational association, include measures of relationship instability across the lifespan, and more precisely highlight the mechanisms underlying the transmission of divorce. Personality characteristics may mediate the genetic confounds (e.g. Jockin, McGue, & Lykken, 1996), but the possibility has never been explicitly tested. Mediators of the quasi-causal pathway must also be tested within a genetically informative context because measures of family functioning or individual characteristics may only be epiphenomena that mark genetic risk or environmental selection (e.g. Rutter et al., 1999).

In summary, the analyses represent one of the first genetically informed studies of the intergenerational transmission of divorce. The analyses sough to account for as many environmental and selection factors as possible. Although the results suggest that genetic factors may partially account for the association between parental and offspring relationship instability, the findings highlight the importance of family risk factors that are environmentally mediated. The findings are in stark contrast to theories that postulate that family environmental experiences in general (Harris, 1998b; Rowe, 1994), and parental divorce in particular (Harris, 1998a), do not influence offspring adjustment after the children leave home.

VI. UNITED STATES – OFFSPRING RELATIONSHIP INSTABILITY

Abstract

The intergenerational transmission of marital instability has been consistently demonstrated by epidemiological studies, but the association may not represent a causal relation. Because shared environmental and genetic processes may act as selection factors that lead to higher rates of divorce in both generations, genetically informed studies are required. The current analyses utilized the Children of Twins Design with a large sample of twins and their offspring from the United States. The intergenerational transmission of marital instability was higher in female than male offspring. Estimates of the association using offspring of twins discordant for divorce were approximately half the size of the association using unrelated comparison groups, but there was no evidence of genetic transmission. Overall, the results suggest that environmental factors that vary between families confound the intergenerational transmission. However, the remainder of the association appears to be due to environmental risk factors associated with parental divorce.

Introduction

Research has consistently shown that parental divorce is one of the strongest predictors of marital instability (e.g. Amato, 1996; Feng, Giarrusso, Bengtson, & Frye, 1999; Glenn & Kramer, 1987; McLanahan & Bumpass, 1988; Mueller & Pope, 1977; O'Connor et al., 1999). The intergenerational transmission of divorce has been found in large samples in the US (Greenstein, 1995), England (Rodgers, 1994), Australia (Rodgers, 1996), and Germany (Diekmann & Engelhardt, 1999) (review in Pryor & Rogers, 2001). Although the rate of divorce transmission has declined over the past 20 years, parental marital instability remains a powerful predictor of offspring divorce, increasing the odds by 50% (Wolfinger, 1999). Generally, most researchers have assumed that this association represents a causal relation (Rutter, 2000). Consequently, current studies have focused on differentiating between possible mediators of the association between parental and offspring marital instability. These possible mediators include life course outcomes (Furstenberg & Teitler, 1994; O'Connor et al., 1999; Teachman, 2002), differences in perspectives on the costs and benefits associated with marriage (Feng, Giarrusso, Bengtson, & Frye, 1999), modeling of unsuccessful relationship and interpersonal skills (review in Gottman, 1994), mate selection (Hetherington, 2003), and lower commitment to marriage (Amato & DeBoer, 2001) in the offspring of divorced parents.

However, the statistical relation between parental and offspring marital instability may not represent a causal process; rather, selection factors that lead to marital instability in both generations may be responsible for the association (Emery, 1999). Whether parental divorce is causal or merely correlated with offspring marital stability is tremendously important not just conceptually but also practically, especially given the increase in divorce rates in the United States and in most industrialized countries. Figure 12 presents a graphical representation of two of the main confounds when studying intergenerational associations. First, shared environmental factors may account for a statistical relation between a parental and offspring characteristic. For example, couples living in poverty (Hernandez, 1993) are more likely to separate, and socioeconomic status could be "third variable" that explains the intergenerational transmission. Statistical controls for possible environmental confounds, such as socioeconomic status, take into account the possibility that some third variables may be important, but such analyses are unable to control environmental risk factors that have not been measured or have been measured inaccurately.

A shared genetic risk for marital instability may also account for the association between parent and offspring marital instability, a specific example of passive gene by environment correlation (rGE) (Eaves, Last, Martin, & Jinks, 1977; Plomin, DeFries, & Loehlin, 1977; Scarr & McCartney, 1983). This possibility is all the more important to consider because twin studies have shown that genetic factors influence divorce (McGue & Lykken, 1992; Trumbetta & Gottesman, 1997). Thus a common underlying genetic predisposition may be responsible for the intergenerational transmission. Researchers have been quick to point out that genes do not code for divorce; rather genetic factors influence intermediate characteristics or endophenotypes (Gottesman & Gould, 2003). One possibility is that personality characteristics that influence divorce (Jockin, McGue, & Lykken, 1996) are transmitted to the offspring and influence their risk of separating from intimate relationships. Under such conditions, the association between parental and offspring divorce would not be causal. In fact, the existent behavior genetic research has led a prominent researcher to claim, "Heredity…makes the children of divorce more likely to fail in their own marriages. Parental divorce has no lasting effects on the way children behave when they are not at home" (Harris, 1998a).

Because studies that explore the intergenerational transmission of divorce cannot use experimental designs (with their inherent control for possible confounds), research must use methodologies that disentangle risk factors that typically go together, especially genetic and environmental processes (Rutter, Pickles, Murray, & Eaves, 2001). The need to incorporate behavior genetic designs in studies of risk factors and intergenerational transmission has been echoed by family researchers (Booth, Carver, & Granger, 2000) and developmental psychologists (Collins et al., 2000). There are many genetically informative designs, but the Children of Twins (CoT) design may be the most appropriate approach to explore the underlying processes related to parental divorce (D'Onofrio et al., 2003). The CoT design utilizes comparison groups that differ in their genetic and environmental risks associated with divorce, thus allowing researchers to separate the intergenerational association into genetic, shared environmental, and the nonshared environmental processes (reviews in D'Onofrio et al., 2003; Heath, Kendler, Eaves, & Markell, 1985; Gottesman & Bertelsen, 1989). Effects attributable to *nonshared* environmental processes estimate the specific environmental association between parental divorce and offspring risk, while effects attributable to the *shared* environment highlight environmental confounds in the intergenerational relationship (for example, a variable like poverty that may be shared by the twin parents). Genetic processes obviously estimate genetic explanations of parent-offspring concordance.

Most studies of the intergenerational transmission of marital instability have compared offspring whose parents are divorced to unrelated offspring from intact families. Statistical controls have been applied to help account for the differences between the two unrelated sets of families, but the salient selection factors may not be measured (see above). Therefore, the statistical associations include the direct influence of divorce and all of the confounds that vary between families. When offspring of siblings discordant for divorce (where one sibling has been divorced and one has remained in an intact relationship) are compared, a within-family comparison can be made. The comparison does not include the influence of confounds in the parent generation that vary between families[1] (see Dick, Johnson, Viken, & Rose, 2000 and Rogers, Cleveland, van der Oord, & Rowe, 2000 for an explanation of the advantages of making within family comparisons). A comparison of offspring of DZ twins discordant for divorce provides a within-family comparison similar to the comparison of the offspring of discordant siblings, but the comparison also controls for differences in age of the parents and some gestational experiences the twins share (Chapter II).

Because offspring from MZ twins are genetically related to their parent and their parent's co-twin similarly, a comparison of children from discordant MZ twins is free from genetic confounds associated with divorce in the twins. If there is no difference in the rate of marital instability among offspring of MZ twins discordant for divorce, the intergenerational association would not represent a causal relation. When there is no difference between the offspring of MZ twins discordant for divorce, the CoT Design can separate the confounds of the intergenerational relation into shared environmental and genetic processes. Because offspring of DZ twins differ with respect to the genetic risk associated with the twins, a larger DZ than the MZ within family estimate would suggest that genetic factors are partly responsible for the intergenerational association. In contrast, if there is no difference in the within family estimates from MZ and DZ families, shared environmental factors would be most salient. Therefore, the CoT Design is able to delineate an intergenerational association into three pathways: a direct environmental mechanism, a shared environmental pathway, and a shared genetic pathway.

We are unaware of any genetically informed studies of the intergenerational transmission of divorce completed to date. Given the specific issues raised above and the widely understood fact that characteristics that "run in families" may be due to either genetic or environmental factors, the current project utilized the CoT Design to explore the effects of the nonshared environment (parental divorce), the shared environment (parental environment confounds), and genetic influences in explaining the intergenerational transmission. The analyses, using a sample of twins and their offspring from the United States, utilized both methodological and statistical controls for possible confounds to explore the way in which genetic and environmental processes act to influence marital instability. Adult twins and their offspring from the Virginia 30,000, a large, genetically informed dataset based on volunteer participation was used for the current project. The convenience sample is not demographically representative (e.g. it is exclusively Caucasian), but the rate of parental divorce is commensurate with epidemiological studies of the United States (Corey, 2000) and offers the unique opportunity to study genetic influences in a large sample of divorced families.

Methods

Samples

The Virginia 30,000 is a sample that contains 14,763 twins and related family members. A full description of the sample can be found in Eaves et al., 1999 and Truett et al, 1994; therefore, a brief description will be provided here. The twins were ascertained from public birth records from the Commonwealth of Virginia born between 1915 and 1971 and from responses to an advertisement in the newsletter of the American Association of Retired Persons (AARP). Twins were sent a questionnaire entitled "Health and Lifestyle" that also asked them to list the names and addresses of family members, such as spouses, siblings, parents, and children. Approximately 69.8% of twins responded to the questionnaire. The average age of the twins was 51.8 years old, and 63.9% were female. A version of the "Health and Lifestyle" questionnaire was sent to all identified family members. The response rate for the relatives was 44.7%, and a total of 4,800 offspring participated. The average age of the offspring was 35.5 years old, and a majority (60.6%) were female. The twins and offspring in the VA 30,000 were almost exclusively Caucasian.

Of the 4800 offspring, 740 could not be included in the analyses because of missing values on avuncular divorce (64% of missing), inability to definitively diagnose the zygosity of the twin pair (79%), the twin's (the offspring's parent) emotional problems (6%), extraversion (3%), neuroticism (3%), psychoticism (3%), lifetime and past year alcohol problems (1%), lifetime smoking (10%), and educational level (10%). However, the incomplete nature of the data was not associated with the relationship instability in the offspring (b=-.06, OR=.94, p=.53). Therefore, the data was considered to be missing at random.

Measures

The mailed questionnaires included questions about twinning, demographic information, alcohol and tobacco use, health, personality, social attitudes, and emotional problems. Questions concerning marital status included an item measuring current status (seven categories), date of separation (if divorced/separated), number of years together with current spouse/partner, and the total number of times married. Based on these responses, a lifetime history of marital instability, that included both divorce and separation, was calculated for each individual, including the adult twins and the offspring.

Zygosity determination was based on items asking about childhood similarity and recognition confusion. The survey method has been validated against blood-typing, and is over 95% accurate (Kasriel & Eaves, 1976).

A number of characteristics of the adult twins that could act as selection factors (characteristics that could lead to both divorce and their offspring's risk for marital instability) were also included in the analyses. Parental education was measured on a 6 point Likert scale, ranging from 0-7 years to 4+ years of college education. The twins' emotional difficulties were measured by a revised version of the Symptom Checklist (SCL)(Derogatis, Lipman, Covi, 1973). Extraversion, Neuroticism, Psychoticism, and Impulsivity were based on short scales of the Eysenck Personality Questionnaire (Eysenck, Eysenck, & Barrett, 1985). These variables were transformed into Z scores so that the scale could be more easily interpreted.

A list of common health problems across the lifetime was also included in the questionnaire. The twins reported whether they had ever been diagnosed or treated by a physician for alcohol problems or depression. Respondents were also asked to report on whether they had experienced any alcohol problems in the past year. Finally, each twin indicated whether they had ever smoked cigarettes in their lifetime.

Results

Comparison of Risks

Survival analyses were completed on the offspring relationship instability using SAS to calculate the lifetime risk of separation across the age span in the sample (Allison, 1995). The risks were Kaplan Meier nonparametric estimates of the failure rate. Roughly 22% of the offspring indicated that they had separated or divorced, corresponding to a risk of .44 (SE=.01) at the age of 44 (the last age that comparisons could be made across the zygosity/family structure groups). Cox regression analyses were used to estimate the influence of parental divorce, offspring gender, and the interaction between the two. Parental divorce was strongly associated with offspring relationship instability in females (b=.55, SE=.09, Hazard Rate=1.75, p<.0001), and males were less likely to report instability (b=-.19, SE=.08, HR=.82, p=.01). The interaction between the parental divorce and offspring gender was significant (b=-.41, SE=.17, p=.02), confirming that the intergenerational association was smaller in male offspring than female offspring. For descriptive purposes the risk for instability was calculated separately for offspring in intact and divorced families. The risk for instability was .42 (SE=.02) in females from intact families and .63 (SE=.04) in females from broken households. In contrast, parental divorce had little, if any, relation to offspring relationship instability in males; the risk was .40 (SE=.02) in males from intact homes and .42 (SE=.05) in male offspring whose parents separated. As a result of the Cox Regression analyses, the remaining analyses were only conducted using the female offspring.

Univariate Twin Analysis of Subgroup with Female Offspring

Previous univariate twin analyses of all of the twins in the VA 30,000 suggested that genetic factors accounted for a small percentage of the variation in marital instability in the adult twins (Chapter III). An analysis of the twins involved in the current sample (twins with complete data and female offspring) was conducted to determine if the underlying biometric model differed for the select group. The tetrachoric correlation (r=.21) and proband concordance rate (CR=.34) for DZ twins (N=547) were slightly lower or equivalent to those for the MZ twins (r=.25, CR=.33, N=612). The pattern suggests a majority of the variation in the current sample is due to nonshared environmental influences, with a moderate influence of shared environmental influences. A twin analyses using Mx resulted in the following estimates: heritability (4%, CI=0-21%), shared environment (9%, 0-18%), and nonshared environment (86%, 79-93%). Although these estimates are slightly different than the variance estimates from the entire sample of twins, regardless of the twin's status as parents, they are well within the confidence intervals of the original estimates.

Comparison of Divorce Risk among Female Offspring between and Within Families

First, the offspring were separated into four family types: families in which both twins never experienced a divorce, families in which the parent did not divorce but the parent's co-twin divorced, families in which the parent divorced but the parent's co-twin did not, and families in which both twins experienced marital instability. The crude prevalence rates and lifetime risk estimates for the offspring in the four groups is presented in Table 19. Divorce risk for the offspring in the two concordant groups differed greatly (.41 both twins married vs .67 both twins divorce), but the comparison of the discordant twins is the best measure of the true effects of parental divorce because the comparison is free from between-family confounds. The results indicate that the divorce risk was intermediate for the offspring of discordant twins (.50 vs .60).

Comparison of Divorce Risk among Female Offspring by Zygosity

Table 20 separates the female offspring into the different family structures by zygosity in order to explore whether there were any differences in the comparison of offspring of MZ and DZ twins discordant for divorce. Comparison of the risks among the zygosity groups provides an initial assessment of the processes responsible for the intergenerational transmission (for a review see 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 relationship instability than their cousins (from intact households), the findings would be consistent with a causal hypothesis. However if there is no difference among the offspring of the MZ twins discordant for divorce the results would suggest that selection factors completely account for the relation between offspring and parental divorce. If the intergenerational transmission of divorce is 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. This is because offspring from discordant MZ families receive the same genetic and shared environmental risk associated with divorce from the twins, but offspring in discordant DZ families only share the same shared environmental risk associated with divorce. The difference between the offspring of the discordant DZ twins (.56 vs .63) appears to be similar, if not slightly smaller, than the difference between offspring of discordant MZ twins (.44 vs .57). The results suggest that genetic factors do not confound the intergenerational relationship. However, the difference between the discordant twins appears to be smaller than the comparison of the concordant twins, indicating that shared environmental confounds may be important.

Hierarchical Linear Models

The Cox Regression analyses above ignored the nested nature of the data. In the CoT design, offspring of twins are nested under nuclear families, which are nested under twin families. Therefore the design represents a three level, nested model (Nance, 1976; Nance and Corey, 1976). Because of the nested nature of the data Hierarchical Linear Models (HLM) were utilized (Raudenbush and Bryk, 2002). The HLM were able to (1) measure the associations between parental and offspring relationship instability considering the nested nature of the data, (2) explore differences between and within MZ and DZ families, and (3) include statistical controls for measured parental variables that may act as selection factors. A detailed description of the analytical approach, including algebraic representations of the HLM, are reported in Appendix B. The software program HLM was used to fit the models, and offspring marital instability was considered a binomial response with the number of trial set to the age of the offspring. Therefore, the models considered offspring relationship instability to be right censored.

The first model estimated the intergenerational association between parental divorce (a second level variable) and offspring relationship instability. The analysis represents the standard approach of comparing offspring from divorced households to unrelated offspring who did not experience their parent's separation. Parental divorce was associated with female offspring instability in model one (b=.42, SE=.08, OR=1.52, p<.001). The second model made the same comparison (unrelated offspring) but also included measured characteristics of the adult twins to help statistically control for possible confounds. Parental educational level, emotional difficulties, lifetime history of smoking, extraversion, neuroticism, psychoticism, impulsivity, lifetime history of alcohol problems, alcohol problems in the past year, and lifetime history of depression were included in the models. Adding these measured variables slightly reduced the intergenerational association (b=.36, SE=.08, OR=1.43, p<.001). Model two represents the standard approach for statistically controlling for possible selection factors. Figure 13 presents the associations between parental and offspring relationship instability. The first two bars in the graph represent the finding from the first two models and demonstrate how the use of statistical controls slightly reduces the estimate.

In addition to parental divorce, a number of parental characteristics were also associated with offspring relationship instability. Table 21 includes the parameter estimates of all of the variables included in the HLM, added simultaneously. The results for model two suggest that an increase in one standard deviation of parental education was associated with an 8% decrease in the risk of offspring relationship instability, controlling for all of the other variables in the model. One standard deviation increase in parental impulsivity was associated with a 7% increase in offspring relationship instability, and parental history of smoking cigarettes was also associated with greater risk for offspring separation (OR=1.25).

Model three separated the intergenerational association into a between and within-family effect. An approximation of the between-family effect of divorce was based on the average number of divorces in a twin family (0 for twins where neither divorced, 0.5 for twins where one was divorced, and 1.0 for twins where both were separated). The within family effect was based on the difference between an individual twin's divorce status and the mean in the twin family (-0.5 for the non-divorced twin in a discordant pair, 0.5 for the divorced twin in a discordant pair, and 0 for twins concordant for being from intact or separated households). The within-family comparison estimates the difference between offspring from the discordant twin pairs, regardless of the twins' zygosity. The within family estimate from model three (b=.22, SE=.12, OR=1.25, p=.06) was lower than the approximation for the between-family comparison (b=.47, SE=.10, OR=1.60, p<.001). The results suggest that the association between parental and offspring relationship instability may be lower than originally estimated. Model four calculated the between and within-family estimates and included the measured characteristics of the adult twin. The statistical controls slightly reduced the between (b=.48, SE=.10, OR=1.62, p<.001) and within-family comparisons (b=.19, SE=.12, OR=1.21, p=.10). The bars in Figure 13 highlight the importance of using within family comparisons as the third and fourth bars are lower than the between family estimate of the influence of divorce when statistical controls were used for parental characteristics.

The fifth model explored whether the within family estimate in MZ families was different than that in DZ families. The HLM estimated the within MZ family estimate and the difference between the MZ and DZ (DZ-MZ) estimates. The within family MZ estimate is free from all genetic and shared environmental confounds related to the twins.

In contrast, the within family estimate in DZ families only controls for environmental factors that influence the twins. The results indicated that there was no difference between the within-family estimate in MZ (b=.23, SE=.16, OR=1.26, p=.14) and DZ twin families (diff b=-.02, SE=.24, p=.92). The last model incorporated the statistical controls for the parental characteristics with the methodological controls found in model five. The use of statistical controls did not alter the within-family estimate in MZ families (b=.24, SE=.15, OR=1.27, p=.12), and the difference between the two within family estimates was somewhat larger but still not statistically significant (b=-.11, SE=.24, p=.64). The results in model five and six suggest that environmental factors that influence the twins account for a portion of the association between parental marital instability and offspring relationship instability. In addition, the within family MZ estimates also imply that environmental risk factors associated with parental divorce (a quasi-causal relation) also account for the intergenerational transmission. Although there is some variation in the last four bars in Figure 13, the results suggest that there is no difference between the MZ and DZ within family estimates.

Discussion

The results of the CoT analyses suggest that environmental factors that vary between families partially confound and inflate estimates of the magnitude of the intergenerational transmission of divorce. The first-order measure of the intergenerational transmission of divorce in the current analyses (OR=1.52) was consistent with current estimates (Wolfinger, 1999), but the comparison of offspring of MZ twins discordant for divorce, with statistical controls for parental characteristics (OR=1.27), was approximately half the magnitude. However, the present study provides the first genetically informed data suggesting that the remaining divorce risk among offspring of divorced parents is due to environmental effects associated with parental divorce, not to genetic risk explained by a gene-environment correlation. Therefore, the study indicates that the association between parental and offspring divorce is smaller than estimated in other research due to shared environmental factors, such as poverty and other unmeasured influences. Yet, the reduced effect is consistent with a specific causal effect of parental divorce.

The results of the twin study of divorce suggest that the percentage of the variation in divorce due to genetic factors may not be as large as originally believed (e.g. McGue & Lykken, 1992). Many studies (e.g. Corey, 2000; Koskenvuo, Langinvainio, Kaprio, Rantasalo, & Sarna, 1979; Trumbetta & Gottesman, 1997) have reported either minimal or no genetic variation in marital instability. Further twin studies of divorce, with epidemiological samples of diverse cultures, are needed. Nevertheless, behavior genetic research that illustrates genetic variation in divorce merely suggests the possibility that shared genetic factors may be responsible for the intergenerational associations (passive rGE) because the source of a risk variable are separate from the mode of risk mediation (Kendler & Karkowski-Shuman, 1997; Rutter, Silberg, & Simonoff, 1993). As a result, caution must be used when making claims about the importance, or lack thereof, of environmental processes in intergenerational associations based solely on the amount of genetic variation in the risk factor. Genetic variation in divorce does not mean that the risk mechanisms associated with parental divorce are genetic.

The results of the current analyses must be considered cautiously. First, the precision of some of the estimates in the HLM was limited due to the low power of many of the comparisons. The analyses presented here relied heavily on the magnitude of the associations rather than focusing exclusively on the statistical significance of the parameters (e.g. Dick, Johnson, Viken, & Rose, 2000) because of low power of the design (Heath, Kendler, Eaves, & Markell, 1985). Second, it is unclear whether the results obtained from the current sample, based on volunteer participation with an exclusively Caucasian sample, will generalize to other samples. However, the risk of divorce and separation in the parent generation (Chapter III), the magnitude of the intergenerational transmission (Wolfinger, 1999), and the higher rate of transmission among female offspring (e.g. Amato & DeBoer, 2001) are commensurate with findings from large, epidemiological studies. Third, the study was unable to include moderators of the intergenerational association, such as family conflict (Amato, Loomis, & Booth, 1995; Booth & Amato, 2001). Age of the offspring at the time of the parental separation may also influence the intergenerational association (e.g. Emery, 1999; Teachman, 2002). Fourth, differences among offspring from MZ twin families discordant for divorce do not prove that parental divorce "causes" offspring marital instability. The finding is merely consistent with a causal hypothesis. Reciprocal interactions from offspring to parents, genetic and environmental influences from the spouses of the twins, and environmental risk factors associated with divorce within families (see footnote) could account for the intergenerational relation (D'Onofrio et al., 2003).

Certainly, the findings from the current CoT analyses of marital instability in parents and children need to be replicated in other samples. Large sample sizes will be necessary to explore moderators of the intergenerational association, in addition to the mediating mechanisms (reviews in Amato, 2000; Emery, 1999; Hetherington & Stanley-Hagan, 1999). In addition, obtaining information from both the twin and their spouses will be important in future studies to help account for some of the limitations of only using adult twins and their offspring (e.g. D'Onofrio, et al., Aus divorce; Jacobs et al., 2003). Future studies of intergenerational transmission will specifically need to explore environmental confounds that vary between families. Church attendance and religious affiliation may be important variables given the relation between religious participation and divorce (Mahoney, Pargament, Tarakeshwar, & Swank, 2001) and the fact that shared environmental factors contribute to variation in these variables in adults (D'Onofrio et al., 1999). Furthermore, the mediators of the within-family environmental influences must be studied within a quasi-experimental design. Only quasi-experimental designs will be able to investigate whether risk factor represents a salient environmental risk factor or whether it merely indexes the true risk factor.

Overall, two general conclusions can be drawn from the current analyses. First, behavior genetic research can highlight the importance of environmental risk factors. Whereas researchers have discounted the importance of shared environmental risk factors in general (Plomin & Rende, 1991), and the role of family experiences specifically (e.g. Harris, 1998b; Rowe, 1994), the current analyses used a genetically informed design to illustrate that shared family experiences appear to influence offspring adjustment, even after the children move out of the home. Other CoT studies (e.g. Jacobs et al., 2003; Lynch et al., submitted) have also found that there are specific environmental influences that influence offspring substance use and behavior problems. Second, the results of the current analyses reinforce the fact that a statistical association between an environmental risk factor and a measure of child's adjustment does not equal causation, even when statistical controls are applied. The importance of shared environmental confounds were only illustrated when related offspring (cousins) were used as the comparison group. Previous children of twin studies exploring parental divorce and offspring outcomes have found that the underlying mechanisms for the intergenerational relations are dependent on the offspring characteristics being explored (Chapter II, III, and IV). Therefore, caution must be used when employing causal language with non-experimental studies of environmental risk factors. The application of genetically informed and other quasi-experimental designs is crucial for the social sciences because research cannot show causality by merely demonstrating a statistical association between an environmental risk factor and a child outcome.

VII. CONCLUSION

Summary of Findings

Two general conclusions about divorce can be drawn from the current analyses. First, the amount of variation in divorce explained by genetic factors is lower than previous estimates. The results highlight the overwhelming role of nonshared environmental factors. Second, the risk mechanisms responsible for the association between parental divorce and offspring adjustment vary across the measures of young adult functioning. Each of these conclusions will be discussed in more detail below.

Heritability of Divorce

The heritability of divorce appears to be smaller than the estimates from well-known studies in the US (e.g. McGue & Lykken, 1992). Although the analyses presented here rely on volunteer samples, each dataset has been shown to be commensurate with the general population on key characteristics. Analyses of the Australian Twin Registry have suggested few detectable differences based on selection biases (Heath et al., 1997; Slutske et al., 1997). With respect to the VA 30,000 dataset, the risk for marital instability for the adult twins is consistent with nation-wide estimates. Furthermore, the biometric results are consistent with analyses of divorce in an epidemiological sample of adult twins in Virginia (Corey, 2000). On the whole, the results of the twin analyses in both samples indicate that environmental influences that make twins dissimilar account for a majority of the variance in marital instability, with small influences of additive genetic and shared environmental factors.

A review of the behavior genetic literature on divorce reveals that genetic factors may only account for a small percentage of the variation in divorce. Studies from the

Minnesota Twin Study are frequently cited as an illustration that genetic factors influence variation in divorce—approximately half of the variation in divorce was due to genetic contribution of one spouse (Jockin, McGue, Lykken, 1996; McGue & Lykken, 1992). However, the heritability estimates appear to be much higher than other twin studies, a concern shared by Matt McGue (personal communication). A small twin study in Australia reported a moderate (.35) heritability estimate for divorce (Heller et al., 1988), and behavior genetic analyses of the WWII Twin Registry yielded a heritability estimate of .21 (Trumbetta & Gottesman, 1997). In contrast, analyses in a nationally representative Finnish twin sample found no influence of genotypic factors on divorce in men and little in women (Koskenvuo, Langinvainio, Kaprio, Rantasalo, & Sarna, 1979). The findings also suggest that divorce in Finland was primarily due to nonshared environmental influences. Similar findings were reported based on a population-based sample of adult twins from Virginia (Corey, 2000). A majority of the variance in divorce status was due to nonshared environmental experiences. Genetic factors did not account for any variation, but approximately a quarter of the variance was due to shared environmental experiences. Overall, the heritability estimates for divorce in the ATR (.15) and entire VA 30,000 (.07) appear to be commensurate with the overall literature.

Mechanisms Underlying the Association between Parental Divorce and Offspring Functioning

Externalizing and Substance Use and Abuse

The analyses presented in the current manuscript are the first genetically informed studies to show that young adult externalizing problems and substance use and abuse are due to environmental risk factors specifically associated with parental divorce. The findings for substance abuse were replicated in both samples and the size of the association remained when statistical controls for characteristics of both parents were utilized in the Australian sample (see Appendix C). The findings are consistent with a causal theory of the consequences of divorce and implicate the role of environmental mediators, such as poor parenting practices, weak parent-child bonds, economic strain, stressful life events, less social capital, continued (and perhaps greater) parental conflict, and the loss of contact with the noncustodial parent.

Internalizing Problems

The results for internalizing problems varied across the samples and different measures of internalizing. The results from the initial Australian analyses (Chapter II) suggested that environmental factors specifically related to divorce accounted for most of the association between parental divorce and internalizing problems, measured by DSM-IV criteria for depression and suicidality items. The parameter estimates from the CoT analyses also suggested the possibility that rGE may partially confound the association, but the effect could not be precisely measured. When statistical controls for the spouses of the twins were added to the analyses, the effect size associated with parental divorce was reduced (Appendix C). Interestingly, adding statistical controls for both parents did not dramatically reduce the effect sizes with externalizing and substance abuse. Overall, the phenotypic association between parental divorce and offspring internalizing of .27 was reduced to .11 when all statistical and methodological controls were included in the analyses. Although, a small role of parental divorce cannot be discounted, the results suggest that the majority of the phenotypic association between parental marital instability and internalizing problems is due to selection factors.

The analyses of the VA 30,000 dataset imply that all of the association between emotional problems and parental divorce is due to rGE. There were no differences among offspring of MZ twins discordant for divorce for lifetime diagnosis and/or treatment for depression or emotional problems as measured by the SCL. Therefore, the results strongly suggest that parental divorce may be a marker for genetic risk for emotional problems in offspring. However, the analyses had limited statistical power to detect small effect sizes. Thus, a small role of environmentally mediated risk cannot be ruled out. In general, the findings insinuate that previous studies of parental divorce and offspring depression may have drawn incorrect conclusions (e.g. causal) about the consequences of parental divorce.

Finally, the life course analyses in the ATR suggest that depressed mood and age of onset of depressed mood is specifically related to parental divorce (i.e. selection factors could not account for the intergenerational relation). Depressed mood was assessed by the gateway questions for the DSM-IV criteria for a major depressive disorder. Therefore, this measure included all individuals (over 50% of the all participants) who had ever experienced a period of two weeks in which they felt depressed or lost enjoyment in pleasurable activities for most of the time.

A few factors could account for the seemingly discrepant findings. First and foremost, the different measures of internalizing problems may be responsible. The underlying mechanisms for being diagnosed or treated for depression could be quite different than for depressed mood. In fact, divorce researchers have highlighted the need to explore measures of pathology *and* sub-clinical distress (Laumann-Billings & Emery, 2000; Kelly & Emery, 2003) because parental divorce may have a greater impact on the latter. Cross-cultural differences in responses to divorce could also alter the findings. Although reviews of the literature suggest that parental divorce influences offspring similarly in Australia and the United States (Rodgers, 1996) the differences in prevalence rates in the two countries (Pryor & Rodgers, 2001) may influence the acceptability of marital instability or the resources available for offspring of divorced families. Finally, differences in the sampling techniques could also account for the discrepant findings. Recent research has suggested that parental conflict before separation interacts with parental divorce (e.g. Hetherington, 1999b; Amato, Loomis, Booth, 1996). The Australian sample of offspring was selected to over-represent adults with a history of conduct disorder, alcohol problems, and divorce. The sample of families may have contained high levels of family conflict, and the statistically controls for measures of parental psychopathology may not have completely controlled for these family dynamics. In contrast, the VA 30,000 dataset was based purely on volunteer participation, and the response rates (although consistent with other mailed studies) suggests the possibility that families with the highest levels of acrimony may not have participated in the study. Certainly, further researcher is needed to explore the relation between parental divorce and offspring internalizing problems.

Life Course Patterns

The findings for life course patterns and demographic outcomes associated with parental divorce further highlight the complexity of the underlying mechanisms responsible for relations with parental divorce. Parental marital instability is associated with educational problems, but the magnitude of the association was only half the original estimate when genetic and shared environmental factors are included in the analyses. The magnitude of the association between parental divorce and age of first intercourse was reduced when confounds were included in the analyses, but the results are consistent with a causal influence of parental marital instability on offspring sexual activity. However, the CoT analyses of the association between parental divorce and offspring cohabitation indicate that the relation may not be causal, especially for parental divorce before the age of 16. Instead, genetic factors appear to account for the statistical association. The results illustrate that the underlying mechanisms associated with parental divorce vary according to the domain of offspring adjustment.

Relationship Instability

The current project also explored the paths responsible for the intergenerational transmission of marital instability. The analyses in the Australia and US samples both indicated that environmental factors associated with parental divorce account for part of the intergenerational transmission of divorce, but the magnitude of the association in both studies was lower than originally expected. In the Australia sample, genetic factors (passive rGE) appeared to partially confound the relation, whereas environmental factors that vary between twin (and sibling) families accounted for part of the intergenerational association in the US. Differences in the findings could be due to differences in measurement; the Australia analyses specifically included separation from cohabiting relationships, whereas the US analyses were not able to determine if individuals considered themselves separated if they had only participated in a cohabiting relationship. Other differences between the samples (see above) could also explain the variation in the results. Overall, the analyses exploring the intergenerational transmission of divorce underline the need for additional family studies to incorporate research designs that account for unmeasured genetic and environmental confounds.

Future Directions

The findings from the analyses of divorce in the adult twins and the use of the CoT Design in the samples from Australia and the United States highlight the need for more genetically informed studies of divorce. Future research on the genetic and environmental pathways related to divorce should focus on a number of areas.

Studies Exploring the Sources of Individual Differences in Marital Instability

More twin studies of divorce and other family processes, using representative samples of twins are needed, especially across different cohorts and cultures. Given the understanding that genetic factors influence all behaviors (Turkheimer, 2000), estimating the percent of variation in divorce due to additive genetic factors could be considered uninformative. However a basic understanding of the underlying biometric model for divorce is important to explore discrepant findings in the literature and provide the basis for further analyses.

In order to gain a better understanding of the causes of divorce, genetically informed studies of relationship formation *and* dissolution are necessary. Ideally, a longitudinal study of twins starting during adolescence would be conducted. The study would also need to include assessments of the partners/spouses and endophenotypes associated with marriage and divorce. These studies would enable researchers to explore the mating process (e.g. how do individuals select partners). The cross-sectional (Heath, 1987) and longitudinal nature of the study would also provide the opportunity to parse the effects of assortative mating from spousal influences on each other. Studies of adult twins would also allow the opportunity to investigate the consequences of marriage and divorce for the adult twins (see introduction for a description of the co-twin control design). The benefits of marriage or the dangers associated with divorce could be causally related to family structure, but selection factors could account for these associations. Genetically informed studies of marriage and divorce will help answer questions that have major policy implications, especially in the US. Furthermore, co-twin control studies would also help characterize the nature and sources of variation in family dynamics during marital transitions.

Prospective, Longitudinal, and Representative, and Genetically Informed Studies

The necessity of prospective, longitudinal, and epidemiological genetically informed studies of the environmental risk factors is the most glaring needs to come out of the present analyses. Although the current project was able to delineate the environmental and genetic pathways between parental divorce and measures of offspring outcomes, the analyses were based on volunteer samples that are not representative of the experiences of many families. In particular, the lack of racial diversity makes it impossible to know whether the findings generalize to other populations. As a result, future CoT studies will need to include families from diverse racial and economic strata. Furthermore, future research will need to include larger samples sizes so that the parameters from the analyses can be estimated more precisely, given the power of the design to delineate between different mechanisms (Heath, Kendler, Eaves, & Markell, 1985). Future research would also benefit from including assessments of the spouses or partners of the twins so that the analyses do not have to make assumptions about assortative mating or negligible influences of one of the parents.

More precise measures of family dynamics and family transitions will also enable researchers to pull apart the influences of environmental risk factors that also vary within twin (and nuclear) families. For example, a precise study of the consequences of divorce requires researchers to explore the family processes before and after the separation (for a review see Hetherington & Stanely-Hagan, 1999b). An accurate portrayal of the consequences of parental divorce will also necessitate measures of adjustment that are frequently not included in major studies, such as sub-clinical distress (Laumann-Billings & Emery, 2000). These analyses will greatly benefit from advances in structural equation model software that efficiently analyzes models with both categorical and continuous variables with missing values (e.g. Muthen & Muthen, 1998-2004). Although the HLM approach used in the current analyses provides advantages over previous statistical analyses of CoT studies (e.g. Gottesman & Bertelsen, 1989), a SEM approach would allow for precise estimates of between family effects and permit tests of various models of assortative mating. Finally, researchers would be able to test for reciprocal interactions in a longitudinal CoT study, a key limitation of the current analyses.

Combination of Behavior Genetic Designs

The importance of combining various behavior genetic designs is illustrated by the inability of the CoT design, as presented in the current project, to account for reciprocal interactions or active/evocative rGE[1]. Silberg and Eaves (2004) have outlined an analytical strategy using the CoT Design to account for reciprocal interactions, but a number of assumptions are required and measures of both parents are necessary to fit the model. Adoption studies have illustrated that genetically influenced characteristics of children influence the parenting they receive (Ge et al., 1996; O'Connor et al., 1998; review in Rutter & Silberg 2002). Although active/evocative rGE may not as important for young children, as some researchers have suggested (e.g. Plomin & Bergeman; Scarr & McCarntey, 1983), the role children play in "selecting" their environment and the risk factors they encounter as they grow older cannot be ignored (e.g Bell & Harper, 1977; Lytton, 1990).

Multiple behavior genetic designs could be used to account for active/evocative and passive rGE. Although they are difficult to conduct, adoption studies represent a powerful method for exploring these processes (e.g. Plomin, 1995). Researchers have called for large, longitudinal adoption studies (e.g. Ge et al., 1996; Scarr & McCartney, 1983; Plomin, 1995, Reiss, 1995), but the design includes major assumptions (Rutter, Pickles, Murray, & Eaves, 2001). Combining the adoption and CoT Designs could take advantage of the unique advantage of each, while limiting the assumptions when each is analyzed separately. The CoT Design can also be combined with traditional studies of twins as children to explore both passive and active/evocative rGE (see Neiderheiser et al., 2004 for an example).

A prime example of the strength of combining different behavior genetic designs is illustrated in the work of Eaves and colleagues using the "Stealth Model" to explore the intergenerational transmission of religious practices and personality characteristics (e.g. D'Onofrio et al., 1999; Eaves et al., 1999; Kirk et al., 1999; Lake, Eaves, Maes, Health, & Martin, 2000; Maes, 1997; Truett et al, 1994). The design can also be used to explore bivariate intergenerational associations (Maes, Neale, Martin, Heath, & Eaves, 1999). The model uses upwards of 30 different family relationships that vary in their degree of environmental and genetic relatedness to test for the mechanisms involved in intergenerational associations while including estimates of assumptions that hinder many behavior genetic designs. However, the research has largely been ignored by researchers outside of the behavior genetic field. Hopefully, the use of the CoT Design, a simplification of the "Stealth Model," will encourage more researchers in the social sciences to explore the use of extended twin studies.

Gene by Environment Interaction

Genetic factors may mediate the relation between parental divorce and child offspring (passive rGE), but genetic factors may also moderate the influence of marital instability. Whereas rGE refers to genetic effects on individual differences in exposure to environmental risk factors, gene-environment interactions (GxE) indicate that there are genetically influenced individual differences in sensitivity to environmental risk factors (e.g. Rutter et al., 1997; Rutter & Silberg, 2002). GxE can also be considered environmental control of genetic expression (Kendler & Eaves, 1986). In trying to determine the causal role of environmental risk factors, the presence of GxE cannot be ignored (e.g. Rutter, Pickle, Murray, & Eaves, 2001). In the presence of GxE, genetic factors would make some children more susceptible to the risks associated with parental divorce than other children.

The possibility that children's genetic predispositions interact with the stresses of marital instability is suggested by three lines of research. First, the variability of responses to environmental risk factors suggest an interplay between genetic and environmental factors (Rutter & Silberg, 2002), and recent research on divorce has underscored the variability of children's responses to parental divorce, not the inevitability of negative outcomes (reviews in Amato, 2000; Hetherington & Kelly, 2002). Second, the stress associated with divorce appears to exacerbate existing difficulties (review in Hetherington, Bridges, & Insabella, 1998). Third, researchers have found that individual characteristics greatly influence one's response to parental separations. For example, personal characteristics, such as difficult temperaments, make it more likely for children to elicit more negative responses from parents during the separation and less likely to be able to take advantage of social support networks (Hetherington, 1991). These findings indicate that individual factors make some children more vulnerable (or resilient) to parental separation, but only genetically informed studies can determine whether these vulnerability factors are genetic in origin.

Two adoption studies have illustrated that genetic factors make some individuals more sensitive to environmental family risk factors, including parental separation and divorce. Cadoret and collegues (1995) reported that genetic risk, as indexed by antisocial personality disorder and drug use/abuse in biological parents, interacted with adverse adoptive home environments to result in more symptoms of conduct disorder and aggressive behaviors. The measure of adverse adoptive home environment was the sum of adverse risk factors, including high levels of marital problems, divorce or separation, anxiety, depression, substance use, and legal problems. In a series of regression equations, the researchers reported that biological background, adverse adoptive home environment, and the interaction between the two uniquely predicted the adult outcomes. The results indicated that children with a genetic risk for antisocial behavior are more vulnerable to family stress than those without an underlying genetic predisposition.

However, it is impossible to determine the specific role of marital instability since the measure was included with other family risk factors.

In order to specifically investigate whether a genetic predisposition for psychopathology exacerbates the risks associated with parental separation O'connor, Caspi, DeFries, & Plomin (2003) utilized the Colorado Adoption Study. Genetic risk was measured by the self-report of negative emotionality by the biological mother. The study reported a significant interaction between genetic vulnerability and parental divorce. Genetic risk only predicted children's internalizing and externalizing problems in the presence of marital instability in the adoptive home. The authors cite the findings as partial evidence for the great variability in children's reactions to family transitions.

The two adoption studies illustrate how genetic and environmental factors can interact, but the results must be interpreted cautiously because of a number of limitations, including low response rates in adoption studies, low power due to small sample sizes, and under-representation of individuals in high risk environments (see Rutter & Silberg, 2002 and Rutter, Pickles, Murray, & Eaves, 2001 for an extensive review of the limitations in adoption studies). Therefore other behavior genetic methods need to investigate the possibility that the stresses of divorce interact with genetic vulnerability to psychopathology. Twin studies that investigate heterogeneity can explore the possibility of GxE. The importance of GxE is supported if the magnitude of genetic influences differs between separate groups of people. Two twin studies have explored the possibility of genetic variability in individual differences in susceptibility to one's own marital status. A twin study of adult female twins reported that the heritability of alcohol consumption was lower in married woman than in single women (Heath et al., 1989).

Being in a married-like relationship has also been found to moderate the influence of genetic factors on depression in females—the heritability of depression was .29 for married woman across the age range, .42 for single women under the age of 30, and .51 for women above the age of 31 (Heath, Eaves, & Martin, 1998).

However, no twin study has explored the possibility of GxE with children's reactions to parental divorce. A recent study by Kendler, Aggen, Jacobson, & Neale (2003) reported no evidence that family dysfunction moderated the impact of genetic factors on neuroticism, but the findings must be taken with caution, especially given several methodological concerns (review in Rutter & Silberg, 2002). There is low power in twin studies to find GxE (Wahlsten, 1990), statistical interactions should not be equated with GxE (Eaves, Last, Martin, & Jinks, 1977) and the GxE is extremely sensitive to the scaling of variables (Mather & Jinks, 1982). Furthermore, detecting GxE in the presence of rGE is very difficult (Rutter & Silberg, 2002).

Certainly the role of gene-environment interaction with family instability needs to be investigated in greater detail. Given the findings from adoption studies that illustrate how genetic vulnerability interacts with family risk factors, including parental separation, (Cadoret et al., 1995; O'Connor, Caspi, DeFries, & Plomin, 2003) the role of GxE must be explored in studying the "causal" influences of parental divorce on offspring outcomes. Studies that do not include measures of individual differences in response to parental divorce will be limited in their ability to truly understand how marital instability influences development. Ultimately a correct understanding of causal mechanisms will incorporate gene-environment correlation and interactions (e.g. Eaves & Erkanli, 2003; Eaves, Silberg, & Erkanli, 2003).

Concluding Remarks

Differentiating between social causation and social selection is one of the fundamental questions facing the social sciences. Understanding the true underlying mechanisms between environmental risk factors and measures of adjustment is crucial because it informs public policy and personal decisions about some of the most important societal questions, such as the consequences of family structure (Amato, 2000), parenting practices (Baumrind, Larzelere, & Cowan, 2002), parental psychopathology (e.g. Gottesman & Bertelsen, 1989; Jacobs et al., 2003), and poverty (Dohrenwend, 1992). Determining causal mechanisms without the use of randomized clinical experiments is extremely difficult (review in Cook & Shadish, 1994). Natural experiments can shed light on causal mechanisms (e.g. Costello, Compton, Keeler, & Angold, 2003), but the studies have a number of limitations (O'Connor, 2003). Therefore, multiple research strategies and designs are required, especially genetically informed approaches.

Behavior genetic studies have raised serious questions about assumptions that most social science researchers make about environmental risk factors (review in Rutter, 2000). In particular, most research in developmental psychopathology has ignored the possibility that one's adjustment may be associated with environments because of passive rGE (e.g. Rutter et al., 1997). Because of this limitation (and others), behavior genetic researchers (e.g. Rutter, Pickles, Murray, & Eaves, 2001), developmental psychologists (Collins et al., 2000), and family psychologists (Booth, Carver, & Granger, 2000) have called for more genetically informed studies of environmental risk factors, especially family constructs.

The current project used a genetically informed approach that has been outlined earlier (e.g. Eaves, Last, Young, & Martin, 1978; Gottesman & Bertelsen, 1989; Heath, Kendler, Eaves, & Markell, 1985) to explore the consequences of parental divorce. The study represents the first genetically informed study of the long-term consequences of parental divorce, specifically exploring whether non-measured environmental or genetic factors act as selection factors. The results reveal a more nuanced understanding of the association between parental marital instability and offspring functioning. In most instances the results provide further support for the social causation theory of the consequences of divorce, discounting the claims by researchers that (within limits) shared environmental experiences (Plomin & Daniels, 1987), especially family experiences (Harris, 1998a; Harris, 1998b; Rowe, 1994), do not influence offspring. However, the magnitude of many of the intergenerational associations were reduced when genetic and environmental confounds were included in the analyses, and some offspring outcomes statistically associated with parental divorce appear to be completely accounted for by shared genetic factors in parents and their children. Further research is certainly needed to more clearly detail these processes.

Overall, the results indicate that investigating causal processes by merely correlating environmental risk factors and child outcomes using traditional family studies has limited utility. As many others have done recently, this paper highlights the need for a greater collaboration between sociological, psychological, and behavior genetic researchers. The current manuscript is the result of one such collaboration. Certainly, further integration of these often disparate fields of study will lead to a much greater understanding of the causes of adjustment problems, academic difficulties, psychopathology, relationship instability, and deleterious family functioning.

FOOTNOTES

I. Introduction

[1] This number is a conservative estimate because it does not include 951,000 children living in single parent households due to spouse absence.

[2] There are many, competing philosophical definitions of “cause” (see Cook and Shadish, 1994 for a review). The term is used in the current manuscript to refer to the “manipulability” or activity theory of causation that postulates a causal process if manipulation of an epiphenomena brings about a desired change. The manipulability theory of causation assumes that the cause-effect association is robust enough to inform our understanding of development and/or inform interventions. See Mackie (1974) for further descriptions and critiques of causal theories.

IV. Australia – Offspring Life Course

[1] We refer to estimates of the importance of divorce using designs that are not genetically informative as phenotypic associations.

[2] Because of the importance of life course patterns, the present manuscript focuses primarily on academic achievement; sexual maturation and living arrangements; timing of substance use; and timing of emotional difficulties. The analysis of association between parental divorce and lifetime risk of psychopathology is presented elsewhere (D’Onofrio et al., submitted).

[3] Complete results are presented in the Appendix D.

[4] The term quasi-causal is used instead of causal because the analyses are still based on correlational data and cannot prove causation. See the discussion on limitations of the study.

VI. United States – Offspring Relationship Instability

[1] The use of discordant adult siblings (and twins) controls for environmental factors that make the adult siblings similar. The design does not control for environmental factors within sibling families that may confound intergenerational relations. For example, an environmental factor which only influences one twin may lead to higher rates of divorce in the adult and their offspring.

VII. Conclusion

[1] Most genetically informed methods, especially cross-sectional studies, are unable to distinguish between active and evocative rGE. Therefore, both the notation "active/evocative" will be used to separate these mechanisms from passive rGE.

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Tables

Table 1.

Twin Correlations for Marital Instability

Zygosity	Prevalence	Concordance Rate[a]	Tetrachoric Correlations	N (pairs)
MZ Female	17.71	.31	.32	1026
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.

[a]Proband concordance rate are presented.

Table 2.

Means of Offspring Psychopathology by Zygosity and Family Structure

Family Structure	Drug and Alcohol M	Drug and Alcohol SD	Externalizing M	Externalizing SD	Internalizing M	Internalizing SD	N
			DZ Twin Families				
Concordant Intact	-.09	.98	-.07	.97	-.02	.96	677
Discordant - Parents Married	.00	.95	-.01	.93	-.08	.95	252
Discordant - Parents Divorced	.14	1.07	.17	.97	.22	1.01	209
Concordant Divorced	.21	1.13	.15	107	.18	.99	108
			MZ Twin Families				
Concordant Intact	-.03	.94	-.07	.92	-.10	.97	717
Discordant - Parents Married	-.10	.86	-.05	.90	-.03	.88	218
Discordant - Parents Divorced	.14	.95	.10	.97	.13	1.03	232
Concordant Divorced	.17	1.05	.32	.92	.09	1.00	114

Note. Concordant Intact represents families in which neither twin has been divorced. Discordant-Parents Married are offspring from the non-divorced co-twin in discordant pairs. Discordant-Parents Divorced are offspring from the divorced co-twin in discordant pairs. Concordant-Divorced are offspring of families where both twins are divorced. The influence of age, age^2, and gender were partialled from the means, which are presented as Z scores.

Table 3.

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

Parameters	Models 1	2	3	4	5
Random (Variance Components)					
Individual (s ^{2})	**.81 (.03)**	**.75 (.03)**	**.75 (.03)**	**.75 (.03)**	**.75 (.03)**
Nuclear-Family Level ($t_p{}^2$)	**.18 (.04)**	**.19 (.04)**	**.19 (.04)**	**.19 (04)**	**.16 (.03)**
Twin-Family Level ($t_ß{}^2$)	.01 (.03)	.00 (.03)	.00 (.03)	.00 (.03)	.00 (.03)
Fixed					
Intercept ($?_{000}$)	.00 (.02)	-.39 (.37)	-.39 (.38)	-.37 (.38)	-.69 (.38)
Divorce					
Parental Divorce ($ß_{01t}$)		**.23 (.05)**			
Between-Family ($?_{001}$)			**.25 (.07)**	**.25 (.07)**	**.15 (.07)**
Within-Family ($ß_{02t}$)			**.20 (.07)**		
Within-Family MZ ($?_{010}$)				**.26 (.10)**	**.24 (.10)**
Within-Family DZ-MZ ($?_{001}$)				-.12 (.14)	-.15 (.14)
Level One Variables					
Age (p_{1nt})		.02 (.03)	.02 (.03)	.02 (.03)	.03.(.03)
Age^2 (p_{2nt})		.00 (.00)	.00 (.00)	.00 (.00)	.00 (.00)
Gender (p_{3nt})		**.41 (.04)**	**.41 (.04)**	**.41 (.04)**	**.41 (.04)**
Twin Type ($?_{002}$)				-.02 (.04)	-.03 (.04)
Parental Psychopathology					
Parental Conduct ($ß_{03t}$)					**.10 (.02)**
Parental Alcohol Dep. ($ß_{04t}$)					**.05 (.02)**
Parental Alcohol Abuse ($ß_{05t}$)					-.03 (.05)
Parental Depression ($ß_{06t}$)					**.02 (.01)**
Parental Drug Use ($ß_{07t}$)					**.15 (.06)**
Parental Suicidality ($ß_{08t}$)					.01 (.02)

Note. See text for explanation of the six models. Standard errors are presented in parentheses, and estimates significant at $p < .05$ are in bold.

Table 4.

Parameter Estimates of Hierarchical Regression Analyses of the Externalizing Factor

	Models				
Parameters	1	2	3	4	5
	Random (Variance Components)				
Individual (s^2)	**.72 (.03)**	**.64 (.03)**	**.64 (.02)**	**.64 (.03)**	**.64 (.02)**
Nuclear-Family Level (t_p^2)	**.13 (.04)**	**.13 (.03)**	**.13 (.03)**	**.13 (.03)**	**.14 (.03)**
Twin-Family Level ($t_ß^2$)	**.16 (.04)**	**.13 (.03)**	**.13 (.03)**	**.13 (.03)**	**.09 (.03)**
	Fixed				
Intercept ($?_{000}$)	-.01 (.02)	**-4.96 (.36)**	**-4.96 (.37)**	**-4.96 (.37)**	**-5.27 (.37)**
Divorce					
Parental Divorce ($ß_{01t}$)		**.25 (.05)**			
Between-Family ($?_{001}$)			**.31 (.07)**	**.30 (.07)**	**.24 (.07)**
Within-Family ($ß_{02t}$)			**.20 (.07)**		
Within-Family MZ ($?_{010}$)				.18 (.09)	.17 (.09) [z]
Within-Family DZ-MZ ($?_{001}$)				.04 (.13)	-.03 (.13)
Level One Variables					
Age (p_{1nt})		**.36 (.03)**	**.36 (.03)**	**.36 (.03)**	**.37 (.03)**
Age^2 (p_{2nt})		**-.01 (.00)**	**-.01 (.00)**	**-.01 (.00)**	**-.01 (.00)**
Gender (p_{3nt})		**.41 (.04)**	**.41 (.04)**	**.41 (.04)**	**.41 (.04)**
Twin Type ($?_{002}$)				-.01 (.04)	.01 (.04)
Parental Psychopathology					
Parental Conduct ($ß_{03t}$)					**.08 (.02)**
Parental Alcohol Dep. ($ß_{04t}$)					.03 (.02)
Parental Alcohol Abuse ($ß_{05t}$)					.04 (.05)
Parental Depression ($ß_{06t}$)					-.01 (.01)
Parental Drug Use ($ß_{07t}$)					**.19 (.06)**
Parental Suicidality ($ß_{08t}$)					.04 (.02)

Note. See note on table 3. [z] The within-family estimate was significant ($p < .05$) in the last model without the interaction with twin type.

Table 5.

Parameter Estimates of Hierarchical Regression Analyses of the Internalizing Factor

Models Parameters	Models 1	2	3	4	5
Random (Variance Components)					
Individual (s ^{2})	**.88 (.03)**	**.82 (.03)**	**.82 (.03)**	**.83 (.03)**	**.82 (.03)**
Nuclear-Family Level (t_p ^{2})	**.07 (.04)**	**.08 (.03)**	**.08 (.03)**	**.07 (.03)**	**.08 (.03)**
Twin-Family Level ($t_ß$ ^{2})	**.06 (.03)**	**.04 (.03)**	**.04 (.03)**	**.04 (.03)**	**.03 (.03)**
Fixed					
Intercept ($?_{000}$)	.00 (.02)	**-1.38 (.38)**	**-1.39 (.38)**	**-1.42 (.38)**	**-1.54 (.38)**
Divorce					
Parental Divorce ($ß_{01t}$)		**.23 (.05)**			
Between-Family ($?_{001}$)			**.21 (.06)**	**.21 (.06)**	**.14 (.07)**
Within-Family ($ß_{02t}$)			**.24 (.07)**		
Within-Family MZ ($?_{010}$)				**.18 (.09)**	.16 (.10) [z]
Within-Family DZ-MZ ($?_{001}$)				.14 (.13)	.07 (.14)
Level One Variables					
Age (p_{1nt})		**.10 (.03)**	**.10 (.03)**	**.10 (.03)**	**.10 (.03)**
Age^2 (p_{2nt})		**-.01 (.00)**	**-.01 (.00)**	**-.01 (.00)**	**-.01 (.00)**
Gender (p_{3nt})		**-.39 (.04)**	**-.39 (.04)**	**-.39 (.04)**	**-.39 (.04)**
Twin Type ($?_{002}$)				.05 (.04)	.04 (.04)
Parental Psychopathology					
Parental Conduct ($ß_{03t}$)					.02 (.02)
Parental Alcohol Dep. ($ß_{04t}$)					.02 (.02)
Parental Alcohol Abuse ($ß_{05t}$)					-.05 (.05)
Parental Depression ($ß_{06t}$)					**.03 (.01)**
Parental Drug Use ($ß_{07t}$)					.10 (.06)
Parental Suicidality ($ß_{08t}$)					.00 (.02)

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

Table 6.

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 7.

Risk of Offspring Psychopathology by Zygosity and Family Structure

Family Structure [a]	Lifetime Alcohol Problems		Alcohol Problems in past year		Cigarette Smoking		Emotional Problems[x]		Lifetime Depression	
	Risk	N	Risk	N	Risk	N	Risk	N	Risk	N
Concordant - Intact	.04	1250	.02	1253	.42	1249	.21	1247	.08	1250
Discordant - Married	.02	277	.03	279	.48	279	.22	277	.09	277
Discordant - Divorced	.16	225	.05	225	.55	225	.29	222	.13	225
Concordant - Divorced	.11	95	.04	95	.47	93	.26	95	.11	95
Concordant - Intact	.04	1519	.03	1527	.47	1518	.23	1511	.08	1519
Discordant - Married	.04	341	.05	341	.46	340	.32	338	.12	341
Discordant - Divorced	.12	312	.08	312	.58	311	.34	308	.12	312
Concordant - Divorced	.09	169	.07	169	.62	167	.33	166	.17	169

Note. Risks are based on Kaplan-Meier nonparametric survival analysis. [a] Concordant-Intact represents families in which neither twin has been divorced. Discordant-Married are offspring from the non-divorced co-twin in discordant pairs. Discordant-Divorced are offspring from the divorced co-twin in discordant pairs. Concordant-Divorced are offspring of families where both twins are divorced. [x]As measured by the top 20% on the SCL.

Table 8.

Parameter Estimates from Hierarchical Linear Models

	Lifetime Alcohol Problems					Alcohol Problems in past year				
Parameters	1	2	3	4	5	1	2	3	4	5
Divorce										
Phenotypic	.74	.56				.39	.29			
Within DZ			.90					-.03		
Within MZ				.59	.63				.30	.30
Within DZ-MZ				.31	.18				-.33	-.40
Between[z]			.68	.68	.49			.57	.56	.40
Gender	.78	.81	.78	.78	.81	.58	.59	.58	.58	.58
Parental Variables										
SCL		.28			.29		.18			.16
Extraversion		.26			.27		.09			.09
Neuroticism		-.11			-.08		-.04			-.04
Psychoticism		.18			.20		-.01			-.01
Life Alc. Prob		.36			.27		-.02			-.01
Last yr Alc. Prob		1.57			1.72		.42			.40
Life Depress.		.27			.30		.48			.47
Life Smoking		.28			.29		.47			.47
(Sample Size)	4097	4097	4097	4097	4097	4108	4108	4108	4108	4108

Note. See text for a description of the five models. [z]The variable is an approximation of the between-family association of marital instability and the offspring characteristics.

Table 9.

Parameter Estimates from Hierarchical Linear Models

	Cigarette Smoking					Emotional Problems[x]				
Parameters	1	2	3	4	5	1	2	3	4	5
Divorce										
Phenotypic	.16	.13				.30	.27			
Within DZ			.10					.41		
Within MZ				.19	.20				-.01	-.01
Within DZ-MZ				-.10	-.13				.42	.41
Between[z]			.17	.17	.12			.40	.40	.36
Gender	.04	.04	.04	.04	.04	-.34	-.33	-.34	-.34	-.33
Parental Variables										
SCL		.13			.12		.45			.44
Extraversion		.03			.03		.00			.00
Neuroticism		.04			.04		.06			.06
Psychoticism		.01			.01		.01			.00
Life Alc. Prob		.21			.21		-.58			-.56
Last yr Alc. Prob		.33			.33		.21			.19
Life Depress.		-.11			-.11		.09			.08
Life Smoking		.20			.20		.02			.01
(Sample Size)	4089	4089	4089	4089	4089	4072	4072	4072	4072	4072

Note. See Table S3. [x]As measured by the top 20% on the SCL.

Table 10.

Parameter Estimates from Hierarchical Linear Models

	Lifetime Depression					Emotional Problems[y]				
Parameters	1	2	3	4	5	1	2	3	4	5
Divorce										
Phenotypic	.40	.33				.10	.09			
Within DZ			.38					.15		
Within MZ				-.01	-.01				-.03	.00
Within DZ-MZ				.39	.40				.18	.13
Between[z]			.64	.64	.54			.15	.15	.11
Gender	-.60	-.59	-.59	-.59	-.59	-.24	-.20	-.24	-.24	-.19
Parental Variables										
SCL		.46			.43		.35			.35
Extraversion		.01			.01		.02			.02
Neuroticism		.00			.00		.06			.06
Psychoticism		.02			.01		.01			.01
Life Alc. Prob		-.18			-.10		-.28			-.27
Last yr Alc. Prob		-.37			-.45		-.04			-.04
Life Depress.		.56			.55		.01			.01
Life Smoking		.18			.16		.01			.01
(Sample Size)	4097	4097	4097	4097	4097	4072	4072	4072	4072	4072

Note. See Table S3. [y]Parameters are effect sizes because emotional difficulties is a continuously distributed variable and is standardized to a mean of zero and variance of one. The models for the variable also controlled for fixed effect of age and age^2.

Table 11

Demographic information and Reliability Estimates for Offspring Characteristics

Variable	Mean/Prevalence	N	Reliability[a]
Age	25.06 (.11)	2554	-
	Education		
Years of Education	13.48 (.04)	2553	.89
Failed Grade	9.52	2553	.85
Sexual Development, Living Arrangements, & Early Parenting			
Age of Menarche	13.01 (.04)	1284	.86
Intercourse	85.88	2543	.60
Age First Intercourse	17.43 (.05)	2168	.95
Cohabited	5.17	2553	.20
Baby before 20	1.41	2554	.80
	Alcohol, Cigarette, & Drug Use		
Drank Alcohol	97.96	2554	1.00
Age First Drink	15.21 (.04)	2502	.80
Intoxicated	86.18	2554	.61
Age First Drunk	16.53 (.05)	2201	.85
Tried Cigarette	75.37	2554	.88
Age First Cigarette	14.58 (.07)	1924	.82
Tried Marijuana	66.12	2550	.82
Age First Use Marijuana	17.39 (.07)	1681	.89
	Emotional Problems		
Depressed Mood	51.16	2549	.67
Age First Depression	19.05 (.15)	1303	.85
Suicidal Ideation	28.70	2547	.69
Age First Ideation	17.72 (.17)	726	.82

Note. Standard errors are in parentheses. [a]Test-retest correlations are presented for continuous variables and Kappas for dichotomous variables.

Table 12.

Sample Size of Offspring by Family Structure and Age of Parental Divorce

Avuncular Divorce	Parental Separation		
	None	Before 16	After 16
		Entire Sample	
No	1418	313	92
Yes	492	141	51
		DZ Twins	
No	692	152	38
Yes	255	70	29
		MZ Twins	
No	726	161	54
Yes	237	71	22

Note. 47 offspring not included in the analyses due to incomplete data.

Table 13.

Percentages and Means of Life Course Outcomes According to Separation Groups:

	Timing of Separation								Overall
	No Separation		Previous[a]		Before Age 16		After Age 16		Significance
Variable	M / %	N	M / %	N	M / %	N	M / %	N	Level [b,c]
Age of Offspring	24.71 (.20)	1876	22.15 (.56)	83	24.26 (.29)	442	27.15 (.43)	153	**F(3,203)=25.04**
Education									
Years of Education	13.57 (.05)	1875	13.67 (.23)	83	13.16 (.10) *	442	13.04 (.17) *	153	**F(3,203)=8.21**
Failed Grade	8.80	1875	6.02	83	11.54*	442	11.38	153	**?^{2}(3)=7.48**
Sexual Development, Living Arrangements, & Early Parenting									
Age of Menarche	13.03 (.05)	946	13.14 (.24)	42	12.88 (.10)	232	12.90 (.19)	64	F(3,88)=.86
Intercourse	85.07	1869	81.39	83	86.76	438	95.42	153	?^{2}(3)=.89
Age 1st Intercourse	17.65 (.07)	1577	17.73 (.30)	68	16.66 (.13) *	377	16.96 (.21) *	146	**F(3,178)=17.88**
Cohabited	4.11	1875	2.41	83	8.14*	442	11.11*	153	**?^{2}(3)=22.56**
Baby before 20	1.07	1876	0.00	83	2.04 *	442	4.48*	153	**?^{2}(2)=15.25** [d]
Alcohol, Cigarette, & Drug Use									
Drank Alcohol	98.19	1876	95.18	83	97.06	442	99.35	153	?^{2}(3)=2.24
Age 1st Drink	15.29 (.06)	1842	15.50 (.25)	79	14.82 (.11) *	429	15.19 (.18)	152	**F(3,198)=5.02**
Intoxicated	85.29	1876	84.34	83	88.01	442	92.81	153	?^{2}(3)=1.69
Age 1st Intoxication	16.64 (.06)	1600	16.63 (.28)	70	16.10 (.12) *	389	16.57 (.19)	142	**F(3,173)=5.11**
Tried Cigarette	74.15	1876	66.27	83	79.86	442	82.35	153	?^{2}(3)=3.12
Age 1st Cigarette	14.74 (.09)	1390	15.16 (.42)	55	14.01 (.16) *	353	14.80 (.27)	126	**F(3,152)=5.64**
Marijuana Use	63.18	1874	66.27	83	74.55*	440	77.78	153	**?^{2}(3)=9.87**
Age 1st Use Marijuana	17.57 (.09)	1180	17.44 (.38)	55	16.83 (.16) *	327	17.52 (.29)	119	**F(3,138)=5.30**
Emotional Problems									
Depressed Mood	48.91	1875	39.76	83	60.73*	438	57.52	153	**?^{2}(3)=11.57**

Age First Depression	19.37 (.16)	916	18.96 (.82)	33	17.63 (.29)*	266	18.99 (.51)	88	**F(3,100)=9.16**
Suicidal Ideation	26.73	1874	25.30	83	35.24*	437	35.95	153	**?^{2}(3)=11.37**
Age First Ideation	17.87 (.20)	496	18.33 (.95)	21	17.16 (.35)	154	17.01 (.58)	55	F(3,42)=1.64

Note. The means were calculated controlling for gender, age, and age2 of the offspring. [a]Twin parent had been separated before having offspring. [b]Values in bold are significant at p<.05. [c]The tests of significance for categorical outcomes controlled for variable exposure based on the age of the offspring. [d]Because of empty cells only the offspring in the last two groups were compared to the no separation group. *Offspring outcomes differ compared to no separation group (p<.05).

Table 14

Parameters for Parental Divorce for Offspring Life Course Outcomes from Hierarchical Linear Models

	Divorce Before the Age of 16 Models[a]						Divorce After the Age of 16 Models[a]					
	1	2	3		4		1	2	3		4	
Variable	Phen	Phen	MZ	DZ-MZ	MZ	DZ-MZ	Phen	Phen	MZ	DZ-MZ	MZ	DZ-MZ
Years of	**-.48**	**-.31**	-.32	.31	-.26	.37	**-.45**	-.34	-.26	-.03	-.17	-.03
Education	**(.11)**	**(.11)**	(.30)	(.43)	(.29)	(.41)	**(.19)**	(.18)	(.38)	(.53)	(.37)	(.50)
Failed Grade	**.39**	**.29**	.26	.10	.21	.01	-.10	.01	-	-	-	-
	(.13)	**(.13)**	(.31)	(.41)	(.31)	(.42)	(.21)	(.22)				
Age at 1st	**-1.01**	**-.83**	-.39	-.44	-.53	-.08	**-.68**	**-.56**	-.44	.11	-.16	-.20
Intercourse	**(.14)**	**(.15)**	(.38)	(.46)	(.37)	(.54)	**(.24)**	**(.23)**	(.31)	(.67)	(.45)	(.65)
Cohabited	**.65**	**.40**	-.16	1.09	-.15	.98	**.90**	**.70**	.55	.11	.16	-.20
	(.17)	**(.17)**	(.48)	(.64)	(.49)	(.63)	**(.22)**	**(.22)**	(.53)	(.67)	(.45)	(.65)
Age at 1st Drink	**-.41**	**-.35**	-.12	-.33	-.13	-.24	-.11	.06	-	-	-	-
	(.11)	**(.12)**	(.21)	(.30)	(.21)	(.30)	(.20)	(.20)				
Age at 1st	**-.50**	**-.42**	-.24	-.10	-.25	.00	-.23	-.16	-	-	-	-
Intoxication	**(.13)**	**(.14)**	(.26)	(.35)	(.26)	(.35)	(.21)	(.45)				
Age at 1st	**-.63**	**-.57**	-.32	-.12	-.33	-.06	-.11	-.07	-	-	-	-
Cigarette	**(.19)**	**(.19)**	(.37)	(.51)	(.37)	(.51)	(.30)	(.31)				
Marijuana Use	**.18**	**.18**	**.16**	-.07	**.18**	-.11	.06	.06	-	-	-	-
	(.04)	**(.04)**	**(.07)**	(.10)	**(.07)**	(.10)	(.06)	(.07)				
Age at 1st	**-.70**	**-.53**	.02	.66	-.02	.43	-.05	.00	-	-	-	-
Marijuana Use	**(.18)**	**(.18)**	(.33)	(.48)	(.33)	(.48)	(.29)	(.29)				
Depressed Mood	**.24**	**.22**	**.23**	.02	**.22**	-.02	.02	.00	-	-	-	-
	(.05)	**(.05)**	**(.10)**	(.14)	**(.10)**	(.14)	(.10)	(.05)				
Age at 1st	**-1.77**	**-1.57**	**-1.52**	-.78	**-1.32**	-.72	-.10	.13	-	-	-	-
Depression	**(.33)**	**(.34)**	**(.65)**	(.90)	**(.66)**	(.42)	(.57)	(.57)				
Suicidal Ideation	**.29**	**.18**	.26	-.16	.25	-.17	.14	.08	-	-	-	-
	(.08)	**(.09)**	(.17)	(.23)	(.18)	(.23)	(.13)	(.14)				

Note. Standard errors are in parentheses. Values in bold are significant at $p<.05$. [a] Phen=phenotypic associations that are comparisons of unrelated individuals. MZ=differences among offspring of MZ twins discordant for divorce. DZ-MZ=difference between the within DZ and MZ family estimates. Parameter estimates are distributed as years for the continuously distributed outcomes and logits for the dichotomous variables. See text for a complete description of the models and statistical controls used in models 2 and 4. (-) outcomes not associated with parental divorce after the age of 16 were not included in the CoT analyses.

Table 15.

Prevalence Rate and Risk for Relationship Instability in Offspring by Family Structure and Zygosity

Structure	Ever in Relationship %	Ever in Relationship Risk	Entire Sample %	Entire Sample Risk	N
		DZ Twins			
Concordant Intact	16.22	.17 (.03)	4.30	.12 (.03)	697
Discordant - Parents Married	13.85	.19 (.08)	3.45	.15 (.07)	261
Discordant - Parents Divorced	34.69	.44 (.09)	8.95	.32 (.08)	190
Concordant Divorced	12.00	.29 (.15) [a]	3.03	.24 (.14)[a]	99
		MZ Twins			
Concordant Intact	9.33	.14 (.03)	2.87	.10 (.03)	731
Discordant - Parents Married	11.49	.14 (.05)	4.17	.10 (.04)	240
Discordant - Parents Divorced	23.88	.23 (.07)	7.34	.16 (.05)	218
Concordant Divorced	26.67	.39 (.12)	8.60	.24 (.08)	93

Note. Risks are based on Kaplan-Meier nonparametric survival analyses, controlling for the gender of the offspring. Standard errors are in parentheses. [a] Risk can only be calculated for age 32.

Table 16.

Percentage of Missing Data on Parental Characteristics

Variables	Mothers	Fathers
Education	8.34	23.56
Church Attendance	8.03	23.40
Age first child	8.27	23.40
Cigarette Smoking	8.19	23.95
Conduct Disorder	5.38	15.60
Alcohol Abuse	8.03	23.25
Depression	5.30	15.45
Drug Use	8.03	23.25
Suicidality	5.30	15.45
Psychoticism	22.07	45.71
Neuroticism	22.07	45.71
Extraversion	22.07	45.71
Impulsivity	22.07	45.71
Lie Scale	22.07	45.71
Harm Avoidance	22.15	45.78
Novelty Seeking	22.15	45.78
Reward Dependence	22.23	45.78
Persistence	22.31	45.78

Table 17.

Parental Characteristics Associated with Offspring Divorce/Separation Status

	Mother			Father		
Variables	b	HR	p	b	HR	p
Education	-.08 (.07)	.92	.26	-.06 (.07)	.94	.45
Church Attendance*	-.10 (.07)	.90	.15	-.12 (.08)	.89	.12
Age first child*	-.08 (.03)	.92	<.01	-.07 (.03)	.93	<.01
Cigarette Smoking	.07 (.20)	1.07	.70	.14 (.25)	1.15	.59
Conduct Disorder*	.14 (.09)	1.15	.09	.11 (.08)	1.12	.16
Alcohol Abuse	.06 (.23)	1.06	.81	.17 (.13)	1.19	.18
Depression*	.06 (.03)	1.06	.04	.03 (.04)	1.03	.47
Drug Use*	.72 (.36)	2.05	.05	.54 (.32)	1.71	.10
Suicidality	.08 (07)	1.08	.26	.17 (.12)	1.19	.17
Psychoticism*	.20 (.12)	1.22	.09	.09 (.12)	1.09	.44
Neuroticism	-.02 (.11)	.98	.86	.05 (.12)	1.05	.70
Extraversion*	.27 (.11)	1.31	.01	.10 (.13)	1.11	.43
Impulsivity*	.24 (.11)	1.27	.02	.13 (.11)	1.14	.25
Lie Scale	-.04 (.11)	.96	.74	.00 (.11)	1.00	.97
Harm Avoidance	-.09 (.10)	.91	.35	.01 (.13)	1.01	.94
Novelty Seeking	.16 (.10)	1.17	.12	.11 (.13)	1.12	.37
Reward Dependence	.08 (.11)	1.08	.46	.07 (.12)	1.07	.56
Persistence	.04 (.10)	1.04	.73	.02 (.14)	1.02	.87

Note. The coefficients (b) are based on Cox Proportional Hazard Models using multiple imputation, ignoring the nested nature of the data, and are distributed as logits. HR are hazard ratios. See text for units of measurement for each variable. *Included in subsequent HLM models predicting offspring divorce/separation status.

Table 18.
Parameter estimates from the Hierarchical Linear Models

Parameter	Models 1	2	3	4	5	6	7	8
Divorce								
Phenotypic	**.69**	**.51**						
Between			**.53**	.29	**.53**	.29	**.53**	.29
Within			**.82**	**.71**				
Within DZ					**1.03**	**.90**		
Within (MZ-DZ)					-.41	-.37		
Within MZ							.62	.53
Within (DZ-MZ)							.41	.37
Offspring Gender	-.26	-.23	-.26	-.23	-.26	-.23	-.26	-.23
Maternal Variables								
Church Attendance		.07		.07		.07		.07
Age at First Child		**-.10**		**-.10**		**-.10**		**-.10**
Conduct Disorder		.08		.08		.08		.08
Depression		.03		.03		.03		.03
Illegal Drug Use		.59		.59		.59		.59
Psychoticism		.02		.02		.02		.02
Extraversion		.10		.10		.10		.10
Impulsivity		-.06		-.06		-.06		-.06
Paternal Variables								
Church Attendance		**-.10**		**-.10**		**-.10**		**-.10**
Age at First Child		-.03		-.03		-.03		-.03
Conduct Disorder		-.01		-.01		-.01		-.01
Depression		.02		.02		.02		.02
Illegal Drug Use		-.13		-.13		-.13		-.13
Psychoticism		.07		.07		.07		.07
Extraversion		.00		.00		.00		.00
Impulsivity		-.02		-.02		-.02		-.02

Note. Parameters in bold were significant at $p<.05$

Table 19.

Prevalence and Risk for Offspring Relationship Instability in Females by Family Structure

Structure	%	Risk	N
Concordant Intact	21.77	.41 (.02)	1660
Discordant - Parents Married	23.59	.50 (.06)	374
Discordant - Parents Divorced	29.85	.60 (.05)	335
Concordant Divorced	35.75	.67 (.06)	160

Note. Risks are Kaplan Meier nonparameteric estimates of the failure rate at age=45.

Table 20.

Prevalence and Risk for Offspring Relationship Instability in Females by Family Structure and Zygosity

Structure	%	Risk	N
	DZ Twins		
Concordant Intact	22.65	.42 (.03)	744
Discordant - Parents Married	24.38	.56 (.07)	160
Discordant - Parents Divorced	30.43	.63 (.07)	138
Concordant Divorced	43.86	.68 (.09)	57
	MZ Twins		
Concordant Intact	21.05	.40 (.03)	916
Discordant - Parents Married	23.00	.44 (.06)	214
Discordant - Parents Divorced	29.44	.57 (.06)	197
Concordant Divorced	35.92	.66 (.07)	103

Note. Risks are Kaplan Meier nonparameteric estimates of the failure rate at age=45.

Table 21.

Parameter estimates from Hierarchical Linear Models

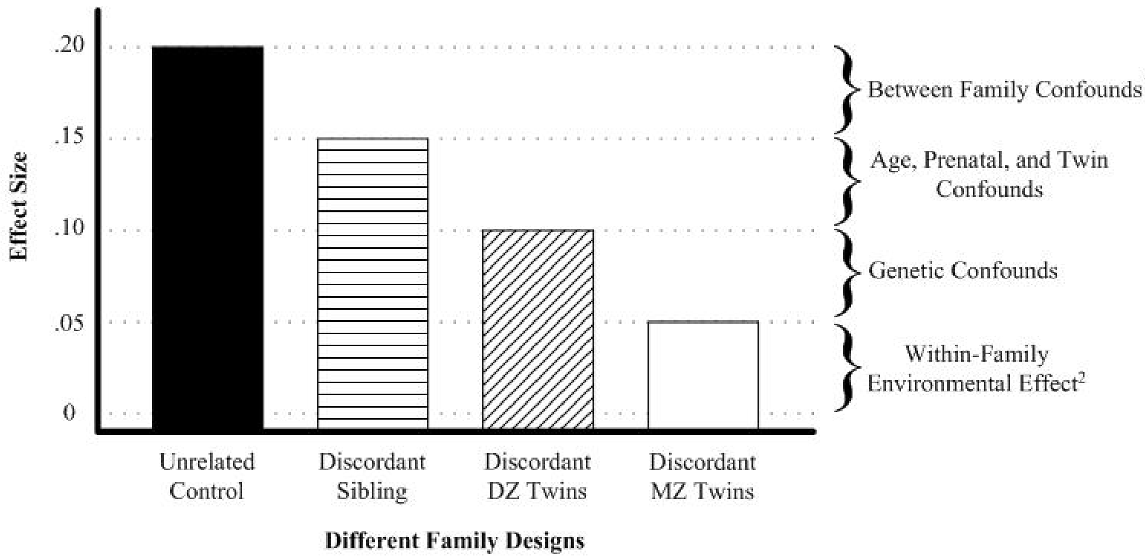
Parameter	Model 1	2	3	4	5	6
Divorce						
Phenotypic	**.42**	**.36**				
Between			**.57**	**.48**	**.57**	**.48**
Within			.22	.19		
Within MZ					.23	.24
Within (DZ-MZ)					-.02	-.11
Parental Variables						
Education Level		**-.08**		**-.08**		**-.08**
Emotional Difficulties		-.11		-.11		-.11
Lifetime Smoking		**.22**		**.21**		**.21**
Extraversion		.01		.01		.01
Neuroticism		-.02		-.02		-.02
Psychoticism		.03		.03		.03
Impulsivity		**.07**		**.07**		**.07**
Lifetime Alc. Problems		-.17		-.15		-.15
Past yr Alc Problems		.20		.20		.20
Lifetime Depression		.09		.08		.08

Note. See text for a description of the models and the distribution of the parental variables. Parameter estimates are distributed as logits, and bold estimates are significant at $p<.05$.

FIGURES

Figure 1.

Exposition of Difference in Effect Sizes Using Different Family Designs



Note. See text for explanation. [1]Includes both environmental and genetic confounds. [2]Differences between offspring in divorced and intact families are due to environmental factor within families which are associated with divorce. This also includes the confounds from the twins' spouses.

Figure 2.

Effect Sizes for Comparisons Using Unrelated Controls, Discordant DZ Twin Families, and Discordant MZ Twin Families for Three Patterns of Intergenerational Associations

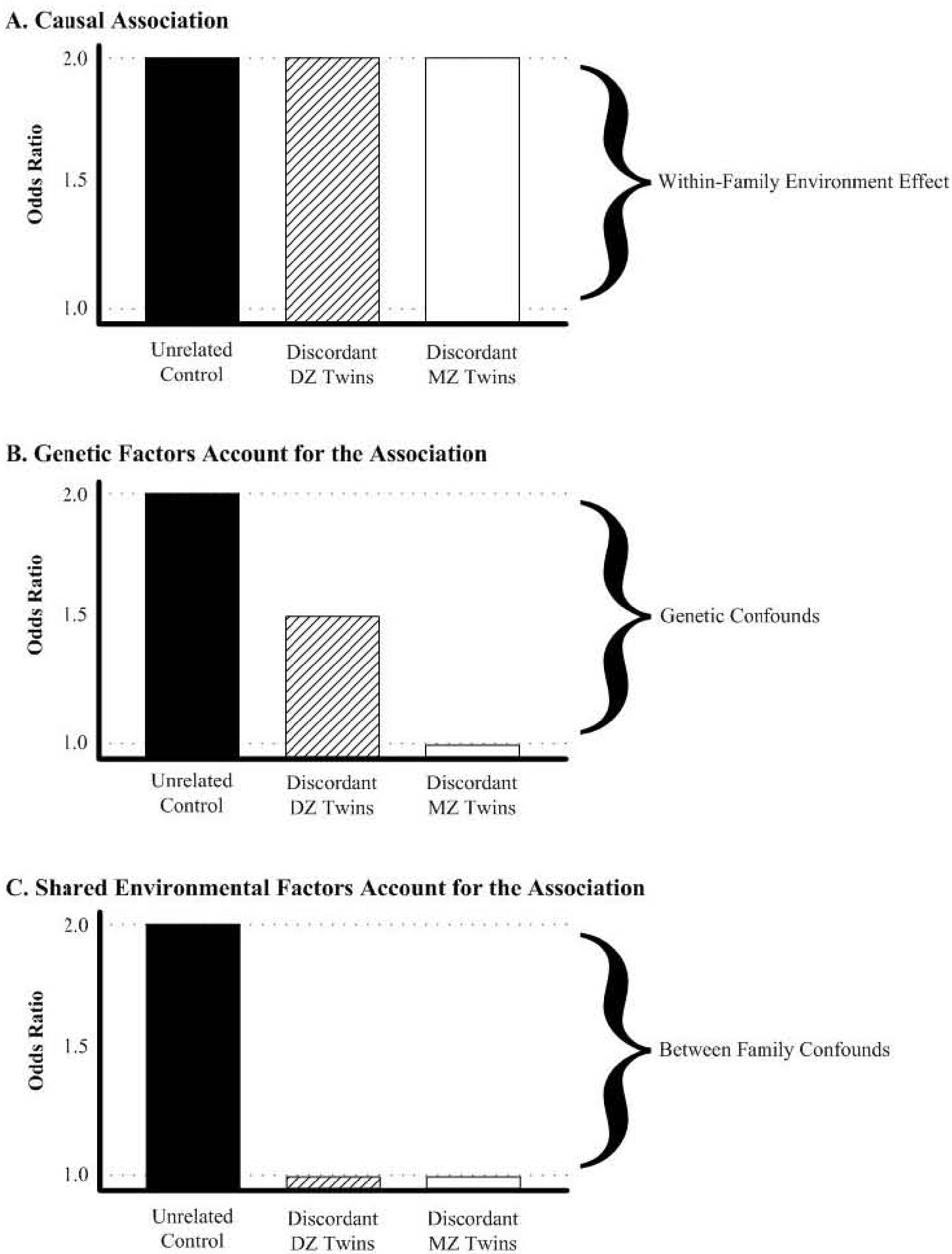
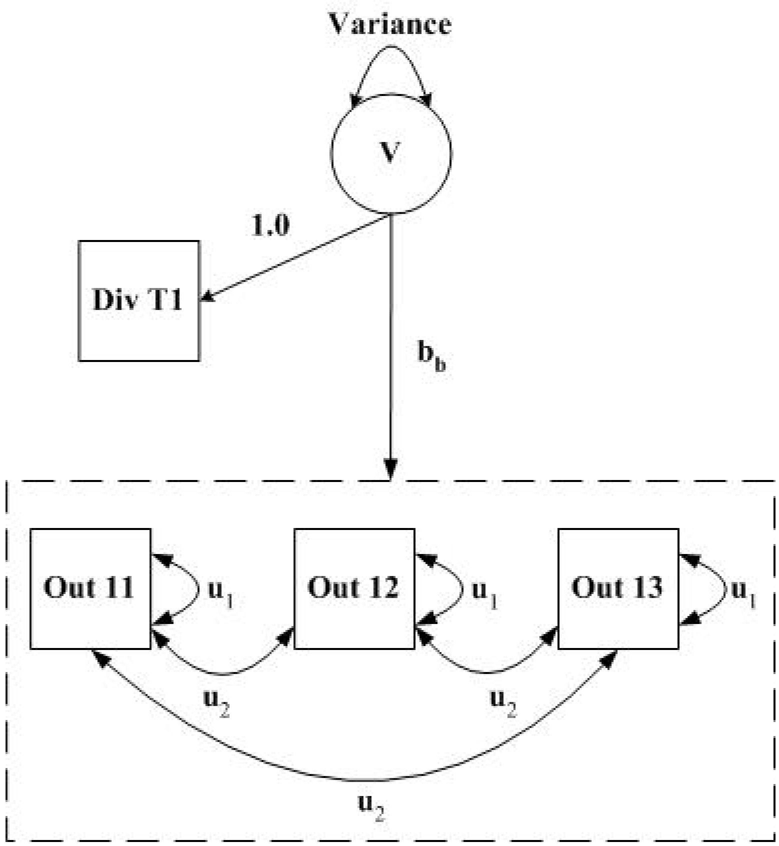


Figure 3

Phenotypic Model to Estimate Unstandardized Between-Family Path Estimate



Note. For ease of presentation, arrows to the box are specified to each offspring outcome in the model.

Figure 4.

Sibling Control Model to Estimate Unstandardized Between and Within-Family Path Estimates

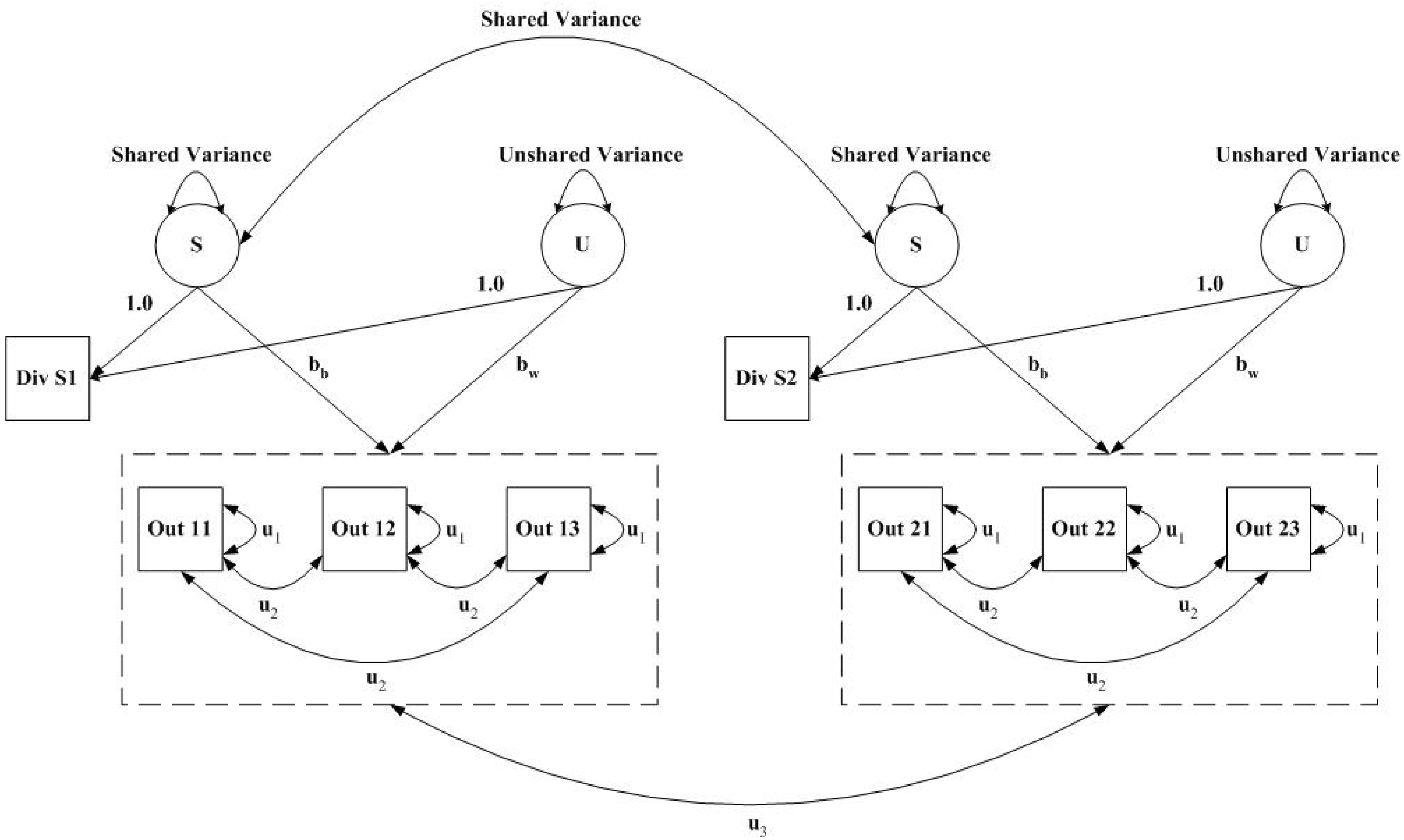


Figure 5

Children on Twins Model to Estimate Unstandardized Genetic, Shared Environmental, and Within-Family Path Estimates

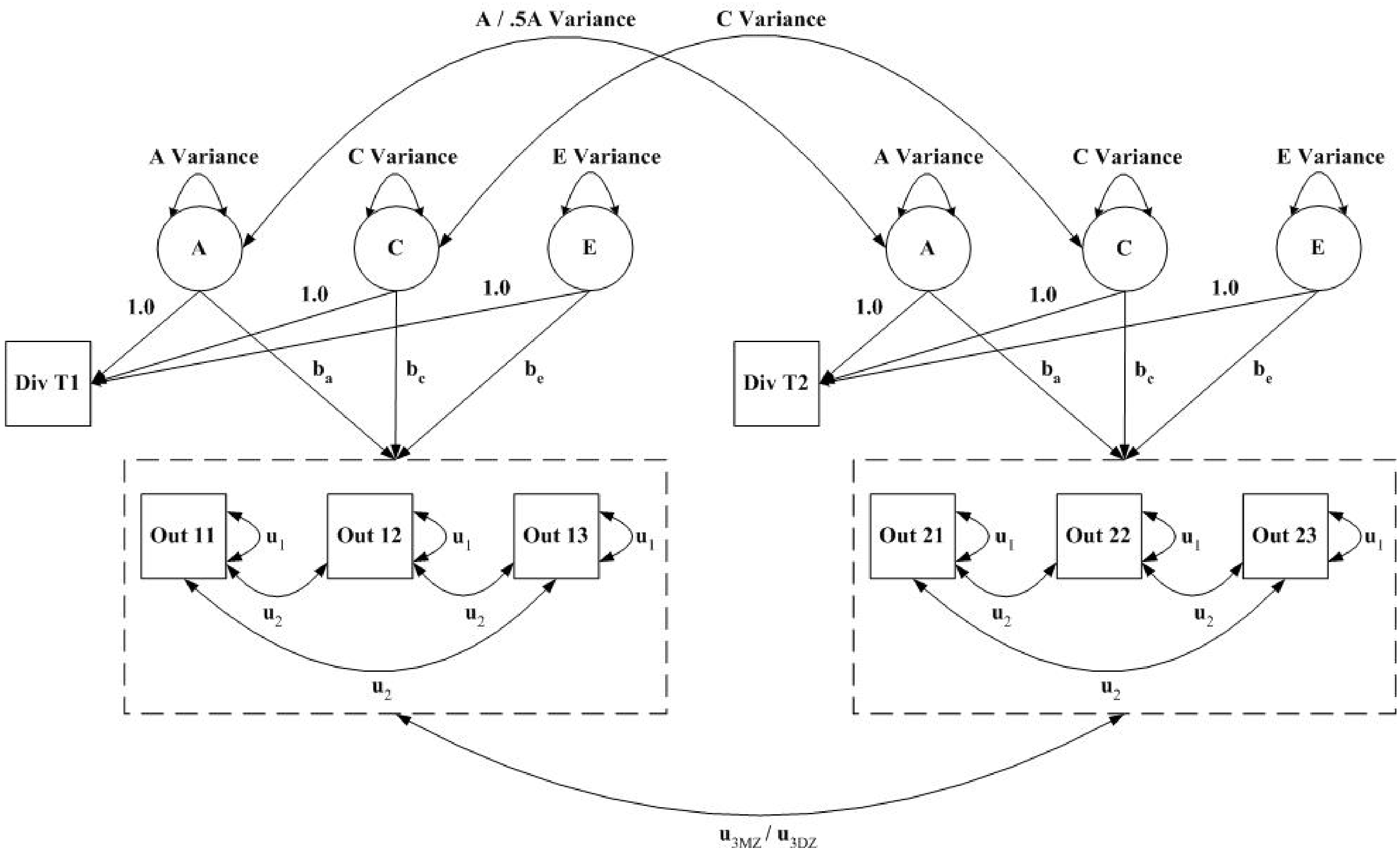


Figure 6.

Family Structures in the Children of Twins Design

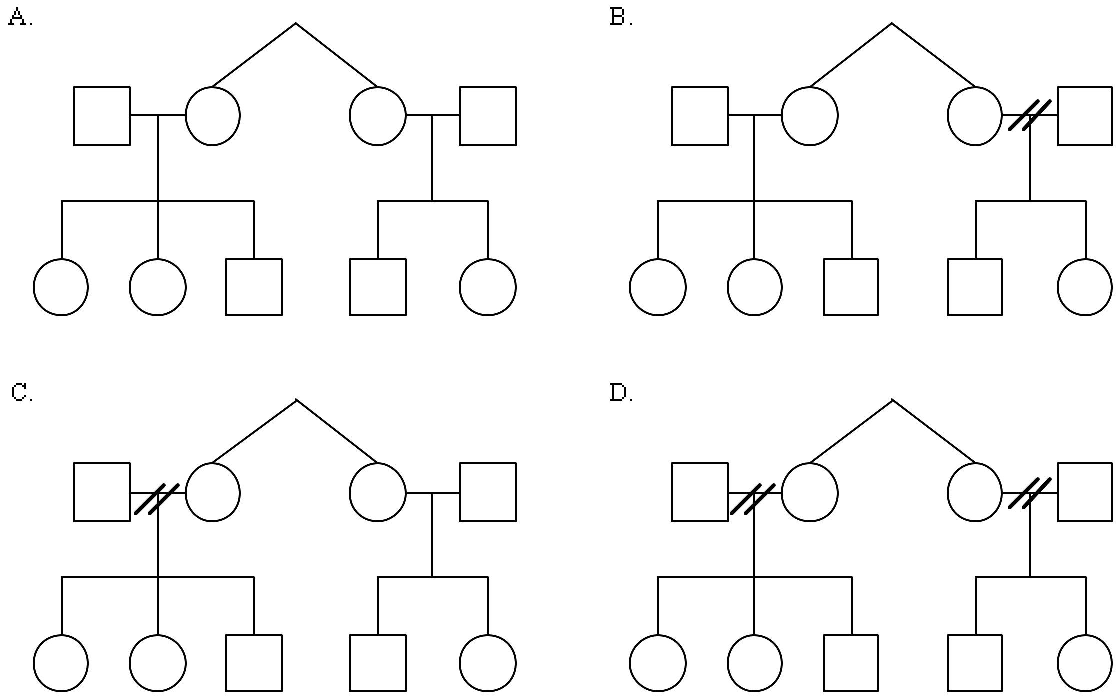
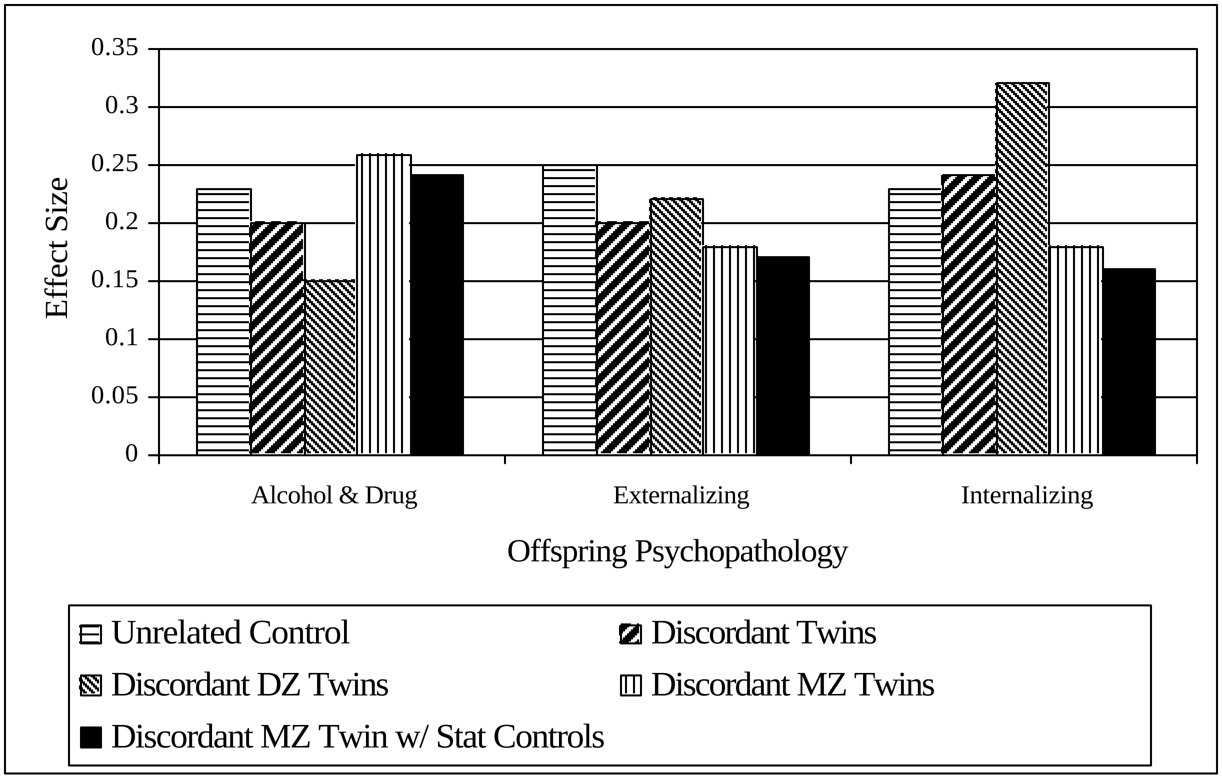


Figure 7.

Effect Sizes between Parental Marital Instability and Offspring Psychopathology Utilizing Different Methodological Controls



Note. The discordant twin method includes both MZ and DZ twins. The effect sizes using twin controls are within-family estimates.

See text for a description of the statistical controls using the adult twin characteristics.

Figure 8.

Associations with Marital Instability Using Different Control Groups and Statistical Controls

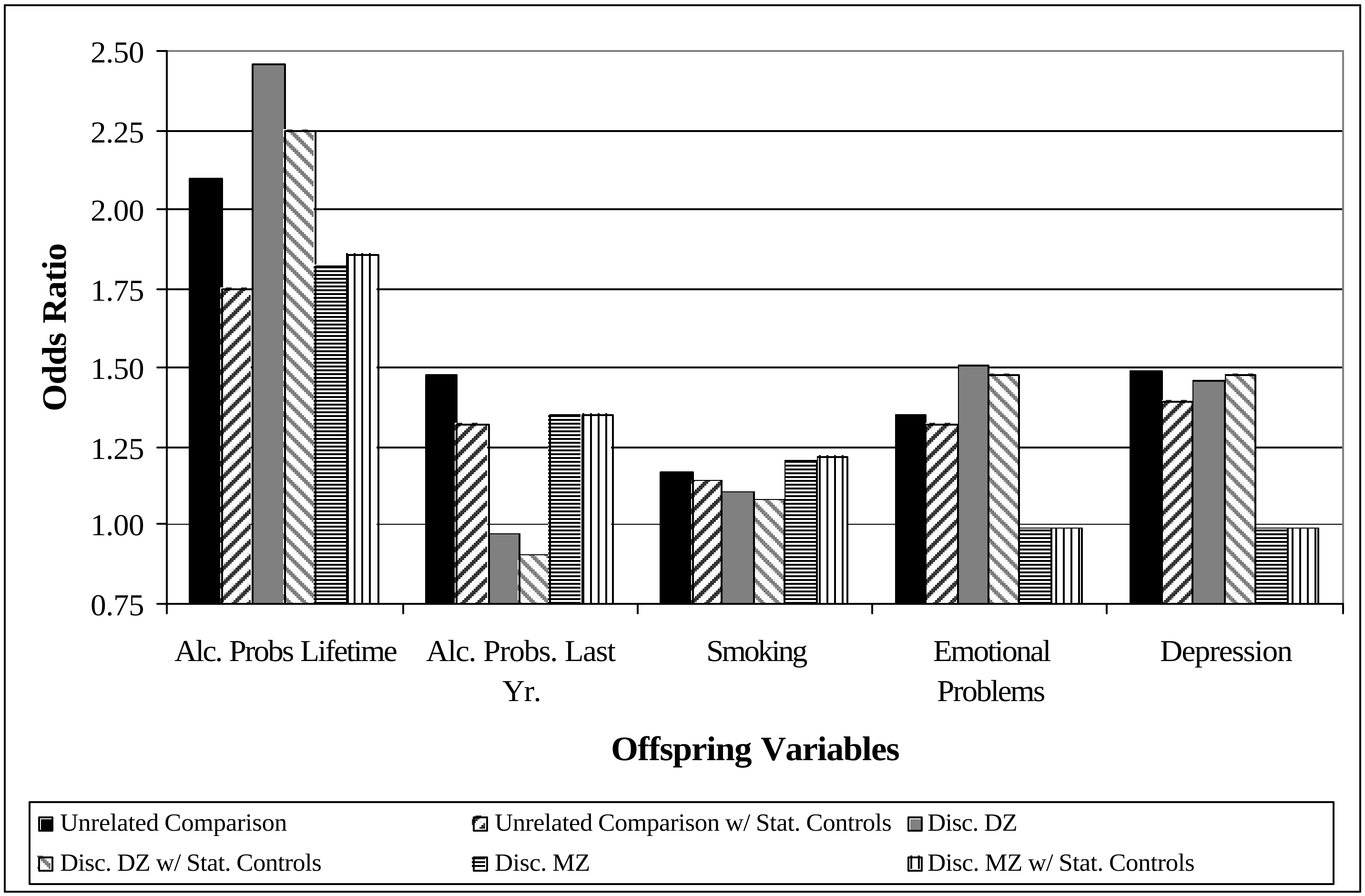
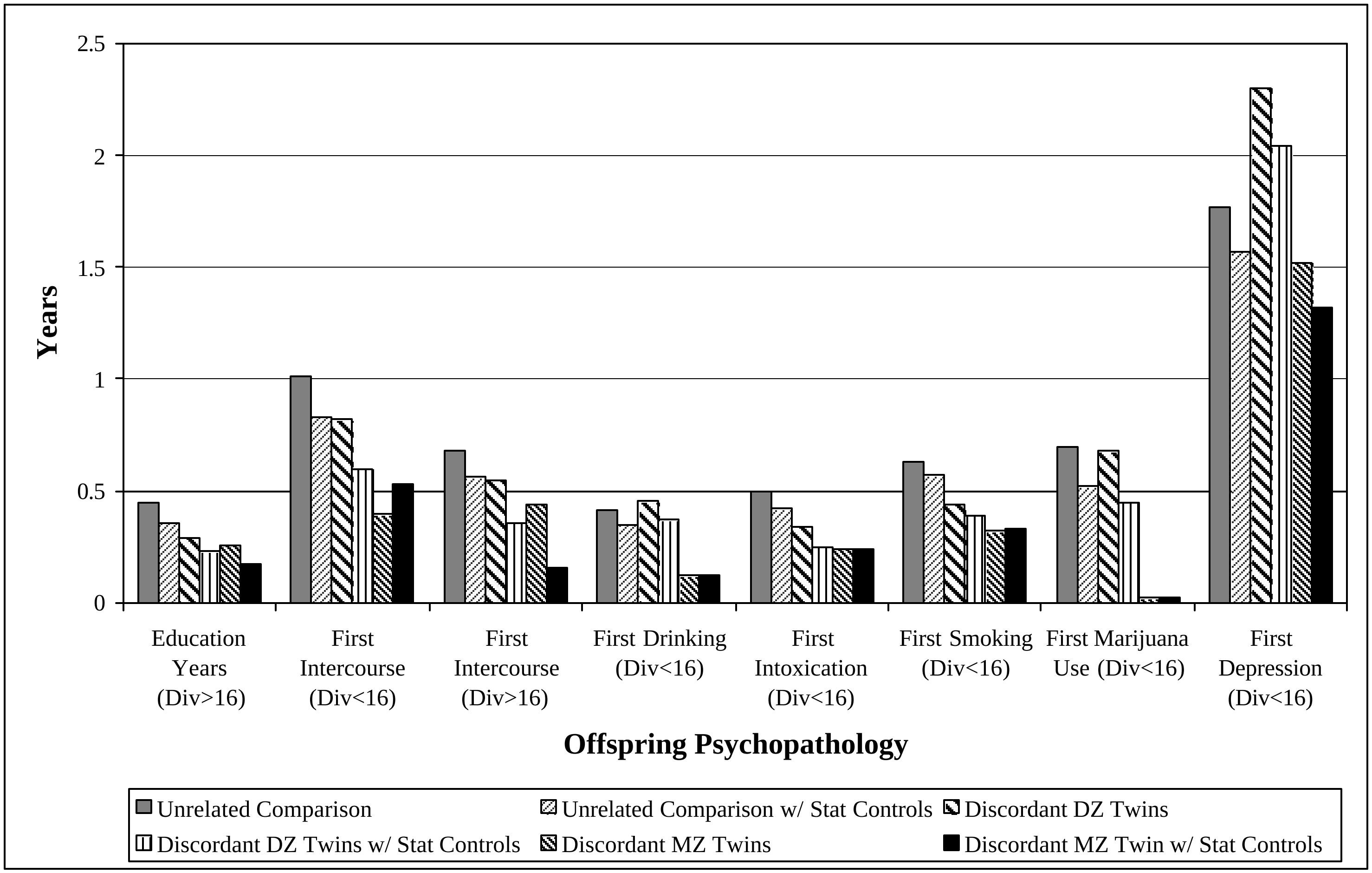


Figure 9.

Age of Onset associated with Parental Divorce Using Methodological and Statistical Controls



Note. The estimates represent the difference in age of offspring from intact and divorced families. Parental divorce lowered the age of onset for each variable.

Figure 10.

Risk for Life Course Patterns with Parental Divorce Using Methodological and Statistical Controls

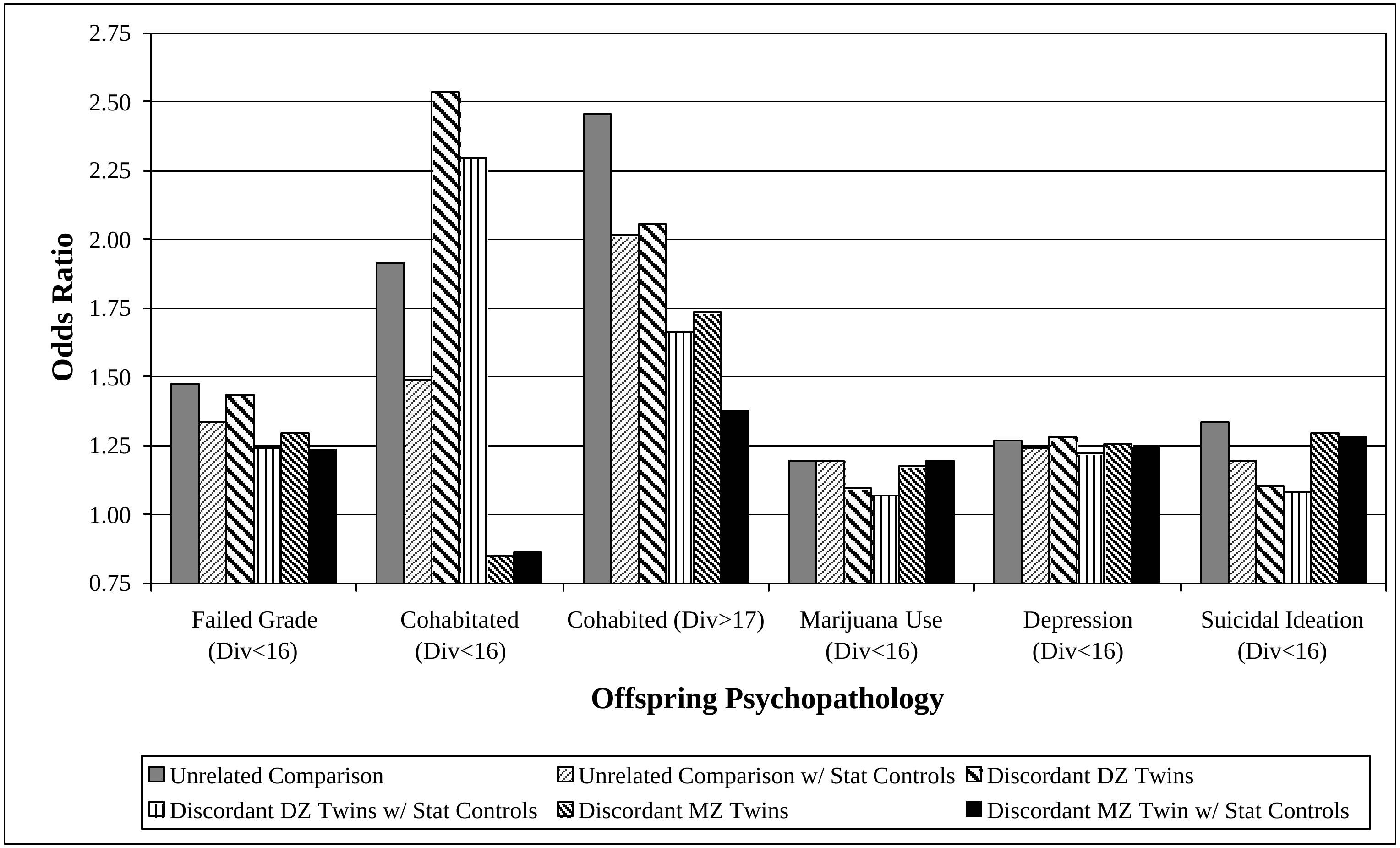
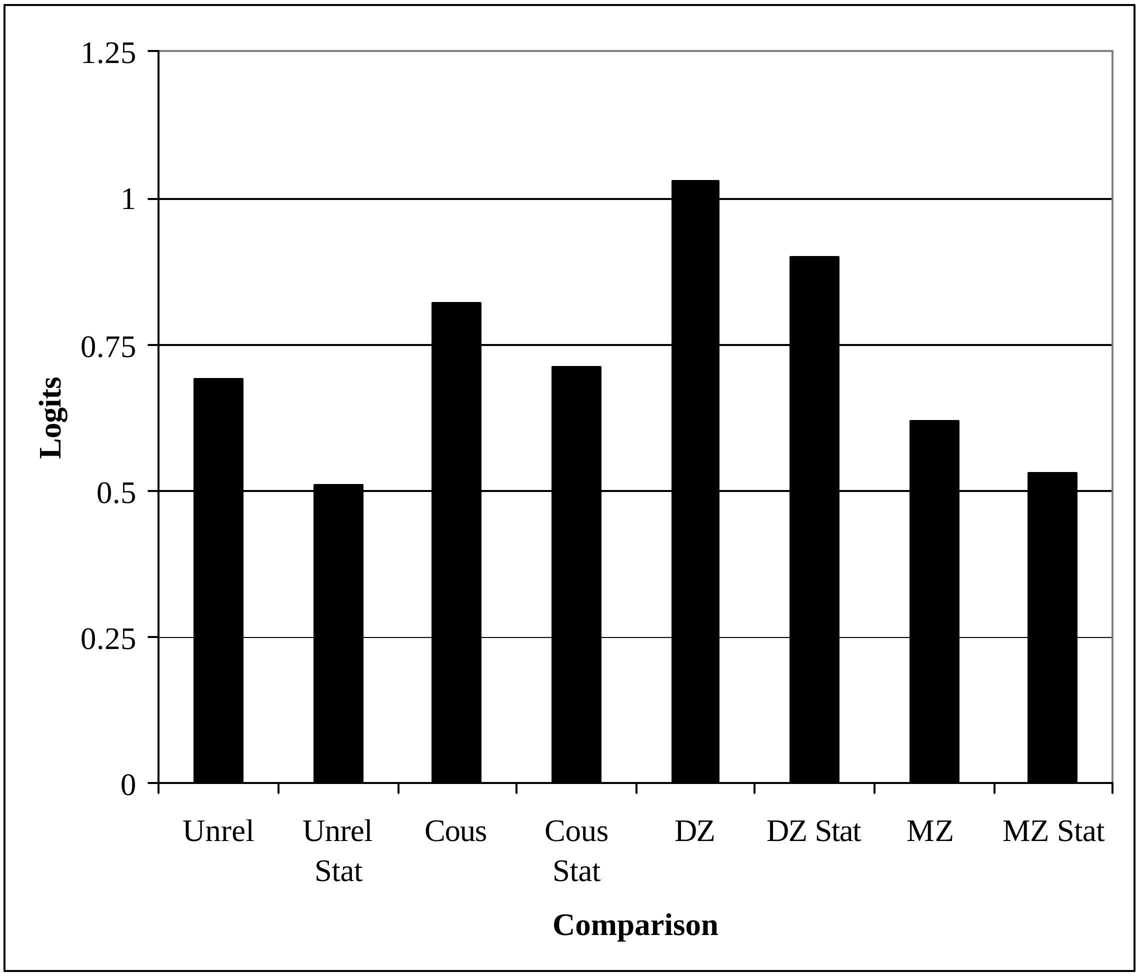


Figure 11.

Association between Parental Marital Instability and Offspring Relationship Instability in the Australian Twin Registry Using Methodological and Statistical Controls



Note. Unrel=a comparison of unrelated offspring. Cous=a comparison of cousins regardless of zygosity of the twins. DZ=a comparison of offspring from DZ twins discordant for divorce. MZ=a comparison of offspring form MZ twins discordant for divorce.

Figure 12.

Environmental and Genetic Confounds to Intergenerational Relations

Note. Reciprocal effects are not considered in the current model.

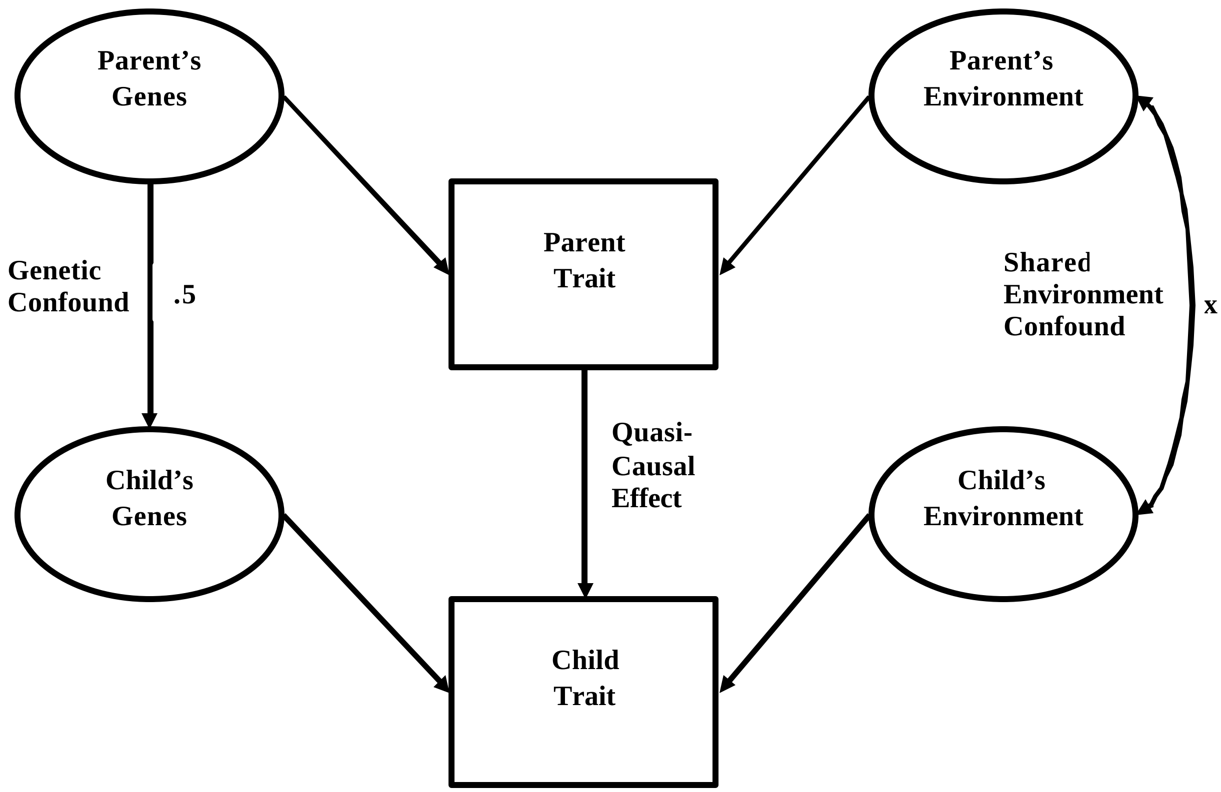
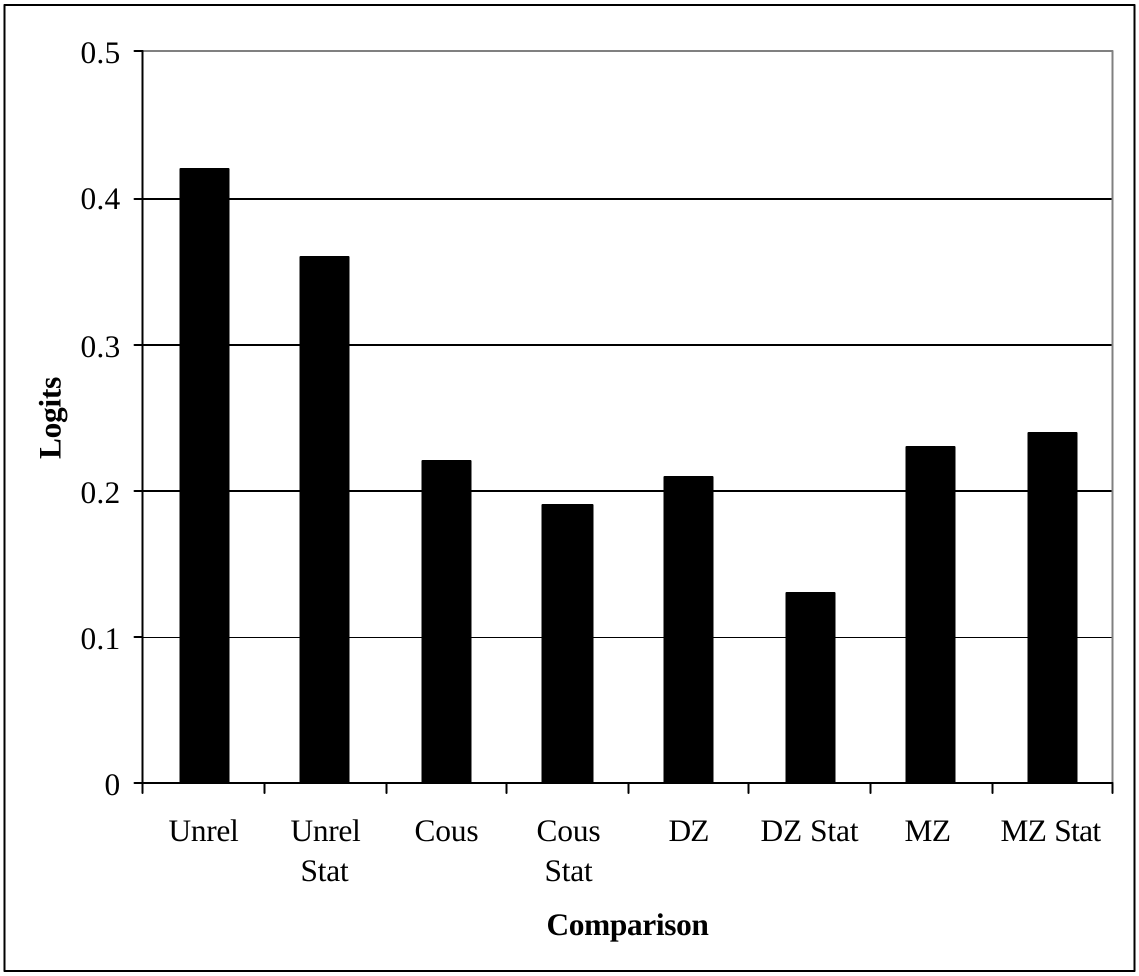


Figure 13.

Association between Parental Marital Instability and Offspring Relationship Instability In the VA 30,000 Dataset Using Methodological and Statistical Controls



Note. Unrel=a comparison of unrelated offspring. Cous=a comparison of cousins regardless of zygosity of the twins. DZ=a comparison of offspring from DZ twins discordant for divorce. MZ=a comparison of offspring form MZ twins discordant for divorce. Within family estimates were used when possible. Standard errors for the estimates are provided in the text.

APPENDIX A – FACTOR ANALYSES OF OFFSPRING SSAGA

The Semi-Structured Assessment for the Genetics of Alcoholism (SSAGA) used for the offspring of adult twins included retrospective recall of DSM-IV items for oppositional defiant disorder, attention deficit hyperactivity disorder (both attention and hyperactivity items), and conduct disorder. It also included lifetime history measures of cigarettes use; regular smoking (smoking cigarettes daily for a period of three weeks); alcohol use; regular alcohol use (drinking once a month for 6 or more months); ever becoming drunk; regular binging (at least 5 drinks/day more than once a week during heaviest period of drinking); regular drunkenness (becoming drunk more than once a week during heaviest period of drinking); consistent drinking (drinking at least 5 days/week during the heaviest period of drinking); 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 lead to dangerous situations; drug use interfered with work or household responsibilities; work caused emotional problems; desire to reduce drug use 3 or more times in lifetime; DSM-IV items for major depressive episode; suicidal ideation; plan for committing suicide; suicide attempt; and self injury.

One offspring per twin family was selected for an exploratory factor analysis. All children were initially not utilized because of the correlated responses due to the offspring being in the same nuclear and twin family. An exploratory factor analysis of the 81 dichotomous variables was conducted using Mplus. Due to the inability to incorporate missing values with an analysis of categorical variables, individuals with missing values were dropped from the analysis. However, 871 of the original 889 selected offspring were included. The Conduct Disorder 7 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 using Promax rotation.

The factor structure and loadings is shown in Table 1. The first factor, referred to as Alcohol and Drug Factor, includes all of the cigarette, alcohol use, alcohol abuse, alcohol dependence, drug use, and problems associated with drug use. Items from the Conduct Disorder criteria, including deliberately destroying property, broking into a house, stealing nontrivial items, and serious violations of rules (including staying despite parental prohibitions, running away from home twice, and truancy) also loaded on the factor. The second factor will be referred to as Externalizing Factor and includes retrospective reports of oppositional defiant behaviors, attention problems, hyperactivity, conduct disorder items (excluding serious violations of rules), and report of recurrent legal problems due to alcohol use. The third factor includes the depressive episode criteria and suicidal items; it will be referred to as Internalizing Factor. Two items, being physically cruel to animals (Conduct Disorder 5) and Self Harm did not load on any factor. An exploratory factor analysis of 2,508 offspring records using Mplus (results not shown), ignoring the correlated structure of the data, resulted in the same three factor structure with similar factor loadings (results are available upon request). The factor correlation are found in table 2. Each factor showed high internal consistency (alpha factor 1 = .90, alpha factor 2 = .87, alpha = .91). Factor scores for each offspring were calculated by summing the items which loaded on each factor. A square root transformation was then completed on each factor to help control for the skew in the variables.

Table 1.

Factor Structure and Loadings for Offspring Psychopathology Items

	Factors				Factors		
Item	1	2	3	Item	1	2	3
Oppositional Defiant 1		.57		Cigarette Use	.62		
Oppositional Defiant 2		.50		Regular Cigarette Use	.65		
Oppositional Defiant 3		.51		Alcohol Use	.71		
Oppositional Defiant 4		.67		Regular Alcohol Use	.99		
Oppositional Defiant 5		.34		Drunkenness	.91		
Oppositional Defiant 6		.67		Regular Binging	.81		
Oppositional Defiant 7		.54		Regular Drunkenness	.70		
Oppositional Defiant 8		.54		Consistent Drinking	.61		
Attention 1		.69		Alcohol Abuse 1	.56		
Attention 2		.73		Alcohol Abuse 2	.67		
Attention 3		.72		Alcohol Abuse 3	.52	.40	
Attention 4		.74		Alcohol Abuse 4	.61		
Attention 5		.68		Alcohol Dependence 1	.66		
Attention 6		.68		Alcohol Dependence 2	.60		
Attention 7		.63		Alcohol Dependence 3	.65		
Attention 8		.76		Alcohol Dependence 4	.61		
Attention 9		.72		Alcohol Dependence 5	.66		
Hyperactivity 1		.47		Alcohol Dependence 6	.53		
Hyperactivity 2		.88		Alcohol Dependence 7	.69		
Hyperactivity 3		.82		Arrested Drunk Driving	.60		
Hyperactivity 4		.85		Drug Use	.91		
Hyperactivity 5		.58		Used More Drugs Wanted	.80		
Hyperactivity 6		.72		Drugs - Tolerance	.79		
Hyperactivity 7		.54		Drugs - Danger Activities	.83		
Hyperactivity 8		.76		Drugs - Interfere w/ Work	.83		
Hyperactivity 9		.66		Drugs - Emotional Probs	.86		
Conduct Disorder 1		.50		Wanted to Reduce Drugs	.76		
Conduct Disorder 2		.57		Depression 1			.98
Conduct Disorder 3		.37		Depression 2			.98
Conduct Disorder 4		.44		Depression 3			.82
Conduct Disorder 5	-	-	-	Depression 4			.97
Conduct Disorder 6		.46		Depression 5			.79
Conduct Disorder 8		.49		Depression 6			.97
Conduct Disorder 9	.41	.43		Depression 7			.88
Conduct Disorder 10	.50	.36		Depression 8			.90
Conduct Disorder 11		.47		Depression 9			.80
Conduct Disorder 12	.53			Suicidal Ideation			.66
Conduct Disorder 13	.35			Suicidal Plan			.60
Conduct Disorder 14	.39			Attempted Suicide			.56
Conduct Disorder 15	.35			Self Harm	-	-	-

Table 2.

Interfactor Correlations for Offspring Psychopathology Factors

	1	2	3
1. Alcohol and Drug	1.00		
2. Externalizing	.49	1.00	
3. Internalizing	.41	.39	1.00

APPENDIX B – ALGEBRAIC APPROACH TO COT DESIGN

A series of HLM were utilized to test differences among effect sizes from different family designs. The models use the general notation utilized by Raudenbush and Bryk (2002), but some of the subscripts have been changed so to make them more applicable for the children of twins design. Overall, two general types of hierarchical models can be used. The first, the unconditional model, separates the variance of the outcome into components at each of the three levels. The conditional model uses predictor variables at any of the levels, as well as estimating the residual variances at the three levels.

Unconditional model

Let Y_{int} be the outcome for the i'th child, in the n'th nuclear family, in the t'th twin family. The unconditional model includes one fixed effect, the grand mean ($?_{000}$), and three random effects, including the variance due to the twin-family level ($t_{ß}^{2}$), the nuclear-family level (t_{p}^{2}), and the individual level (s^{2}).

Conditional model

In the first level of the conditional model (p) is the number of individual characteristics that predict Y_{int} and (p_{pnt}) is the regression weight associated with each predictor variable (a_{pnt}) at level 1. Examples of level one variables are the offspring's age and gender. These are fixed effects in the model.

$$Y_{int} = p_{0nt} + p_{1nt}(a_{1nt})...p_{pnt}(a_{pnt}) + e_{int}$$

Each regression weight in the first level can be the outcome of a model at the second level. In order to include nuclear-family predictors into the equation as fixed effects the variables are included in a model for the intercept in the first level (p_{0nt}). For simplicity, only random effects which 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 (ß$_{0qt}$) where (q) is the number of nuclear-family variables (?$_{0qt}$). An example of nuclear-family predictors is parental psychopathology because all of the children in a nuclear family share the characteristic.

$$p_{0nt} = b_{00t} + b_{01t}(x_{01t})....b_{0qt}(x_{0qt}) + r_{0nt}$$

Finally, variables in the third level (w_{st}) can predict the nuclear-family intercept 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.

$$b_{00t} = l_{000} + l_{001}(w_{1t})....b_{00s}(w_{st}) + u_{00t}$$

Hierarchical Linear Models Utilized in the Study

Model 1 fit an unconditional model (see above) to the data in order to determine how the overall variance of the outcome is separated into the individual, nuclear-family, and the overall twin-family level. Model 2 included the nuclear-family level variable of parental divorce (pa_div) and estimated the variance components at the three levels. The model will also include individual-level variables which will control for characteristics of each offspring; these include the age, age^2, and gender of the offspring.

$$(2) Y_{int} = g_{000} + b_{01t}(pa\_div_{nt}) + p_{1nt}(age_{int}) + p_{2nt}(age^2_{int}) + p_{3nt}(gender_{int}) + u_{oot} + r_{ont} + e_{int}$$

The third model separated the association between divorce and offspring outcome into between and within-family estimates. The average of the divorces in the two twin families (0, 0.5, or 1) was included as a variable (tfamdiv) in the twin-family level because it is a characteristic which all cousins within a twin-family share. The parameter associated with the variable tfamdiv is actually an average of the within and between family estimate (see Turkheimer, D'Onofrio, Waldron, Mendle, Lynch, & Emery, in preparation for an algebraic estimate). The deviation of each twin's divorce status from the twin-family level divorce variable (tfamdiv) will be included as a second-level variable (nfamdiv). The variable is zero for twin families where either both or neither of the twins are divorced. In discordant twins, the nfamdiv variable will be -.5 for the children those parents were never divorced and .5 for the children whose parents had been divorced. The parameter associated with nfamdiv is an exact estimate of the within-family effect of divorce.

$$(3) Y_{int} = g_{000} + g_{001}(tfamdiv_{t}) + b_{02t}(nfamdiv_{nt}) + p_{1nt}(age_{int}) + p_{2nt}(age^{2}_{int}) + p_{3nt}(gender_{int}) + u_{oot} + r_{ont} + e_{int}$$

Model four estimated the within-family estimates separately for MZ and DZ families. In order to estimate two regression weights, the within-family estimate from equation 3 (ß$_{01t}$) is separated into a main effect (?$_{010}$) and the interaction between the within-family effect and twin type (?$_{011}$). The twin type variable is 0 for MZ twins and 1 for DZ twins, so (?$_{001}$) is the within family effect in MZ twins and (?$_{010}$) is the difference between MZ and DZ twins. The main effect of twin type has also been added (?$_{002}$) to the overall equation.

$$(4) Y_{int} = g_{000} + g_{001}(tfamdiv_{t}) + g_{002}(ttype_{t}) + g_{010}(nfamdiv_{nt}) + g_{011}(nfamdiv_{nt})(ttype_{t}) + p_{1nt}(age_{int}) + p_{2nt}(age^{2}_{int}) + p_{3nt}(gender_{int}) + u_{oot} + r_{ont} + e_{int}$$

Finally, model 5 included measures of adult psychopathology. The measures include the adult twin's history of conduct disorder (pa_cond), alcohol dependence (pa_alcdep), alcohol abuse (pa_alcabu), depression (pa_dep), drug use (pa_drug), suicidality (pa_suic).

$$(5) Y_{int} = g_{000} + g_{001}(tfamdiv_t) + g_{002}(ttype_t) + g_{010}(nfamdiv_{nt}) + g_{011}(nfamdiv_{nt})(ttype_t) + b_{03t}(pa\_cond_{nt}) + b_{04t}(pa\_alcdep_{nt}) + b_{05t}(pa\_alcabu_{nt}) + b_{06t}(pa\_dep_{nt}) + b_{07t}(pa\_drug_{nt}) + b_{08t}(pa\_suic_{nt}) + p_{1nt}(age_{int}) + p_{2nt}(age^2_{int}) + p_{3nt}(gender_{int}) + u_{oot} + r_{ont} + e_{int}$$

APPENDIX C –AUSTRALIAN ANALYSES WITH SPOUSAL CONTROLS

Introduction

The Children of Twins (CoT) Design 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 a methodological control for environmental risk factors associated with divorce that vary within twin families (e.g. an environmental risk factor that influences only one of the adult twins and their offspring). Furthermore, the design does not account for the genetic and environmental influence of the spouses of the twins. Therefore, measures characteristics of the twins and their spouses can be included into the analysis to account for these limitations (Rutter, Pickles, Murray, & Eaves, 2001; see Jacobs et al., 2003 for an example).

The CoT analyses of the consequence of parental divorce in Australia presented in the text (Chapters II and IV) only included measures of the adult twins in the initial analyses because of the complexity of the models. Therefore, the current analyses explored whether the genetic and environmental influences of the spouses would alter the results.

Methods

Samples

The twins and their spouses were assessed via telephone beginning in 1992 with a semi-structured diagnostic interview (86% response rate, Heath, et al., 1997). The twin study is referred to as the SSAGA study (N = 5,889 individual twins), and the spouse study was named the SSAGA-Spouse study (N=3,844).

Measures

Adult Twins and Their Spouses

The twins and their spouses completed the Semi-Structured Assessment for the Genetics of Alcoholism (SSAGA; Bucholz et al., 1994). The SSAGA, based on previously validated research interviews, has demonstrated moderate to high reliability (Bucholz et al., 1994), especially in Australia (e.g., Slutske et al., 1998). The number of lifetime symptoms of DSM-III-R diagnoses for *conduct disorder, alcohol abuse, and major depression* were calculated for the twins and their spouses. The lifetime history of cigarette smoking and illegal drug use was also included. The individual's history of suicidality was calculated based on 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).

The twins and their spouses reported the dates of birth of all of their children. Based on the information, each parent's age at the birth of their first child was calculated. Church attendance was based on a 5 point Likert Scale ranging from never to more than once a week. The adults also reported their highest level of education on a seven-point Likert scale; A) less than 7 years' schooling, B) 8-10 years' schooling, C) 11-12 years' schooling, D) apprenticeship, diploma, etc., E) technical or teachers' college, F) university first degree, and G) university post-graduate training.

Spousal information was only included in the analyses if they were the biological parent of all of the offspring in the current study. The twin and spousal information was converted 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 Adjustment

Psychopathology.

If the initial analyses supported a quasi-causal association with a measure of offspring adjustment, the variables were included in the current manuscript. The offspring also completed a version of the SSAGA, which included DSM-IV criteria for conduct, oppositional, attention-deficit hyperactivity, alcohol abuse, alcohol dependence, and depression, in addition to measures of suicidality, and alcohol and drug use. A factor analysis of the measures resulted in a three factor solution (see Appendix A). The first factor, referred to as Alcoho l and Drug Factor, includes all of the cigarette, alcohol use, alcohol abuse, alcohol dependence, drug use, and problems associated with drug use. Items from the Conduct Disorder criteria, including deliberately destroying property, broking into a house, stealing nontrivial items, and serious violations of rules (including staying despite parental prohibitions, running away from home twice, and truancy) also loaded on the factor. The second factor will be referred to as Externalizing Factor and includes retrospective reports of oppositional defiant behaviors, attention problems, hyperactivity, conduct disorder items (excluding serious violations of rules), and report of recurrent legal problems due to alcohol use. The third factor includes the depressive episode criteria and suicidal items; it will be referred to as Internalizing Factor.

Life Course Patterns.

The SSAGA included assessments of educational attainment, age of first consensual sexual intercourse, age of first intoxication, and age of first depressed mood (a period of two weeks in which the individual was depressed or lost interest in pleasurable activities for most of the time).

Analyses

Four Hierarchical Linear Models were fit with each of the offspring measures. The first model included the fixed effect of parental divorce, offspring gender, age of offspring, and age of offspring squared, in addition to the random effects to account for the three level nature of the data. As a result, the model provided a phenotypic estimate of the association between parental divorce and offspring adjustment (i.e. using unrelated comparisons). Model two includes the same parameters but also includes measures of maternal and paternal psychopathology and demographic information. The variables included educational level, church attendance, age at birth of first child, history of cigarette smoking, conduct disorder, alcohol abuse, depression, lifetime history of illegal drug use, and suicidality for each parent.

Because some of the information on both parents is incomplete, the analyses were conducted on 10 multiply imputed datasets (for reviews see Little & Rubin, 1987; Rubin, 1987; Schafer, 1997). Multiple imputation estimates values of the missing data points, assuming the data is missing at random. After the data has been imputed (m) times, the analyses are calculated on each of the (m) datasets and the parameter estimates are summarized based on the (m) analyses. As a result, the estimates of the parameters and the standard errors using MI reflect the uncertainty of the data due to the missing values. The percentage of missing data for the parental variables is presented in Table 1.

Model three estimated an approximation of the between family estimate of divorce, the within MZ family estimate, and the difference between the DZ and the MZ

(DZ-MZ) within family estimates (see text for more details). Finally, model four included the parameters in model three and includes the statistical controls for the parental variables. Again, the analyses were conducted on 10 multiply imputed datasets to account for the incomplete data.

Results

Psychopathology

For alcohol and drug problems, model one indicated a strong association with parental divorce (b=.28, SE=.05, p<.0001). Model two found that the relation remained robust when characteristics from both parents were included in the model (b=.18, SE=.05, p<.0001). The between family (b=.25, SE=.07, p<.005) and within MZ family estimate of divorce (b=.26, SE=.10, p<.01) were similar in model three. The difference between the within MZ and DZ estimates was in the opposite direction from what would be expected from a genetic transmission model (b=-.12, SE=.14, p=.40). A similar pattern, although with slightly lower estimates, was found in model four for the between (b=.12, SE=.07, p=.07), within MZ family (b=.19, SE=.10, p=.05), and the difference between the within MZ and DZ estimates (b=-.15, SE=.14, p=.27).

Parental divorce was also strongly associated with offspring externalizing problems in model one (b=.26, SE=.05, p<.0001) and two (b=.19, SE=.05, p<.0001). The results for model three suggest that the between family estimate (b=.31, SE=.07, p<.0001) is slightly larger than the within MZ family estimate (b=.17, SE=.09, p=.06), with little difference between the MZ and DZ within family estimates (b=.04, SE=.13, p=.75). Including measures of parental characteristics in model three reduced the between family estimate of divorce (b=.18, SE=.07, p=.01), but the within MZ family estimate (b=.16, SE=.10, p=.10) and the magnitude of the difference between the MZ and DZ within family estimate (b=.00, SE=.13, p=.94) remained the same.

Parental separation had a strong statistical association with internalizing problems in the offspring in model one (b=.27, SE=.04, p<.0001). The magnitude was reduced in model two (b=.17, SE=.05, p<.005) but still robust. Model three indicated that the between (b=.21, SE=.07, p<.005) and within MZ family parameters (b=.18, SE=.10, p=.06) were similar. The model suggested that the within DZ family estimate may be larger than the MZ within estimate (diff b=.13, SE=.13, p=.32). Including statistical controls for characteristics of both parents reduced the between (b=.11, SE=.07, p=.10) and within MZ estimates (b=.11, SE=.10, p=.23), but the difference in the within estimates remained approximately the same (b=.10, SE=.13, p=.48).

Figure 1 compares the results from the original analyses presented in the text (statistically controlling for characteristics of one parent) with the estimates from the CoT analyses that included statistical controls for both parents. For ease of presentation, only the original phenotypic association and the within MZ family estimates are included. The first bar, the phenotypic association, represents the first-order association with parental divorce. Next, the figure presents the comparison of unrelated offspring, while statistically controlling for characteristics of both parents. The third bar represents the difference between offspring of MZ twins discordant for divorce, without any statistical controls. The fourth bar presents the magnitude of the association in offspring of MZ twins while statistically controlling for one spouse (the twin). The final bar is the measure of parental divorce statistically in offspring of discordant MZ twins controlling for both characteristics of both parents. The figure illustrates how adding statistical and methodological controls reduces the association between parental divorce and the measures of offspring psychopathology. However, the difference between the last two bars for each outcome is minimal for the substance use and externalizing problems, indicating that statistically controlling for the second spouse does not drastically reduce the magnitude of the associations with parental divorce. For internalizing problems, the statistically controlling for both parents reduced the magnitude of the estimate, suggesting that approximately half of the phenotypic association may be due to selection factors.

Life Course Patterns

Offspring who experienced parental divorce, either before or after the age of 16, completed roughly a half year less of education (b=-.48, SE=.10, p<.0001). Controlling for characteristics in both parents reduced the magnitude of the association (b=-.34, SE=.10, p=.001), but the association was still robust. The results of model three indicated that the between (b=-.65, SE=.15, p<.0001) and within MZ family estimates were sizeable (b=-.49, SE=.18, p<.01). The difference between the within MZ and DZ estimates was in the opposite direction of what would be expected from a genetic transmission model (b=.29, SE=.26, p=.27). The parameters from model 4 were similar for the between (b=-.41, SE=.15, p=.005), within MZ (b=-.43, SE=.19, p=.02), and the DZ-MZ within estimates (b=.33, SE=.27, p=.21).

There was also a large phenotypic association between parental divorce at any age and age of first consensual sexual intercourse (b=-.94, SE=.13, p<.0001). The statistical controls for characteristics of both parents in model 2 reduced the estimate (b=-.68, SE=.14, p<.0001). The results from model three indicated that the with MZ estimate (b=-

.65, SE=.24, p<.01) was slightly smaller than the between estimate (b=-1.09, SE=.24, p<.0001). The difference between the within MZ and DZ estimates (b=-.31, SE=.35, p=.38) suggest that genetic factors may account for the association, but the statistical precision of the estimate is limited. The statistical controls in model 4 did not reduce the within MZ estimate (b=-.65, SE=.25, p<.01), but between family (b=-.65, SE=.19, p<.001) and difference between the within MZ and DZ parameters (b=-.12, SE=.35, p=.74) were reduced.

The age of first intoxication was related to parental divorce before the age of 16 (b=-.51, SE=.13, p<.0001). The magnitude of the association was slightly reduced in model 2 (b=-.42, SE=.14, p<.005). In model three the within MZ parameter (b=-.25, SE=.25, p=.31) appeared to be smaller than the between family estimate (b=-.61, SE=.16, p<.005), and the difference between the within MZ and DZ estimates was negligible (b=-.08, SE=.35, p=.81). Similar estimates were obtained in model 4: between family (b=-.47, SE=-.17, p=.005), within MZ (b=-.26, SE=.25, p=.31), and DZ-MZ within family (b=-.01, SE=.35, p=.93).

In the entire sample, age of first depression was associated with parental divorce before the age of 16 (b=-1.72, SE=.33, p<.0001). The parameter was slightly smaller in model 2 (b=-1.55, SE=.36, p<.0001). In model 3, the between family (b=-1.22, SE=.42, p<.005) appeared to be similar to the within MZ estimate (b=-1.48, SE=.63, p=.02). The difference in the within family estimates (b=-.80, SE=.89, p=.37) suggested the possibility that genetic factors may partially confound the association. The parameters in model four are similar to the estimates in the previous model: between family (b=1.04, SE=.45, p=.02), within MZ (b=-1.28, SE=.65, p=.04), and DZ-MZ within (b=-.74, SE=.90, p=.41).

Figure 2 compares the estimates of parental divorce for life course pattern outcomes. The results for years of education indicate that statistical and methodological controls did not greatly reduce the estimate of the influence of parental divorce. The use of MZ twins discordant for divorce reduced the overall association with age of first intercourse, but the within MZ estimate (even with statistical controls) was still sizeable. The use of CoT Design indicates that the influence of parental divorce before the age of 16 may only be half of the original estimate for age of first intoxication. However, the CoT Design suggests that parental divorce before the age of 16 has a substantial relation with age of first depression. Overall, the comparison of the last two bars suggests that statistically controlling for both parents does not alter the conclusions drawn in the original analyses.

Discussion

The current analyses explored whether adding statistical controls for measured characteristics of both spouses would influence the results of the CoT analyses of the association between parental divorce and offspring adjustment. The current analyses only included offspring characteristics that appeared to be causally associated with parental divorce (e.g. offspring cohabitation was excluded). Overall, the results suggest that adding statistical controls for both parents, as compared to only controlling for one parent’s characteristics, did not dramatically alter the original conclusions for most of the offspring characteristics. However, the estimate for internalizing problems was substantially reduced. The results are consistent with the overall divorce literature illustrating that parental divorce has a larger effect on offspring externalizing problems than internalizing problems (e.g. Emery, 1999).

The current analyses represent some of the most advanced techniques for controlling for selection factors for the association between parental divorce and offspring adjustment. Whereas previous studies only statistically control for one parent's psychopathology (e.g. Capaldi & Patterson, 1991; Emery, Waldron, Kitzmann, & Aaron, 1999; Simons & Associates, 1996), both parents' history of conduct disorder, alcohol abuse, depression, drug use, suicidality, educational attainment, church attendance, and age at first child were included here. Furthermore, the use of the CoT Design also controls for genetic risk factors associated with divorce from the twin parent. Therefore, the findings provide the strongest support to date for the causal theory of the influences of parental divorce, especially for offspring substance abuse, externalizing problems, educational attainment, earlier onset of sexual intercourse, and earlier experience of depressed mood. Counter to what some researchers have suggested (e.g. Harris, 1998a), parental divorce appears to have long-term consequences for offspring.

Table 1.

Percentage of Missing Data for Parental Measures

Variables	Mothers	Fathers
Education	8.34	23.56
Church Attendance	8.03	23.40
Age first child	8.27	23.40
Cigarette Smoking	8.19	23.95
Conduct Disorder	5.38	15.60
Alcohol Abuse	8.03	23.25
Depression	5.30	15.45
Drug Use	8.03	23.25
Suicidality	5.30	15.45

Figure 1.

Comparison among Parental Divorce – Offspring Psychopathology Estimates Using Different Methodological and Statistical Controls

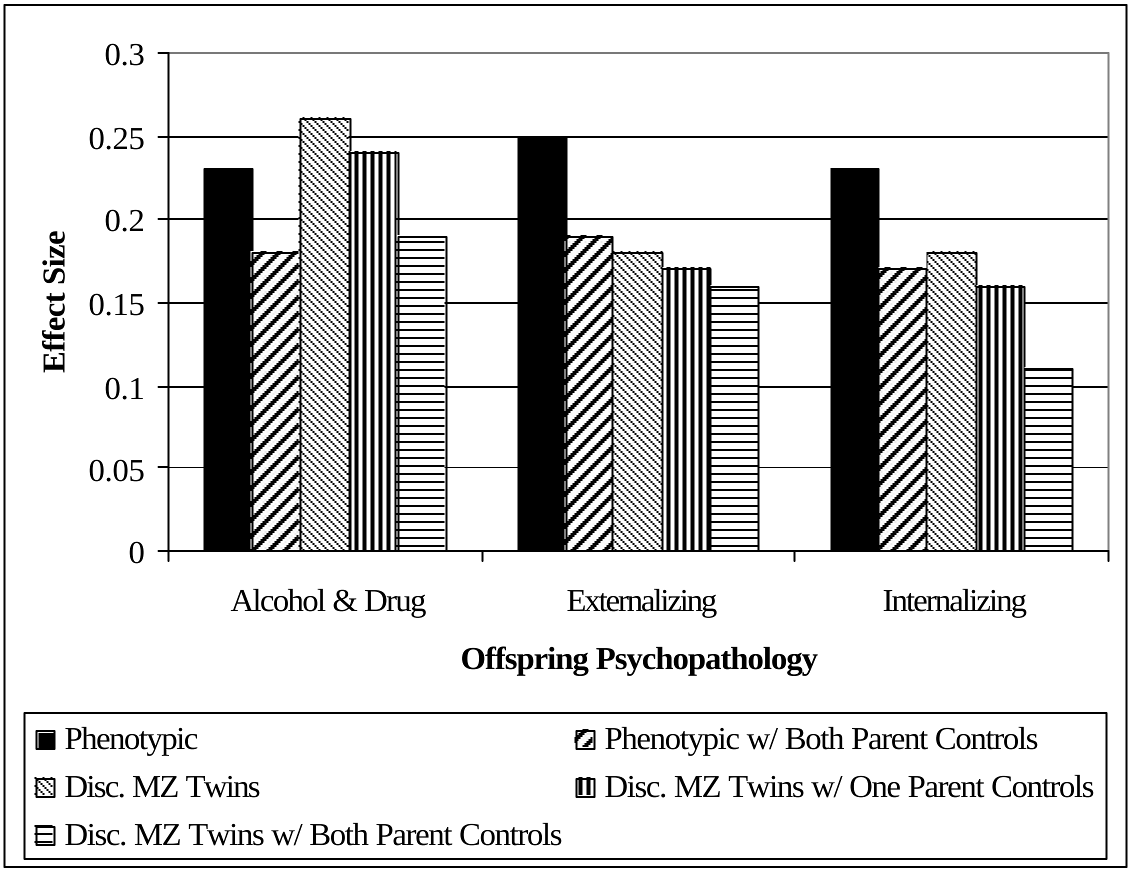
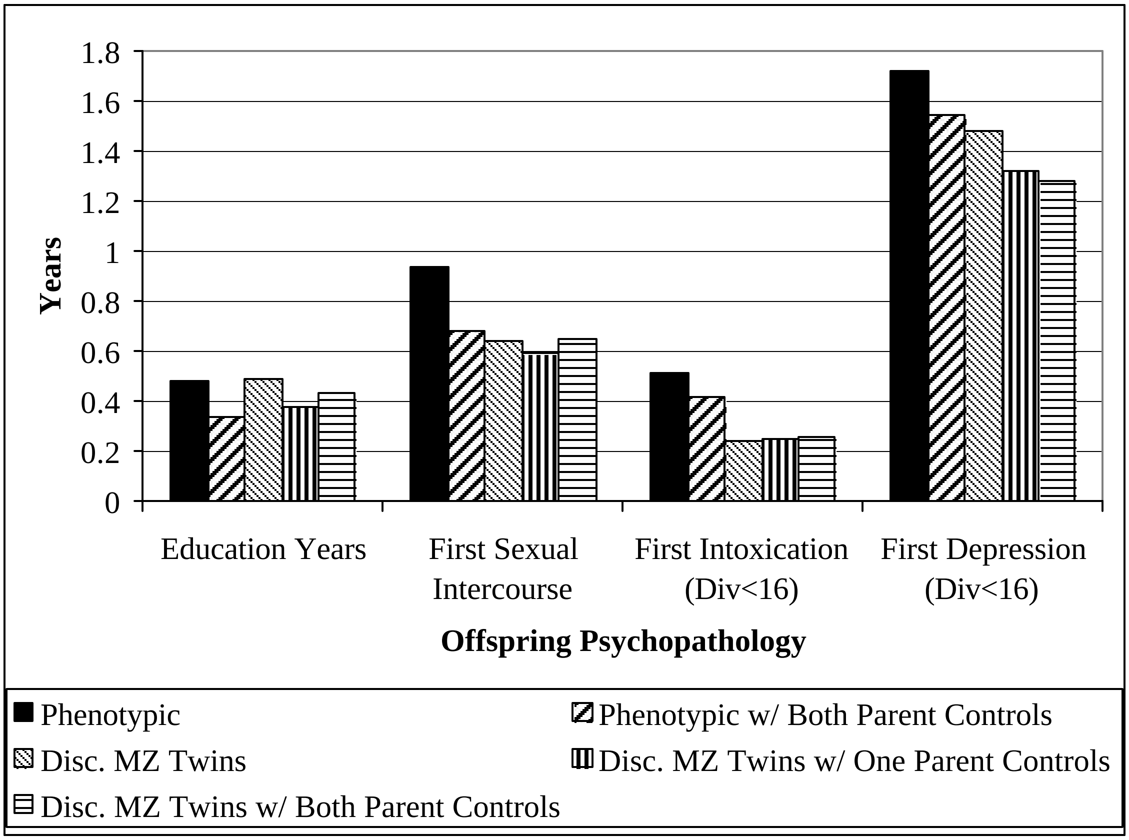


Figure 2.

Comparison among Parental Divorce – Offspring Life Course Pattern Estimates Using Different Methodological and Statistical Controls



APPENDIX D –AUSTRALIAN LIFE COURSE ANALYSES DOCUMENTATION

Comparison of offspring with missing data to those included in the analyses

The offspring with incomplete data did not differ from those included in the analyses with respect to years of education [t(2551)=-.76, p=.45], repeating a grade [?^{2}(1)=.06, p=.81], age of first intercourse [t(2166)=-.07, p=.95], cohabitation [?^{2}(1)=1.09, p=.30], baby before the age of 20 [?^{2}(1)=.68, p=.41], first use of alcohol [t(2500)=.90, p=.37], first intoxication [t(2199)=.79, p=.43], age first smoked cigarette [t(1922)=-1.20, p=.23], marijuana use [?^{2}(1)=.11, p=.74], age first marijuana use [t(1679)==1.43, p=.15], depressed mood [?^{2}(1)=.76, p=.38], or suicidal ideation [?^{2}(1)=.66, p=.40].

Within Family Comparisons

There were nine families with 25 offspring in which some offspring experienced a separation (n=15) and others did not (n=10). For the continuously distributed variables, a comparison within families revealed trends similar to the ANCOVA analyses above for years of education [b=-1.27, SE=.98, p=.22, n=25], age at first intercourse [b=-2.21, SE=1.39, p=.15, n=21], age of first cigarette use [b=-1.65, SE=2.03, p=.45, n=17]. The trends were not supported for age of first alcohol use [b=.12, SE=.84, p=.89, n=24], age of first intoxication [b=.85, SE=1.60, p=.89, n=22], age of first marijuana use [b=.32, SE=1.81, p=.86, n=15], and age of first depression [b=2.93, SE=5.01, p=.58, n=10]. However, the small sample sizes preclude any definitive conclusion. Because of the small sample sizes and empty cells, no comparisons could be made for any of the dichotomous outcome variables.

The entire sample included 32 nuclear families (89 offspring) where some of the offspring experienced a separation before the age of 16 (n=41) and some after (n=48). The trends (before 16 versus after 16) in the comparison were consistent with the ANCOVA analyses for education years [b=.36, SE=.38, p=.35, n=89], age of first intercourse [b=-.39, SE=.40, p=.34, n=81], age started drinking [b=-.48, SE=.46, p=.30, n=85], age of first intoxication [b=-.10, SE=.56, p=.86, n=75], age of first smoking [b=-.95, SE=.63, p=.14, n=73], and age of first suicidal ideation [b=-1.07, SE=1.65, p=.56, n=25]. The direction of the comparison was not consistent with the ANCOVA results for age of initial marijuana use [b=.09, SE=.76, p=.90, n=63] and age of first depression [b=.10, SE=1.32, p=.94, n=46], but the small samples prohibit accurate estimation. Due to the low prevalence of the dichotomous outcomes, again, no parameters could be accurately estimated for the comparisons within families.

Avuncular Divorce	Variable	Parental Separation		
		None	Before 16	After 16
DZ Twins				
No	Failed Grade	8.67	11.18	13.16
	Cohabitation	4.20	10.53	13.16
	Baby before 20	1.16	1.32	5.26
	Marijuana Use	61.85	71.71	78.95
	Depressed Mood	51.59	61.59	57.89
	Suicidal Ideation	26.73	32.45	47.37
Yes	Failed Grade	7.84	11.43	6.90
	Cohabitation	3.14	2.86	13.79
	Baby before 20	.78	4.29	3.45
	Marijuana Use	65.88	74.29	72.41
	Depressed Mood	48.24	62.86	48.28
	Suicidal Ideation	29.41	41.43	37.93
MZ Twins				
No	Failed Grade	8.40	14.29	12.96
	Cohabitation	3.72	6.21	11.11
	Baby before 20	1.38	2.48	5.56
	Marijuana Use	64.00	73.13	66.67
	Depressed Mood	45.45	60.00	53.70
	Suicidal Ideation	25.66	35.85	24.07
Yes	Failed Grade	10.59	12.68	9.09
	Cohabitation	5.49	9.86	4.55
	Baby before 20	0	1.41	0
	Marijuana Use	64.41	82.86	95.45
	Depressed Mood	49.15	59.42	54.55
	Suicidal Ideation	28.39	33.33	31.82

Avuncular Divorce	Variable	Parental Separation		
		None	Before 16	After 16
DZ Twins				
No	Years of Education	13.58	13.15	13.18
	Age first Intercourse	17.83	16.49	16.97
	Age first Alcohol	15.33	14.71	14.76
	Age first Intoxication	16.57	16.24	15.77
	Age first Cigarette	14.71	14.07	14.48
	Age first Marijuana	17.72	16.71	17.56
	Age first Depression	18.76	16.53	20.36
Yes	Years of Education	13.43	13.00	14.41
	Age first Intercourse	17.60	15.95	17.75
	Age first Alcohol	15.16	14.60	14.82
	Age first Intoxication	16.51	15.48	16.82
	Age first Cigarette	14.52	13.71	15.31
	Age first Marijuana	17.44	16.36	17.47
	Age first Depression	18.96	15.25	21.50
MZ Twins				
No	Years of Education	13.61	13.08	13.11
	Age first Intercourse	17.52	16.87	17.09
	Age first Alcohol	15.28	15.04	16.16
	Age first Intoxication	16.69	16.40	17.22
	Age first Cigarette	14.74	14.46	14.28
	Age first Marijuana	17.54	17.10	18.16
	Age first Depression	19.31	18.90	20.72
Yes	Years of Education	13.56	13.07	13.54
	Age first Intercourse	17.60	16.76	17.09
	Age first Alcohol	15.27	14.75	15.04
	Age first Intoxication	16.63	15.79	16.72
	Age first Cigarette	14.72	14.05	14.71
	Age first Marijuana	17.13	16.65	17.95
	Age first Depression	21.24	18.51	21.50

Parameter Estimates from HLM Analyses of Life Course Transitions

	Education Years[a]				Failed Grade[b]				Age 1st Intercourse[a]				Cohabited[b]			
Parameters	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Divorce																
Phenotypic<16	**-.48**	**-.31**			**.39**	**.29**			**-1.01**	**-.83**			**.65**	**.40**		
Within MZ <16			-.32	-.26			.26	.21			-.39	-.53			-.16	-.15
DZ-MZ <16			.31	.37			.10	.01			-.42	-.07			1.09	.98
Phenotypic>16	**-.45**	**-.34**			.10	.01			**-.68**	**-.56**			**.90**	**.70**		
Within MZ >16			-.26	-.17							-.44	-.16			.55	.31
DZ-MZ <16			-.03	-.03							.10	-.20			.17	.19
Gender	**-.20**	**-.20**	**-.20**	**-.20**	**.55**	**.55**	**.54**	**.55**	-.10	-.12	-.10	-.12	-.07	-.07	-.06	-.05
Age	**1.13**	**1.17**	**1.13**	**1.17**	-	-	-	-	**.53**	**.54**	**.53**	**.53**	-	-	-	-
Age2	**-.02**	**-.02**	**-02**	**-.02**	-	-	-	-	**-.01**	**-.01**	**-.01**	**-.01**	-	-	-	-
Parent																
Age 1st child		**.06**		**.05**		-.01		-.01		**.06**		**.06**		**-.06**		**-.06**
Education		**.23**		**.23**		**-.10**		**-.10**		**.09**		**.09**		-.07		-.08
CD		.06		-.06		-.03		-.03		**-.12**		**-.12**		.06		.06
Alcohol Abuse		-.03		-.03		-.02		-.02		-.05		-.05		.04		.04
Alcohol Dep.		.02		.02		.09		.09		.05		.05		-.19		-.19
Depression		-.02		-.02		.02		.02		.03		.03		**.05**		**.05**
Cigarette Use		-.13		-.13		.11		.11		**-.61**		**-.61**		**.44**		**.45**
Drug Use		.10		.09		.04		.04		.21		.20		-.48		-.51
Suicidality		.01		.01		.01		.01		**-.14**		**-.14**		.03		.01
Sample Size	2506	2506	2506	2506	2499	2499	2499	2499	2131	2131	2131	2131	2499	2499	2499	2499

Note. [a] Parameters are in years. [b] Parameters are logits. The dichotomous outcomes are based on variable exposure to risk based on the age (-) of the offspring. See text for standard errors for divorce parameters. The intercept, variance components, and approximation of the between-family divorce effects are not presented in the table.

	Age of 1st Drink[a]				Age 1st Intoxication[a]				Age 1st Cigarette[a]				Marijuana Use[b]			
Parameters	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Divorce																
Phenotypic<16	**-.41**	**-.34**			**-.50**	**-.41**			**-.63**	**-.57**			**.18**	**.18**		
Within MZ <16			-.12	-.13			-.24	-.25			-.32	-.33			**.16**	**.18**
DZ-MZ <16			-.33	-.24			-.10	.00			-.12	-.06			-.07	-.11
Phenotypic>16	-.11	-.06			-.23	-.16			-.11	-.07			.06	.06		
Within MZ >16																
DZ-MZ <16																
Gender	**-.46**	**-.47**	**.45**	**-.47**	**-.34**	**-.35**	**-.34**	**-.35**	**-.46**	**-.49**	**-.45**	**-.48**	**.15**	**.15**	**.15**	**.15**
Age	**.17**	**.16**	**.18**	**.16**	**.30**	**.30**	**.31**	**.30**	**.40**	**.39**	**.40**	**.39**	**-**	**-**	**-**	**-**
Age2	.00	.00	.00	.00	**-.01**	**.01**	**-.01**	**-.01**	**-.01**	**-.01**	**-.01**	**-.01**	**-**	**-**	**-**	**-**
Parent																
Age 1st child		.01		.01		**.03**		**.03**		.03		.02		.00		.00
Education		-.05		-.05		-.06		-.05		**.10**		.10		.03		**.03**
CD		-.08		-.08		-.04		-.04		-.10		-.10		**.03**		**.03**
Alcohol Abuse		.12		.12		.04		.04		.02		.02		**.08**		**.08**
Alcohol Dep.		-.08		-.08		-.07		-.06		.03		.04		.03		.03
Depression		.00		.00		.00		.00		.02		.02		-.01		-.01
Cigarette Use		**-.39**		**-.39**		**-.27**		**-.26**		**-.33**		-.33		**.10**		**.10**
Drug Use		-.23		-.23		-.02		-.03		-.14		-.16		-.01		.00
Suicidality		-.02		-.02		-.03		-.03		-.01		-.02		**.03**		**.03**
Sample Size	2457	2457	2457	2457	2159	2159	2159	2159	1885	1885	1885	1885	2497	2497	2497	2497

Note. [a] Parameters are in years. [b] Parameters are logits. The dichotomous outcomes are based on variable exposure to risk based on the age (-) of the offspring. See text for standard errors for divorce parameters. The intercept, variance components, and approximation of the between-family divorce effects are not presented in the table.

Parameters	Age 1^{st} Marijuana Use [a]				Depressed Mood[b]				Age 1^{st} Depression[a]				Suicidal Ideation[b]			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Divorce																
Phenotypic<16	**-.70**	**-.52**			**.24**	**.22**			**-1.77**	**-1.57**			**.29**	**.18**		
Within MZ <16			-.02	-.02			**.23**	**.22**			**-1.52**	**-1.32**			.26	.25
DZ-MZ <16			-.66	-.43			.02	-.03			-.78	-.72			-.16	-.17
Phenotypic>16	-.05	-.01			.02	.00			-.10	.13			.14	.08		
Within MZ >16																
DZ-MZ <16																
Gender	**-.32**	**-.34**	**-.32**	**-.34**	**-.20**	**-.20**	**-.20**	**-.20**	-.39	-.44	-.34	-.39	-.04	-.03	-.04	-.03
Age	**.70**	**.68**	**.70**	**.69**	-	-	-	-	**.55**	**.55**	**.53**	**.53**	-	-	-	-
Age2	**-.01**	**-.01**	**-.01**	**-.01**	-	-	-	-	.00	.00	.00	.00	-	-	-	-
Parent																
Age 1^{st} child		.01		.01		.00		.00		-.01		-.01		**-.02**		-.02
Education		.01		.01		.05		.05		-.12		-.12		**.09**		**.09**
CD		**-.17**		**-.17**		.00		.00		**-.27**		**-.28**		.04		.05
Alcohol Abuse		.05		.05		.04		-.04		**.77**		**.76**		-.03		-.03
Alcohol Dep.		-.02		-.02		-.05		.04		**-.39**		**-.38**		.04		.04
Depression		.00		.00		**.02**		**.02**		**-.11**		**-.11**		**.04**		**.04**
Cigarette Use		**-.43**		**-.41**		.01		.01		.35		-.33		.01		.01
Drug Use		-.30		-.33		.10		.10		.12		-.14		.10		.10
Suicidality		-.13		-.12		.00		.00		.02		.02		.02		.02
Sample Size	1651	1651	1651	1651	2494	2494	2494	2494	1276	1276	1276	1276	2494	2494	2494	2494

Note. [a] Parameters are in years. [b] Parameters are logits. The dichotomous outcomes are based on variable exposure to risk based on the age (-) of the offspring. See text for standard errors for divorce parameters. The intercept, variance components, and approximation of the between-family divorce effects are not presented in the table.