

Sex Differences in the Heritability of Resilience

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We examine the heritability of psychological resilience among US adults aged 25 to 74 years. Using monozygotic and same sex dizygotic twin pairs from the National Survey of Mid-Life Development in the United States (MIDUS) we show that positive affect is equally heritable among men ($h^2 = .60$) and women ($h^2 = .59$). We then estimate the heritability of positive affect after controlling for an exhaustive list of social and interpersonal stressors, and we operationalize the residual for positive affect as resilience. According to this specification, the heritability of resilience is higher among men ($h^2 = .52$) compared to women ($h^2 = .38$). We show that self-acceptance is one of the most important aspects of psychological functioning that accounts for the heritability of resilience among both men and women. However, compared to women, men appear to derive additional benefits from environmental mastery that may enable otherwise sex-neutral resilient tendencies to manifest.

Two individuals who have experienced comparable events throughout most of their lives may respond very differently to the same stressful life event such as a divorce, loss of a job, or the death of a loved one. Those who successfully navigate these adversities and report little to no adverse mental health consequences are often characterized as resilient. Resiliency is understood as a general, rather than domain specific, orientation (Rutter, 2003), 'implying a relative resistance to environmental risk experiences, or the overcoming of stress or adversity' (Rutter, 2006, p. 1).

Previous research has identified several sources of resiliency with a particular emphasis on psychological, material, and social resources available to individuals (Cicchetti & Rogosch, 1997). However, more recent findings suggest that genetic factors are also important for understanding individual differences in resilience (Rutter, 2003; Silberg et al., 2001). For example, Caspi et al. (2003) show a strong association between the number of stressful life events that adults have experienced and their subsequent risk of major depression. However, among those individuals with two long alleles of a gene responsible for serotonin transmission (5-HTT) there is no clear

association between chronic exposure to stressful life events and poor mental health. That is, individuals who are homozygous for this allele are particularly resilient to stressors that may otherwise lead to a major depressive episode.

Few have examined the possibility that the genetic effects on resilience may be different for men and women. This is particularly relevant to the study of gene-environment interactions because sex may constrain the genetic expression of resiliency among women, and it may enable this potential among men (Shanahan & Hofer, 2005). In their review of gene-environment interaction studies, Shanahan and Hofer (2005) argue that environments can 'control phenotypes despite genetic propensities to the contrary' but they can also 'help actualize genetic potential' (Shanahan & Hofer, 2005, p. 70). Within the gene-environment interaction literature, the 'environment' is defined as narrowly as nutritional intake (Allen & Farell, 1996) and as broadly as birth cohorts (Kendler et al., 2000). And despite the fact men and women are socialized differently, engage in different roles in life, and have differential access to social and material resources, sex is not typically considered as an 'environmental' moderator within behavioral genetic research (for exceptions see Walters, 2002). Because of the distinct environments in which men and women (on average) are socialized, we argue that biological sex, as a proxy for these different environments, enables genetically oriented resilience among men and restricts these same genetic tendencies among women. This understanding may explain why others have demonstrated that the heritability of depression as a function of prior stressors is roughly 30% among girls, but nonevident among adolescent boys (Silberg et al. 1999). Similar results are also reported in a recent study by Kendler and colleagues (2006) who, using data on over 15,000 adult twin pairs, calculate significantly different heritability

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estimates for major depression among men ($h^2 = .29$) and women ($h^2 = .42$).

Aspects of psychological functioning that are thought to underpin ability to effectively cope are often implicated in research of resiliency to childhood adversity, and sex differences have been noted. Women have been shown to have lower self-confidence, lower self-esteem, and lower self-efficacy compared to men (Costa et al., 2001; Feingold, 1994; Kling et al., 1999; Lynn & Martin, 1997). Pearlin and Schooler (1978) evaluated the efficacy of different psychological resources and active coping responses in mediating four role-based stressors. They find that men are equipped with more psychological resources (e.g., self-esteem and mastery) than women, concluding that in addition to other unmeasured factors, socialization better equips men with effective psychological resources, buffering them from the otherwise deleterious impact of stressors on wellbeing.

Interestingly, although previous work demonstrates significant sex differences in psychological wellbeing, there is less evidence that these factors are differentially heritable. Kessler et al. (2004) assess six aspects of psychological wellbeing including autonomy, mastery, personal growth, positive social relations, purpose in life, and self-acceptance. These authors demonstrate a sizable heritable component for each of these factors, ranging from .11 to .43, and there is very little evidence that these factors are differentially heritable for men and women.¹ The differential availability of these resources as a consequence of gendered experience, may translate to other important aspects of mental health. That is, if there is a latent orientation toward resilience that has genetic underpinnings, then access to psychological resources, especially those related to sense of mastery, agency, and worth, may provide the requisite foundation to enable resilience (Shanahan & Hofer, 2005). Thus, sex may indirectly affect the structure of the genetic etiology of general resilience through the provision of these gendered social psychological resources.

In this article we examine the possibility that resilience is a heritable trait among adults, and we look for evidence of resilience above and beyond other indicators of psychological wellbeing. Further, most resilience research has focused on resiliency to childhood stressors and has devoted scant attention to resiliency to environmental stressors during adulthood. We build on this literature by including life-stressors that are more germane to adult populations, including problematic work environments or troubled relationships with spouses or children, and we examine the possibility that resilience is highly heritable among men, but only weakly among women.

Methods

This study makes use of data from the National Survey of Midlife Development in the United States (MIDUS), 1995–1996 (Brim et al., 1996). MIDUS is a

nationally representative survey designed to study the effects of midlife development on the self-reported physical health, psychological wellbeing, and social consciousness of adults aged 25 to 75. Data in the survey were collected through the use of a telephone interview and a questionnaire mailed to nearly 7000 respondents. The MIDUS Twin Screening Project was used to identify 998 adult twin pairs to participate in the study. After a screening of roughly 50,000 households via a telephone interview, MIDUS interviewers contacted the respondent who was then asked to contact their twin to participate in the study.

Of the 998 pairs, we used data from same sex pairs with a determined zygosity. There were 367 pairs of monozygotic (MZ), and 352 pairs of dizygotic (DZ) twins included in the MIDUS study. We dropped 263 pairs of opposite sex DZ twins and 16 pairs of undetermined zygosity. Because of the possibility of population stratification, we further dropped non-white pairs ($n = 45$) and pairs with missing race data ($n = 44$), leaving 630 white pairs.² We use only twin pairs where both twins are not missing on the positive affect measures, and impute missing values of covariates for 78 pairs (a maximum of two imputations per person), using the impute command in STATA 9 (StataCorps, 2005). In total our sample includes 527 twin pairs [male: MZ ($n = 129$), DZ ($n = 104$); female MZ ($n = 155$), DZ ($n = 139$)].

Measures

Resilience

We operationalize resilience as a positive affect despite chronic exposure to stressful life events. We use a positive affect scale (Mroczek & Kolarz, 1998) created by averaging responses from six items. Respondents were asked ‘During the past 30 days, how much of the time did you feel ... Cheerful? In good spirits? Extremely happy? Calm and peaceful? Satisfied? Full of life?’ Responses were coded on a scale of 1 (*All the time*) to 5 (*None of the time*); the items were then standardized and summed, such that higher scores indicate better mood (Chronbach’s alpha [α] = .91). Descriptive statistics for all variables used in the analyses are presented in Table 1.

Chronic and Acute Stressors

Role-based stress is measured with three scales gauging the strain associated with one’s spouse, children, and parents. These scales were constructed from a checklist of ten problems experienced by the respondent in each respective role. The ‘yes’ responses were summed to yield possible scale scores between 0 and 10, with higher scores indicating more strain. We used the spousal strain scale to classify married or partnered individuals into high strain and low strain categories. Those in the 70th percentile (those with two or more strains) were classified as high strain. We also coded those without a spouse or partner as either never married or widowed/divorced/separated, using a set of dummy variables to model spousal strain and

Table 1
Descriptive Statistics for all Variables Used in the Analyses

	Male	Female	Male	Female
	MZ	DZ	MZ	DZ
Positive Affect	0.02 (.97)	0.10 (.94)	-0.01 (1.02)	-0.08 (1.05)
Demographic controls				
High school or less	29.28	39.08	39.18	45.05
Age	45.24 (11.29)	44.98 (11.7)	42.51 (11.68)	45.04 (11.62)
Spousal relationship				
Never married	8.11	5.75	6.72	8.11
No longer married	8.11	5.17	11.19	11.26
Low spouse strain	69.37	70.69	61.57	59.01
High spouse strain	14.41	18.39	20.52	21.62
Psychological functioning				
Positive relationships	15.80 (4.14)	15.73 (4.09)	17.28 (3.75)	16.93 (4.03)
Self-acceptance	16.99 (3.47)	17.34 (3.05)	16.99 (3.68)	16.55 (3.41)
Autonomy	16.32 (3.23)	16.33 (3.1)	16.26 (3.47)	16.32 (3.46)
Personal Growth	17.89 (2.93)	17.93 (2.74)	18.43 (3.05)	17.98 (2.80)
Environmental mastery	16.49 (3.55)	16.90 (2.89)	16.14 (3.6)	16.30 (3.49)
Purpose in Life	16.99 (3.48)	16.94 (3.30)	17.06 (3.29)	16.80 (3.36)
Measures of stress and strain				
Children strain	0.93 (1.54)	0.73 (1.18)	1.11 (1.70)	1.16 (1.73)
Child status				
Has kids	80.63	83.91	83.58	82.43
Parent strain	0.64 (1.09)	0.63 (1.04)	1.08 (1.57)	0.88 (1.36)
Job strain	0.00 (.49)	-0.02 (.54)	0.04 (.46)	0.08 (.48)
Job support	-0.05 (.65)	-0.09 (.63)	0.06 (.60)	0.05 (.62)
Not employed	6.31	10.92	25.75	22.97
Friend/family strain	1.96 (.49)	1.92 (.44)	2.04 (.46)	2.01 (.46)
Friend/family support	2.76 (.55)	2.81 (.48)	2.99 (.44)	2.94 (.49)
Financial strain	-0.29 (.68)	-0.03 (.78)	-0.13 (.83)	-0.03 (.86)
Negative health status	-0.27 (.53)	-0.17 (.68)	-0.19 (.64)	-0.08 (.74)
Neighborhood quality	3.53 (.47)	3.56 (.43)	3.39 (.53)	3.39 (.56)
Childhood SES	-0.02 (.68)	0.07 (.81)	0.01 (.71)	-0.15 (.72)

Note: Cell entries represent means and standard deviations (in parentheses) for continuous variables and percents for nominal responses. All data come from the twin sample of the National Survey of Midlife Development in the United States (MIDUS), 1995–1996 (Brim et al. 1996). A total of 527 twin pairs are used in these analyses (MZm(129); MZf(155); DZm(104); DZf(139)).

marriage status. The child strain scale is treated as continuous, giving those without children a score of zero. We included a dummy variable for whether or not respondents have children, to allow for the possibility that having children can be beneficial to wellbeing. Parental strain is treated as continuous; those without parents were given a zero on the scale. Respondents with a spouse, child, or parent, but missing all ten items for the respective scale, were given a missing value on the scale. Reliability coefficients are not reported for these scales, as the items do not reflect an underlying construct; rather, they are believed to represent the cumulative effects of independent stressors. Scale questions, response sets, and reliability coefficients, when appropriate, appear in Appendix A.

In addition to role-based stressors, we included measures of work-related strain (Bosma & Marmot, 1997; Karasek et al., 1981; Karasek & Theorell, 1990; Schwartz et al., 1988). The job strain measure assesses the skill discretion, work demands, and the authority one has over decisions; the job support measure reflects the support one receives from coworkers and supervisors. Those unemployed or out of the labor force are given a zero on the standardized scales, and a dummy variable was included to indicate whether or not the respondent was employed. We included measures of strain from family and friends (Schuster et al., 1990; Whalen & Lachman, 2000), financial strain, poor health status, perceived neighborhood quality (Keyes, 1998), childhood SES, and two demographic characteristics: age and education, which were dummy coded as high school diploma or less, and some college or more. To better capture the impact of stressful life events, chronic stressors, and acute stressors, we also include measures for social support including perceived support from friends, and support from their place of employment.

Psychological Functioning

The literature on life events, stress, and wellbeing indicates that genetically oriented vulnerability may operate through endophenotypic characteristics such as self-esteem or sense of mastery (Kessler et al., 1992; Kendler et al., 1998; McGuffin et al., 1996; Tennant, 2002). Support for this perspective is evident in the fact that personality traits such as extraversion and neuroticism are consistently associated with happiness, positive affect, and subjective well-being (Costa, et al., 1980; DeNeve & Cooper, 1998; Emmons & Diener, 1985; Hills & Argyle, 2001; Pavot et al., 1990). Accordingly, we define psychological functioning as traits that describe cognitive or behavioral dispositions to see oneself in a particular way. We posit that these resources condition one's response to stressors, and may partially explain resilience to stressors. We use the following six measures of positive psychological functioning: (a) positive relations with others ($\alpha = .58$); (b) self-acceptance ($\alpha = .59$); (c) autonomy ($\alpha = .48$); (d) personal growth ($\alpha = .55$); (e)

environmental mastery ($\alpha = .52$); and (f) purpose in life ($\alpha = .36$; Ryff, 1989; Ryff & Keyes, 1995).

Statistical Analysis

We use a DeFries-Fulker (DF) regression technique to estimate the relative contribution of genetic factors to the demonstration of resilience (DeFries & Fulker, 1985). The estimates from this model are used to calculate the proportion of variance for a particular trait due to (1) genetic characteristics (broad sense heritability); (2) shared environment; and (3) unshared environment. In this model the value for the first twin of pair j (y_{1j}) is modeled as a function of their co-twin's score on that same attribute (y_{2j}), a measure of zygosity (g_j) coded .5 for MZ twins and 0 for DZ twins, and an interaction between their sibling's score and their zygosity ($g_j y_{2j}$).³ The estimate for b_3 is operationalized as the proportion of phenotypic variance due to genetic factors (broad sense heritability). This estimate simply describes the degree of resemblance among twins as a function of their zygosity. Because the original DF model was designed around a proband design, we use a double-entry structure and standard errors are adjusted accordingly.

$$y_{1j} = b_0 + b_1 y_{2j} + b_2 g_j + b_3 g_j y_{2j} + e_j \quad (1)$$

This model is particularly useful for our purposes because it allows for control variables in addition to the three covariates included in model 1. Because we are interested in the heritability of resilience, we model salutary affect, but also include an exhaustive list of chronic and lifetime stressors and social and demographic characteristics that are known correlates of positive affect. We operationalize the residual variance in positive mood — that is, after adjusting for life stressors — as resilience. Therefore, whereas the estimate for b_3 in equation 1 describes the heritability of positive affect, the same estimate in equation 2 — after controls for k stress-related or protective factors — denotes the heritability of resilience.

$$y_{1j} = b_0 + b_1 y_{2j} + b_2 g_j + b_3 g_j y_{2j} + \sum_k b_k x_{1kj} + e_j \quad (2)$$

The heritability of resilience can be further decomposed as a function of factors that are theoretically linked to resilience. As described above, there are established aspects of psychological functioning that may bear on an individual's resilience. Therefore, we estimate one final set of models in which we include an array of controls for psychological functioning. As with the transition from equation 1 to equation 2, we are primarily concerned with changes in the heritability estimate with the inclusion of these variables. Because we hypothesize differential effects by sex, we estimate separate models for men and women.

The logic of quantitative genetic twin analysis assumes that MZ and DZ twins experience similar shared environments. Violations of this assumption, resulting from MZ twins being treated more similarly (equal environments assumption), or from MZ twins attempting to differentiate themselves more than DZ

twins (twin differentiation assumption), can increase or decrease concordance among twins as a function of zygosity, respectively. Violations of these assumptions can yield inaccurate heritability estimates. Others have found violations of the equal environment assumption, but not the twin differentiation assumption, using the same data (Kessler et al., 2004). To adjust for these concerns, we included statistical controls for three questions about the similarity of respondents' childhood experiences; these questions assess how often twins were dressed alike, placed in the same classrooms, and had the same playmates.

Results

DeFries-Fulker regression estimates are presented in Table 2. According to these estimates (Models 1 and 3), positive affect is highly heritable, and there are no observable differences in this estimate for men ($h^2 = .60$) and women ($h^2 = .59$). Models 2 and 4 include controls for sociodemographic characteristics, social support mechanisms, and an exhaustive list of role strains and social stressors. These controls significantly improved model fit for both men and women ($r^2_{\text{men}} = .32$; $r^2_{\text{women}} = .39$). Support derived from friends and family is strongly associated with positive affect and negative health status — one of the most important stress factors in the current literature (Ensel & Lin, 1991), and deleterious for both men and women. We operationalize resilience as the change in the heritability estimate for positive affect with the inclusion of these controls. That is, those who report high positive affect above and beyond this list of stressors and life strains are operationalized as resilient. Importantly, the heritability estimate for women decreases ($h^2 = .38$), whereas the same estimate for men only reduces slightly ($h^2 = .52$).⁴ Thus, we find evidence that resilience is a heritable characteristic, but more so among men compared to women.⁵

As discussed above, we expect the heritability of resilience to be moderated by psychosocial factors that facilitate adjustment to psychological stressors, and we further anticipate the mediating role of psychological functioning to be different for men and women. The estimates presented in Tables 3 and 4 present a series of DF models in which controls for psychological functioning are included individually and we pay particular attention to changes in the heritability estimate. The first entry (model 1) of Table 3 is identical to model 2 of Table 2, but we only present the quantitative genetic estimates to focus on the heritability estimate. Model 2 of Table 3 includes a control for positive relations with others. Among men, this control reduced the heritability estimate from .51 to .48, corresponding to a 6% reduction in the estimate. The full array of covariates reduced the heritability estimate for resilience for men to 27%, and the effect was no longer statistically significant. Table 4 presents the same analysis among women, and tests of the mediator effects of psychological resources are summarized in Table 5. Among men,

Table 2

DeFries-Fulker Regression Estimates Among Same Sex MZ and DZ Twin Pairs: The Heritability of Resilience By Sex

	Men		Women	
	Model 1	Model 2	Model 3	Model 4
Twin 2 score (T2)	0.08 (0.09)	0.04 (0.08)	0.18+ (0.10)	0.07 (0.08)
Genetic association (G)	-0.24 (0.16)	-0.30+ (0.16)	-0.06 (0.13)	0.01 (0.14)
T2 * G (H2)	0.60* (0.23)	0.52* (0.21)	0.59* (0.24)	0.38* (0.19)
High spouse strain		-0.19 (0.11)		-0.35** (0.10)
Children strain		-0.05 (0.03)		-0.04+ (0.02)
Has a child		0.29* (0.15)		0.01 (0.13)
Parent strain		0.00 (0.04)		-0.06* (0.02)
Job strain		-0.04 (0.08)		-0.19* (0.08)
Job support		0.13+ (0.07)		0.16* (0.08)
Friend/family strain		-0.27** (0.09)		-0.07 (0.10)
Friend/family support		0.26** (0.08)		0.37** (0.09)
Financial strain		-0.13* (0.06)		-0.09+ (0.05)
Negative health		-0.31** (0.07)		-0.30** (0.07)
Childhood SES		-0.11+ (0.06)		0.00 (0.05)
Perceived neighborhood quality		0.15+ (0.09)		0.17* (0.09)
Constant	0.40* (0.16)	-0.94 (0.69)	0.40** (0.14)	-1.80** (0.60)
R-squared	0.10	0.32	0.16	0.39

Note: ** $p < .01$, * $p < .05$, + $p < .10$. Cell entries represent unstandardized regression coefficients with standard errors in parentheses. Models 2 and 4 include controls for sociodemographic characteristics (e.g., age, marital status, employment status, and education), controls for the equal environment assumption, and a dummy variable indicating if any sociodemographic covariates were imputed. All data come from the twin sample of the National Survey of Midlife Development in the United States (MIDUS), 1995–1996 (Brim et al., 1996). A total of 527 twin pairs are used in these analyses (MZm(129); MZf(155); DZm(104); DZf(139)).

the only psychological resource that significantly impacted the heritability measure was environmental mastery. Although the heritability of resilience among men remained statistically significant, this one item explained nearly 40 per cent of the effect; this mediating effect was statistically significant. Environmental Mastery consists of three questions that evaluate one's appraisal of their ability to meet external demands and responsibilities. Perhaps unsurprisingly, the ability to maintain a sense of empowerment and competency, and a positive view of oneself in the face of psychosocial stressors appears to constitute a substantial portion of

psychological resiliency for men. Further, while this reduction was only marginally significant ($p < .09$), controls for self-acceptance reduced the heritability of resilience estimate among men by 33%. Taken together, these two aspects of psychological wellbeing appear to be largely responsible for the realization of genetic tendencies to be relatively resilient.

Although the magnitude of the heritability estimate is notably smaller, similar analyses were performed for women and are presented in Table 4. As with men, the full array of psychological resources reduced the heritability estimate to nonsignificance for women ($h^2 = .04$). Most of this reduction appears to be linked with one particular psychological resource, self-acceptance. This one control reduced the heritability estimate by over 70 per cent, and rendered the heritability of resilience statistically nonsignificant. This was not the case for any of the single measures of psychological resources among men.

Discussion

The key finding of this article is that resilience, as operationalized here, is a heritable feature. More importantly, the heritability of resilience is higher among men compared to women. Including controls for psychological functioning reduced the heritability estimates for both men and women. This implies that genetic factors — mediated through more proximate measures of psychological functioning — play an important role in heritable resilience to environmental stressors. Self-acceptance appears to be an important mechanism through which resilience manifests for both men and women. While environmental mastery emerged as an important factor responsible for the heritability of resilience among men, this factor was significantly less important among women.

Though sex may capture physiological differences, such as hormonal or sex-linked genetic differences, sex also confers different, broadly defined environments for men and women. Our findings are particularly relevant to gene–environment interaction studies because they suggest that sex is an important environmental moderator of latent genetic factors that contribute to salutary mental health. This point is made clear when one considers that the two measures of psychological functioning that appear to underlie the heritability of resilience (self-acceptance and environmental mastery) are themselves highly heritable, but they are not differentially heritable for men and women. According to Kessler et al. (2004), the heritability of self-acceptance and environmental mastery are .41 and .33, respectively. When these models were modified to allow a sex-specific estimate, the inclusion of this additional parameter estimate did not improve the overall model fit. Thus, there is no evidence that either self-acceptance or environmental mastery is differentially heritable among men and women.

Table 3

DeFries-Fulker Regression Estimates Among Same-Sex MZ and DZ Male Twin Pairs: Psychological Functioning Mediators

	1	2	3	4	5	6	7	8
Twin 2 score (T2)	0.04 (0.08)	0.01 (0.08)	0.00 (0.07)	0.05 (0.07)	0.03 (0.08)	0.00 (0.07)	0.04 (0.08)	-0.00 (0.07)
Genetic association (G)	-0.30+ (0.16)	-0.29+ (0.16)	-0.16 (0.16)	-0.26 (0.16)	-0.25 (0.16)	-0.12 (0.15)	-0.30+ (0.16)	-0.11 (0.15)
T2 * G(H2)	0.51* (0.21)	0.48* (0.20)	0.34+ (0.19)	0.43* (0.19)	0.47* (0.20)	0.31+ (0.18)	0.52* (0.21)	0.27 (0.17)
Positive relations w/others		0.05** (0.01)						0.02** (0.01)
Self-acceptance			0.12** (0.01)					0.07** (0.01)
Autonomy				0.06** (0.01)				0.03* (0.01)
Personal growth					0.06** (0.02)			0.01 (0.02)
Environmental mastery						0.11** (0.01)		0.06** (0.01)
Purpose in life							-0.00 (0.01)	-0.03** (0.01)
Constant	-0.97 (0.69)	-1.38* (0.69)	-2.73** (0.67)	-1.86** (0.71)	-2.08** (0.74)	-3.12** (0.62)	-0.94 (0.70)	-3.56** (0.64)
R-squared	0.32	0.36	0.44	0.36	0.35	0.43	0.32	0.49

Note: ** $p < .01$, * $p < .05$, + $p < .10$. Cell entries represent unstandardized regression coefficients with standard errors in parentheses obtained from a series of regression models in which each psychosocial resource and measure of personality are included individually. The first entry is the same as model 2 of Table 2. These models include controls for sociodemographic characteristics (e.g., age, marital status, employment status, and education), controls for the equal environment assumption, and a dummy variable indicating if any sociodemographic covariates were imputed. All data come from the twin sample of the National Survey of Midlife Development in the United States (MIDUS), 1995–1996 (Brim et al. 1996). A total of 527 twin pairs are used in these analyses (MZm(129); MZf(155); DZm(104); DZf(139)).

This is important because it suggests that the mediating role of psychological functioning — as a determinant of sex differences in the genetic effects of resilience — is social rather than biological in origin. That is, it appears as though men are better able to ‘cash in’ on this genetically oriented resource. Accounting for this phenomenon goes beyond the scope of this paper, but it is likely that men have greater opportunity to express resilience and are more likely to be rewarded for exhibiting traditional signs of resilience. In other words, gender socialization may interact with genetic factors to either diminish resilience for women, or help men to actualize some genetic potential that confers resilience. We cannot establish which of these two possibilities may be the case. Genes only influence phenotypes within an environment; to determine whether resilience is suppressed or actualized would require us to assume that some are socialized without clear gender roles, and this is a difficult assumption to justify.

One explanation for the better prediction of a female’s positive affect may be that women are socialized to be relationship-oriented, while men are socialized to be independent. Under the ‘cost of caring’ hypothesis, women are thought to be more sensitive to the problems faced by their friends and family (Kessler & McLeod, 1984; Maciejewski et al., 2001). If this is this case, women may be less resilient

to stressors involving friends and family due to their social roles as caregivers. For example, Kendler et al., (2001) show that, compared to men, women are no more susceptible to stressful life events in general. However, they show clear differences in sensitivity to specific life events including divorce, housing problems, and relationship conflicts. Many of the strains and supports included in our models were interpersonal in nature, assessing one’s role as a spouse, parent, child, or employee; the relationship-oriented variables witnessed the most differences among men and women. Further, the relationship strains only consider problems experienced by a spouse, child, parent or interpersonal relationships among friends and family. If women are more sensitive to the problems of friends, these models may not specify these sources of stress, acting to make female twins more discordant and reducing heritability estimates for women.

A second possibility is that women use different coping strategies than men. Our analysis considers psychological functioning, but not repertoires of coping strategies. A number of studies document differences in the coping styles of men and women, with many noting a more active style among men compared to women (Pearlin & Schooler, 1978; Nolen-Hoeksema, 1987). Notably, active styles have been found to be more protective against the ill-effects of stressors (Pearlin & Schooler, 1978). Nolen-Hoeksema

Table 4
DeFries-Fulker Regression Estimates Among Same-Sex MZ and DZ Female Twin Pairs: Psychological Functioning Mediators.

	1	2	3	4	5	6	7	8
Twin 2 Score (T2)	0.07 (0.08)	0.07 (0.08)	0.09 (0.07)	0.07 (0.08)	0.07 (0.08)	0.08 (0.08)	0.08 (0.08)	0.10 (0.07)
Genetic association (G)	0.01 (0.14)	0.00 (0.14)	0.02 (0.14)	0.01 (0.14)	0.04 (0.14)	0.04 (0.13)	0.00 (0.14)	0.03 (0.13)
T2 * G (H2)	0.38* (0.19)	0.33+ (0.19)	0.11 (0.17)	0.38* (0.19)	0.30 (0.19)	0.28 (0.18)	0.37+ (0.19)	0.04 (0.16)
Positive relations w/others		0.04** (0.01)						0.01 (0.01)
Self-acceptance			0.11** (0.01)					0.09** (0.01)
Autonomy				0.03** (0.01)				-0.01 (0.01)
Personal growth					0.06** (0.01)			0.03* (0.01)
Environmental mastery						0.08** (0.01)		0.04** (0.01)
Purpose in life							-0.02 (0.01)	-0.03** (0.01)
Constant	-1.80** (0.60)	-2.25** (0.59)	-3.21** (0.59)	-2.19** (0.59)	-2.75** (0.59)	-2.66** (0.59)	-1.60** (0.60)	-3.49** (0.58)
R-squared	0.39	0.41	0.49	0.40	0.41	0.44	0.39	0.51

Note: ** $p < .01$, * $p < .05$, + $p < .10$. Cell entries represent unstandardized regression coefficients with standard errors in parentheses obtained from a series of regression models in which each psychosocial resource and measure of personality are included individually. The first entry is the same as model 4 of Table 2. Models include controls for sociodemographic characteristics (e.g., age, marital status, employment status, and education), the equal environment assumption, and a dummy variable indicating if any sociodemographic covariates were imputed. All data come from the twin sample of the National Survey of Midlife Development in the United States (MIDUS), 1995–1996 (Brim et al. 1996). A total of 527 twin pairs are used in these analyses (MZm(129); MZf(155); DZm(104); DZf(139)).

Table 5
Summary of Psychological Functioning Mediators by Sex

	Men				Women			
	$b_2 - b_1$	$s_{b_2 - b_1}$	p <	%	$b_2 - b_1$	$s_{b_2 - b_1}$	p <	%
Positive relationships	-0.03	0.15	n.s.	6	-0.05	0.1	n.s.	14
Self-acceptance	-0.17	0.13	0.09	33	-0.27	0.08	0.00	72
Autonomy	-0.08	0.14	n.s.	16	0.00	0.11	n.s.	0
Personal growth	-0.04	0.15	n.s.	9	-0.08	0.1	n.s.	22
Environmental mastery	-0.20	0.12	0.05	39	-0.10	0.09	n.s.	26
Purpose in life	0.00	0.16	n.s.	0	-0.01	0.11	n.s.	2

Note: Cell entries summarize Tables 3 and 4. Standard errors are calculated using second-order Taylor series and exact variance estimating procedures (Goodman 1960). The column labeled ‘%’ describes the percent reduction in the heritability of resilience estimate presented in models 2 and 4 of Table 2. All data come from the twin sample of the National Survey of Midlife Development in the United States (MIDUS), 1995–1996 (Brim et al., 1996). A total of 527 twin pairs are used in these analyses (MZm(129); MZf(155); DZm(104); DZf(139)).

(1987) proposes that women are more likely than men to ruminate over problems, whereas men typically distract themselves physically or instrumentally. Importantly, ruminative coping styles have been shown to lengthen depressive episodes (Kuehner & Weber, 1999; Nolen-Hoeksema, 1991). Nolen-Hoeksema et al. (1999) also propose that women experience more chronic strains, often have a weaker sense of mastery than men, and tend to ruminate over problems. As rumination has been shown to mediate the effect of

chronic strains and mastery on depression, women are subsequently more vulnerable because of these different coping strategies. The finding that the sex difference in depression is mediated by a more dysfunctional repertoire of coping styles among women has been replicated (Hanninen & Aro, 1996). Twin analyses have demonstrated sex differences in the heritability and shared environmental impact of coping strategies (Kato & Pedersen, 2004). Thus, one explanation for the sex difference in heritability of resilience

while controlling for psychological functioning is the possibility that women experience normative pressure to cope with stressors in a maladaptive manner.

There are important limitations that should be considered when interpreting these results. First, although we adjust for the nonlinear association with age, there is a wide range of ages in the study. This is important because of differential genetic effects across the life course (Vaupel et al., 1998) but also because of clear cohort differences in genetic associations (Carey et al., 1992). For example, Kendler et al. (2000) estimate the heritability of tobacco use by comparing regular tobacco use among twin pairs raised together and those raised apart across the following three cohorts: 1910–1924, 1925–1939, or 1940–1958. They present a consistent estimate for men across birth cohorts ($h^2 \sim .55$), but they show that the estimate for women increases over time; the heritability for the first cohort was zero, but increased to 21%, and peaked at 64% in the third cohort. Thus, by the third cohort, there were no sex differences in the heritability of regular tobacco use. The authors argue that the social restrictions on women's tobacco use have relaxed significantly across these three cohorts, which made it possible for genetic tendencies for tobacco use to manifest. With respect to our study, we are not able to differentiate between age, period, or cohort effects, and our results should be considered generalizable to this adult population only. Second, our focus is on the parameter estimate for heritability, and we do not explore sex differences in environmental factors in further detail. For example, shared environmental influences are indicated by the coefficients for the twin's score (t_2) in the models of Table 3. There appears to be a shared environmental effect for women, but not men. This shared environment may reflect the degree to which female twins grow up in traditional versus non-traditional households. Again, given that the sample ranges in age from 25 to 74, the significant coefficient for shared environment in model 6 is noteworthy.

Despite these limitations, this paper makes an important contribution because we position biological sex as an environmental moderator. This perspective is important because behavioral genetic studies often report sex differences in heritability, linkage, or associations, but do not anticipate these differences with a priori hypotheses about the presence or direction of these differences. Given the long standing work in the social sciences regarding the role of sex in terms of identity, structure, and agency (Collins, 2000), in conjunction with consistent differences in heritability for men and women across a wide range of different outcomes (Read et al., 2006), efforts should be made to develop a testable and generalizable theory regarding the role of sex in behavioral genetic studies among humans.

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Endnotes

- 1 The genetic contribution is only moderately different for men and women for two of these six factors; personal growth ($h^2_{\text{women}} = .43$; $h^2_{\text{men}} = .33$) and purpose in life ($h^2_{\text{women}} = .39$; $h^2_{\text{men}} = .19$) are both shown to be significantly higher among women compared to men.
- 2 We imputed race for 115 individuals by using the twin's identified race. We further set 13 pairs to missing because the twins were discordant on reported race. The following pairs were dropped: Missing (44), Black (36), Native American (4), Other (5).
- 3 It is common to use zygosity values of 1 for MZ pairs and .5 for DZ pairs because MZ pairs share 100 percent and, on average, DZ pairs share 50 percent of their genes. However, the use of 0 for DZ makes the interpretation of the intercept more meaningful as it pertains to DZ pairs rather than pairs who share 0 percent of their genes.
- 4 While the reduction in the heritability estimate is not statistically significant among men, this same reduction was significant among women ($p < .10$, one-tail).
- 5 We also use a bivariate Cholesky decomposition model to the data to demonstrate whether comparable results are demonstrated using a variance components model as with the DF analyses. The results of these analyses are presented in the appendix and confirm the finding that the heritability of resilience is stronger among men compared to women.

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Appendix A
Description of Scales Used as Predictors in the Resilience Models

Measure — Alpha	Question	Range
Spousal Strain		
In the past 12 months has your spouse had:		
SM21A_1	A chronic disease or disability	Yes / No
SM21B_1	A frequent minor illness	Yes / No
SM21C_1	Emotional problems	Yes / No
SM21D_1	Alcohol or substance abuse problems	Yes / No
SM21E_1	Financial problems	Yes / No
SM21F_1	Problems at work or school	Yes / No
SM21G_1	A problem finding or keeping a job	Yes / No
SM21H_1	Marital or partner relationship problems	Yes / No
SM21I_1	Legal problems	Yes / No
SM21J_1	Difficulty getting along with people	Yes / No
Child strain		
In the past 12 months has any of your children had:		
SM21A_3	A chronic disease or disability	Yes / No
SM21B_3	A frequent minor illness	Yes / No
SM21C_3	Emotional problems	Yes / No
SM21D_3	Alcohol or substance abuse problems	Yes / No
SM21E_3	Financial problems	Yes / No
SM21F_3	Problems at work or school	Yes / No
SM21G_3	A problem finding or keeping a job	Yes / No
SM21H_3	Marital or partner relationship problems	Yes / No
SM21I_3	Legal problems	Yes / No
SM21J_3	Difficulty getting along with people	Yes / No
Parent Strain		
In the past 12 months have your parents or the people who raised you had:		
SM21A_2	A chronic disease or disability Yes / No	Yes / No
SM21B_2	A frequent minor illness	Yes / No
SM21C_2	Emotional problems	Yes / No
SM21D_2	Alcohol or substance abuse problems	Yes / No
SM21E_2	Financial problems	Yes / No
SM21F_2	Problems at work or school	Yes / No
SM21G_2	A problem finding or keeping a job	Yes / No
SM21H_2	Marital or partner relationship problems	Yes / No

Measure — Alpha (CONTINUED)

Item(s)	Question	Range
Parent Strain		
SM211_2	Legal problems	Yes / No
SM21J_2	Difficulty getting along with people	Yes / No
SC2C	Mother died in 1994 or 1995	Yes / No
SD4C	Father died in 1994 or 1995	Yes / No
Friend/family strain — alpha = .82		
Questions were asked of both friends and family members (excluding spouse)		
SM15/SM6	How often do [they] make too many demands on you?	1 (Often)–4 (Never)
SM16/SM7	How often do they criticize you?	1 (Often)–4 (Never)
SM17/SM8	How often do they let you down when you are counting on them? "	1 (Often)–4 (Never)
SM18/SM9	How often do they get on your nerves?	1 (Often)–4 (Never)
Friend/family support — alpha = .85		
Questions were asked of both friends and family members (excluding spouse)		
SM11/SM2	How much do [they] really care about you?	1 (A lot)–4 (Not at all)
SM12/SM3	How much do they understand the way you feel about things?	1 (A lot)–4 (Not at all)
SM13/SM4	How much can you rely on them for help if you have a serious problem?	1 (A lot)–4 (Not at all)
SM14/SM5	How much can you open up to them if you need to talk about your worries?	1 (A lot)–4 (Not at all)
Job strain — alpha = .82		
SI28B	How often do you learn new things at work?	1 (All the time)–5 (Never)
SI28C	How often does your work demand a high level of skill or expertise?	1 (All the time)–5 (Never)
SI28I	How often does your job provide you with a variety of things that interest you?	1 (All the time)–5 (Never)
SI28D	On your job, how often do you have to initiate things — such as coming up with your own ideas or figuring out on your own what needs to be done?	1 (All the time)–5 (Never)
SI28E	How often do you have a choice in deciding how you do your tasks at work?	1 (All the time)–5 (Never)
SI28F	How often do you have a choice in deciding what tasks you do at work?	1 (All the time)–5 (Never)
SI28G	How often do you have a say in decisions about your work?	1 (All the time)–5 (Never)
SI28H	How often do you have a say in planning your work environment — that is, how your workplace is arranged or how things are organized?	1 (All the time)–5 (Never)
SI29B	How often you control the amount of time you spend on tasks?	1 (All the time)–5 (Never)
SI28A	How often do you have to work very intensively — that is, you are very busy trying to get things done?	1 (All the time)–5 (Never)
SI28J	How often do different people or groups at work demand things from you that you think are hard to combine?	1 (All the time)–5 (Never)
SI29A	How often you have too many demands made on you?	1 (All the time)–5 (Never)
SI29C	How often you have enough time to get everything done?	1 (All the time)–5 (Never)
SI29D	How often you have a lot of interruption?	1 (All the time)–5 (Never)

Item(s)	Question	Range
Measure — Alpha (CONTINUED)		
Job Support — alpha = .83		
SI30A	How often do you get help and support from your coworkers?	1 (All the time)—5 (Never)
SI30C	How often do you get the information you need from your supervisor or superiors?	1 (All the time)—5 (Never)
SI30D	How often do you get help and support from your immediate supervisor?	1 (All the time)—5 (Never)
SI30E	How often is your immediate supervisor willing to listen to your work-related problems?	1 (All the time)—5 (Never)
Negative health status — alpha = .76		
BADL	Basic Activity of Daily Living — Scale based on SA17B & SA17G. (Number: Mean Response Missing)	1 (A lot)—4 (Not at all)
	How much does your health limit you in doing: Bathing or dressing yourself?	1 (A lot)—4 (Not at all)
	How much does your health limit you in doing: Walking one block	1 (A lot)—4 (Not at all)
IADL	Intermediate activity of daily living. Mean response of SA17A, SA17C, SA17D, SA17E, SA17F, SA17H, SA17I	1 (A lot)—4 (Not at all)
	How much does your health limit you in doing:	
	Lifting or carrying groceries	1 (A lot)—4 (Not at all)
	Climbing several flights of stairs	1 (A lot)—4 (Not at all)
	Bending, kneeling, or stooping	1 (A lot)—4 (Not at all)
	Walking more than a mile	1 (A lot)—4 (Not at all)
	Walking several blocks	1 (A lot)—4 (Not at all)
	Vigorous activity (e.g., running, lifting heavy objects)	1 (A lot)—4 (Not at all)
	Moderate activity (e.g., bowling, vacuuming)	1 (A lot)—4 (Not at all)
QA4	Overall rating of physical health	1 (Poor)—5 (Excellent)
CHRONIC	Number of chronic conditions reported in SA9A-SA9CC: In the past 12 months have you experienced or treated for any of the following? Asthma, bronchitis, or emphysema; ulcer; Tuberculosis; Hernia or rupture; Other lung problems; Piles or hemorrhoids; Arthritis, rheumatism, or other bone or joint diseases; Sciatica, lumbago, or recurring backache; Persistent skin trouble (e.g., eczema); thyroid disease; hayfever; recurring stomach trouble, indigestion or diarrhea; urinary or bladder problems; being constipated all or most of the time; gallbladder trouble; persistent foot trouble (e.g., bunions, ingrown toenails); trouble with varicose veins requiring medical treatment; AIDS or HIV infection; lupus or other autoimmune disorders; persistent trouble with your gums or mouth; persistent trouble with your teeth; high blood pressure or hypertension; anxiety, depression, or some other emotional disorder; alcohol or drug problems; migraine headaches; chronic sleeping problems; diabetes or high blood sugar; multiple sclerosis, epilepsy, or other neurological disorders; stroke	Yes / No
Financial strain — alpha = .83		
SJ1	How would you rate your financial situation these days?	0 (Worst)—10 (Best)
SJ6	In general, would you say you and your family living with you have more money than you need, just enough money for your needs or not enough money for your needs?	1 (More money); 2 (Just enough); 3 (Not enough)
SJ7	How difficult is it for you (and your family) to pay your monthly expenses?	1 (Very difficult)—4 (Not at all difficult)
Perceived neighborhood quality — alpha = .88		
Please indicate how much each of the following statements describe your situation.		
SL5A	'I feel safe being out alone in my neighborhood during the daytime.'	1 (A lot)—4 (Not at all)
SL5B	'I feel safe being out alone in my neighborhood at night.'	1 (A lot)—4 (Not at all)

Item(s)	Question	Range
Measure — Alpha (CONTINUED)		
Perceived neighborhood quality — alpha = .68		
SL5E	I could call on a neighbor for help if I needed it.	1 (A lot)—4 (Not at all)
SL5G	People in my neighborhood trust each other.	1 (A lot)—4 (Not at all)
Childhood SES — alpha = .79		
SE9	When you were growing up, was your family better off or worse off financially than the average family was at that time?	1 (A lot better off)—7 (A lot worse off)
M_TSEI80	Mother occupation sei	
D_TSEI80	Father occupation sei	
QC2	Father educational attainment: 1 (No school / Some grade school), 2 (8th grade/ Junior high school), 3 (Some high school), 4 (GED), 5 (Graduated from high school), 6 (1–2 years college—no degree yet), 7 (3+ years college—No degree yet), 8 (Associate/vocational degree), 9 (Bachelor degree), 10 (Some graduate school), 11 (Masters degree), 12 (PhD or other professional degrees)	1 (No school / Some grade school) 12(PhD or other professional degrees)
QC8	Mother educational attainment	1 (No school / Some grade school) 12(PhD or other professional degrees)
Positive relations with others — alpha = .58		
SF1F	'Maintaining close relationships has been difficult for me.'	1 (Strongly agree)—7 (Strongly disagree)
SF1M	'People would describe me as a giving person, willing to share my time with others.'	1 (Strongly agree)—7 (Strongly disagree)
SF1P	'I have not experienced many warm and trusting relationships with others.'	1 (Strongly agree)—7 (Strongly disagree)
Self-acceptance — alpha = .59		
SF1A	'I like most parts of my personality.'	1 (Strongly agree)—7 (Strongly disagree)
SF1B	'When I look at the story of my life, I am pleased with how things have turned out so far.'	1 (Strongly agree)—7 (Strongly disagree)
SF1E	'In many way I feel disappointed about my achievements in life.'	1 (Strongly agree)—7 (Strongly disagree)
Autonomy — alpha = .48		
SF10	'I tend to be influenced by people with strong opinions.'	1 (Strongly agree)—7 (Strongly disagree)
SF10	'I have confidence in my own opinions, even if they are different from the way most other people think.'	1 (Strongly agree)—7 (Strongly disagree)
SF1R	'I judge myself by what I think is important, not by the values of what others think is important.'	1 (Strongly agree)—7 (Strongly disagree)
Personal has growth — alpha = .55		
SF1K	'For me, life been a continuous process of learning, changing, and growth.'	1 (Strongly agree)—7 (Strongly disagree)
SF1L	'I think it is important to have new experiences that challenge how I think about myself and the world.'	1 (Strongly agree)—7 (Strongly disagree)
SF1N	'I gave up trying to make big improvements or changes in my life a long time ago.'	1 (Strongly agree)—7 (Strongly disagree)
Environmental mastery — alpha = .52		
SF1D	'The demands of everyday life often get me down.'	1 (Strongly agree)—7 (Strongly disagree)
SF1H	'In general, I feel I am in charge of the situation in which I live.'	1 (Strongly agree)—7 (Strongly disagree)
SF1I	'I am good at managing the responsibilities of daily life.'	1 (Strongly agree)—7 (Strongly disagree)
Purpose in life — alpha = .36		
SF1C	'Some people wander aimlessly through life, but I am not one of them.'	1 (Strongly agree)—7 (Strongly disagree)
SF1G	'I live life one day at a time and don't really think about the future.'	1 (Strongly agree)—7 (Strongly disagree)
SF1J	'I sometimes feel as if I've done all there is to do in life.'	1 (Strongly agree)—7 (Strongly disagree)

Appendix B

The bivariate Cholesky Decomposition model partitions the variance of both phenotypes (we use a continuous measure of strain using principle components analysis with STATA 9.0. A 1-factor solution was calculated for men and women separately ($r_{\text{men}} = .14$; $r_{\text{women}} = .16$) into that due to genetic, shared environmental, and nonshared environmental (with error) variance. Furthermore, the model enables us to decompose the covariance between the two variables into the same variance components.

Consequently, it is also possible to determine the extent to which the genetic and environmental variance of resilience is shared in common with the strain variable, and the extent to which they are unique to resilience. This is a similar analysis to that shown in the DF analysis. For instance, if the genetic influence on resilience decreases after inclusion of the risk variables, it implies that some of the genetic risk for resilience is accounted for by its association with the included variables. However, if such a reduction does not occur, we would assume that the genetic risk for resilience is not shared with the risk variables.

The fit of the full model was compared with that obtained from saturated model in which there are no constraints and all possible parameters (means, variances, and covariances) are estimated. These descriptive models fit the data perfectly, serving as a comparative model for nested models. We determine how well the full model explains the observed data by comparing minus twice the log-likelihood ($-2\ln$) fit and degrees of freedom (df) of the full model with the saturated model produces a χ^2 statistic. A low, nonsignificant χ^2 statistic indicates that the bivariate Cholesky Decomposition model explains the observed data well and does not violate the assumptions of model fitting (e.g., MZ and DZ variances do not differ significantly).

Comparison of the full bivariate ($-2\ln = 5444.984$, $df = 2086$) and the saturated model ($-2\ln = 5399.352$, $df = 2052$) resulted in a χ^2 fit of the full bivariate model of 45.632, and difference in df of 34; therefore, $p = .088$, the χ^2 is nonsignificant and our bivariate Cholesky decomposition model fits the observed data well. The resulting standardized path coefficients for males and females are presented in Figure 1 and Figure 2 respectively. Using the rules of path analysis, the contribution of each variance component to each of the 2 variables was estimated by squaring the path coefficients. For males, A_1 (the genetic variance shared in common with the strain variable) contributes 5% of the total variance of resilience, and A_2 (the genetic variance unique to resilience) contributes 27% of the total variance of resilience. Thus, of the total genetic variance for resilience (.32), 84% is unique to resilience. This is similar to the results from the DF analyses for females, in which we demonstrated that inclusion of the risk variables decreased the genetic effect on resilience, because some of the genetic risk was accounted for by the risks. Therefore, the results of fitting variance components demonstrate comparable findings to those of the DF model.

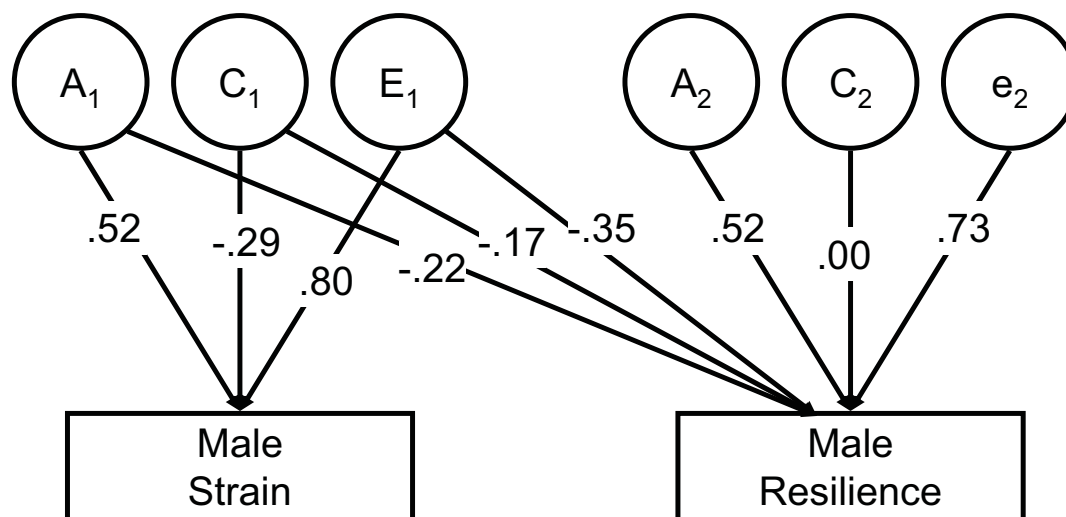
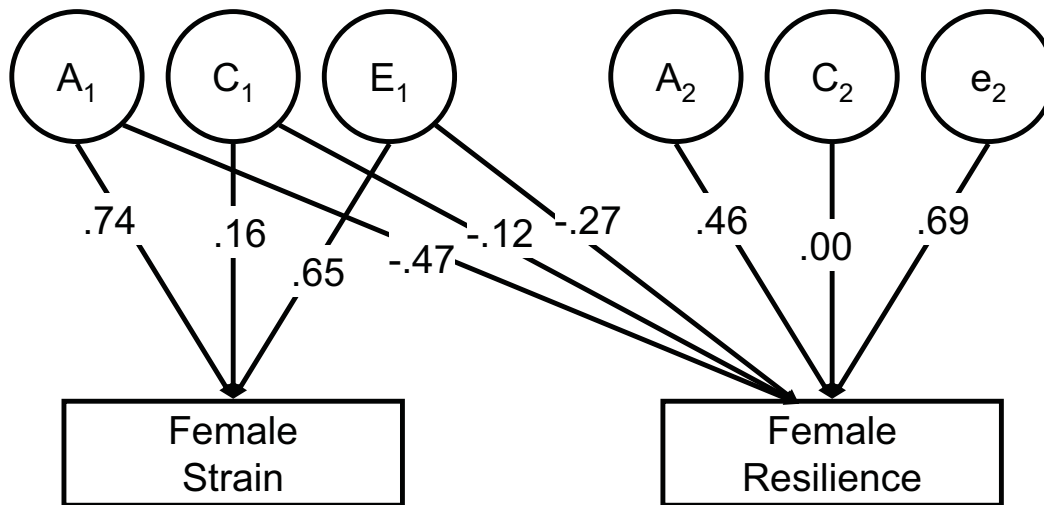


Figure 1

Male standardized path coefficients for the bivariate Cholesky Decomposition between strain and resilience.

Note: A_1 = Genetic variance common to Strain and Resilience; C_1 = Shared environment variance common to Strain and Resilience; E_1 = Non-shared environment variance common to Strain and Resilience; A_2 = Genetic variance unique to Resilience; C_2 = Shared environment variance unique to Resilience; e_2 = Non-shared environment variance unique to Resilience.

**Figure 2**

Female standardized path coefficients for the bivariate Cholesky Decomposition between strain and resilience.

Note: A_1 = Genetic variance common to Strain and Resilience; C_1 = Shared environment variance common to Strain and Resilience; E_1 = Non-shared environment variance common to Strain and Resilience; A_2 = Genetic variance unique to Resilience; C_2 = Shared environment variance unique to Resilience; E_2 = Non-shared environment variance unique to Resilience.