Published in final edited form as:

Behav Genet. 2016 January ; 46(1): 124–142. doi:10.1007/s10519-015-9767-x.

Romantic Relationship Satisfaction Moderates the Etiology of Adult Personality

Susan C. South, Ph.D.,
Purdue University

Robert F. Krueger, Ph.D.,
University of Minnesota

Irene Elkins, Ph.D.,
University of Minnesota

William G. Iacono, Ph.D., and
University of Minnesota

Matt McGue, Ph.D.
University of Minnesota

Abstract

The heritability of major normative domains of personality is well-established, with approximately half the proportion of variance attributed to genetic differences. In the current study, we examine the possibility of gene x environment interaction (GxE) for adult personality using the environmental context of intimate romantic relationship functioning. Personality and relationship satisfaction are significantly correlated phenotypically, but to date no research has examined how the genetic and environmental components of variance for personality differ as a function of romantic relationship satisfaction. Given the importance of personality for myriad outcomes from work productivity to psychopathology, it is vital to identify variables present in adulthood that may affect the etiology of personality. In the current study, quantitative models of GxE were used to determine whether the genetic and environmental influences on personality differ as a function of relationship satisfaction. We drew from a sample of now-adult twins followed longitudinally from adolescence through age 29. All participants completed the Multidimensional Personality Questionnaire (MPQ) and an abbreviated version of the Dyadic Adjustment Scale (DAS). Biometric moderation was found for eight of the eleven MPQ scales examined: Well-Being, Social Potency, Negative Emotionality, Alienation, Aggression, Constraint, Traditionalism, and Absorption. The pattern of findings differed, suggesting that the ways in which relationship quality moderates the etiology of personality may depend on the personality trait.

Keywords

personality; relationship satisfaction; biometric moderation; GxE

Correspondence concerning this article should be addressed to: Susan C. South at 703 Third Street, West Lafayette, IN 47907. ssouth@purdue.edu.

The heritability of personality is one of the most consistent findings in the behavior genetics literature. Time and again, researchers have found that the proportion of variance in most major normative personality traits due to genetic factors is approximately 40–50%, with the rest of the contribution coming primarily from nonshared environmental effects (Bouchard & Loehlin, 2001). The inability of molecular genetic findings to explain more than a small percentage of the variance in personality, however, led many to wonder what happened to this “missing heritability.” With the advent of statistical modeling techniques in the last 15 years that allow for examination of gene x environment interplay (Purcell, 2002), many are now asking whether certain environments may moderate the etiological components of personality. These quantitative Gene x Environment interaction (quantGxE) models allow for the possibility that estimates of genetic and environmental influences on personality may differ depending on a person’s level of a second, moderator variable (R. F. Krueger, South, Johnson, & Iacono, 2008). Findings from this work have implications for improving the search for personality genes and for testing theoretical models of gene-environment interplay in the development of personality. In the current paper, we examine whether romantic relationship quality moderates the genetic and environmental variance of adult personality.

Biometric Modeling of Personality Including GxE

There is a long history of using genetically informative family data to study genetic and environmental influences on personality. The univariate twin model uses personality data collected from identical (monozygotic, MZ) and fraternal (dizygotic, DZ) twins to estimate the relative magnitude of additive genetic influences (abbreviated A), common or shared environmental influences, which make family members more similar to one another (C), and unique or nonshared environmental influences (E), which make family members less similar to one another. Most biometric modeling of personality has focused on the domains and facets of the Five Factor Model (FFM; Costa & McCrae, 1992) or related traits. In a review of twin modeling of FFM higher-order personality domains, heritability ranged from .33 to .61, with shared environment consistently estimated at zero (Bouchard & Loehlin, 2001). Estimates for lower-order domains are similar, with heritabilities ranging from approximately 30–50% (Jang, McCrae, Angleitner, Riemann, & Livesley, 1998), although the heritability estimates for residual facets (with common variance of the five factors removed) is lower. Twin modeling of the Multidimensional Personality Questionnaire (MPQ; Tellegen & Waller, 2008) showed that roughly 40–50% of variance is due to genetics with the rest attributable to nonshared environment (Finkel & McGue, 1997). This is in many ways not surprising, given that the MPQ and FFM constructs fit within the same overall structure when submitted to factor analysis (e.g., Markon, Krueger, & Watson, 2005). These normative personality constructs overlap considerably with maladaptive personality traits, which have also been examined using twin modeling. For instance, the four higher-order domains of the Dimensional Assessment of Personality Pathology (Livesley & Jackson, 2001), designed to capture maladaptive aspects of personality, have been shown to have similar heritability estimates, ranging from 38 to 53% (Jang, Livesley, Vernon, & Jackson, 1996).

The consistency of these findings naturally led many researchers to search for specific molecular polymorphisms associated with personality. If genes accounted for roughly 50% of the variation in personality, then logically it followed that it should be possible to identify DNA sequences associated with personality. This endeavor has proved challenging. In the largest genome-wide association study conducted to date, the researchers examined approximately 2.4 million single nucleotide polymorphisms (SNPs) from a total sample of more than 20,000 people who completed a measure of the FFM (de Moor et al., 2012). The authors reported only two significant findings, between SNPs and conscientiousness and openness to experience, but these associations did not completely replicate across samples.

Researchers have suggested many possible reasons for the problem of "missing" heritability, that is, the failure to find any evidence of genes that account for a substantial amount of the variance in personality when we know from decades of behavior genetic research that genetic influences are strongly involved in understanding differences in personality in the population. One possibility that has gained prominence in the literature is the presence of gene x environment interaction (GxE). This type of interaction arises when genetic influences on a phenotype of interest are either "triggered" or "buffered" by a certain environment; or conversely, for an environmental influence to have an effect it is dependent on an individual having a genetic predisposition. The first published papers reporting a *measured* gene x environment interaction (mGxE) appeared in the literature more than ten years ago (Caspi et al., 2002; Caspi et al., 2003), and since that time GxE has become a popular theoretical and statistical paradigm among researchers, in particular those studying development and psychopathology (Belsky & Pluess, 2009; Moffitt, Caspi, & Rutter, 2006).

At the same time that mGxE was gaining prominence in the literature, new statistical methods for measuring quantitative gene X environment interaction (quantGxE) appeared (Purcell, 2002). These methods built on well-known twin models for biometric modeling, but added the ability to estimate genetic and environmental influences on a phenotype (P) as a function of a moderator variable (M; see Figure 1). Instead of estimating ACE influences on P that were the same for everyone in the sample, these models provided different ACE estimates at different levels of M. Heritability estimates have long been misinterpreted to mean that 50% of personality is due to genetics, instead of the more accurate interpretation that 50% of the variance in the sample-specific population is due to genetic differences between people in that population. These new models for quantGxE, however, actually made it possible to get closer and closer to individual-level heritability. In this vein, one study examined whether the genetic and environmental influences on internalizing psychopathology (a factor comprised of symptoms of depression and anxiety and the personality trait of neuroticism) would differ as a function of marital satisfaction. Applying the Purcell model in a nationwide twin sample, where the average age was 46 and average length of marriage was 23 years, the authors created a relationship satisfaction score by summing items assessing different aspects of the relationship; results indicated that heritability of internalizing is much greater among people in extremely unsatisfying marriages (−2 standard deviations below the average for the sample) than it is for people in extremely satisfying marriage (+2 standard deviations above the mean; S.C. South & Krueger, 2008). Of note, the same study found that the shared environmental effects on internalizing increased from low (3%) to high (61%) levels of marital satisfaction. A sometimes underappreciated aspect of quantGxE modeling is that it shows how the influence of the shared and nonshared environment changes as a function of the moderator. Significant and substantial estimates of the shared environment are notoriously difficult to find in adult biometric modeling of adult twin data (Turkheimer, 2000), and one possibility is that the shared environment may play a greater role in extreme environments.

To date, there has been very little work examining quantGxE for personality (Burt, 2008). Most studies so far have focused on either temperament traits in childhood (Lemery-Chalfant, Kao, Swann, & Goldsmith, 2013) or personality traits in adolescent and young adult twins (Boomsma, de Geus, van Baal, & Koopmans, 1999). For instance, in one of the largest studies to date, Krueger and colleagues (2008) examined quantGxE for the personality domains of negative emotionality, positive emotionality, and constraint (from the MPQ) as a function of the amount of regard and conflict in the parent-child relationship, using a sample of adolescent twins (average age of 17) from the Minnesota Twin Family Study. For negative emotionality and positive emotionality, there was evidence that the parent-child relationship moderated the variance components of personality; the genetic variance in positive emotionality, for instance, increased from low to high levels of parental regard. The few studies that have utilized adult twin samples have focused on moderators related to the family of origin, including parental bonding, traumatic events experienced by age 16, or family environment (Jang, Dick, Wolf, Livesley, & Paris, 2005) and overall family dysfunction (Kendler, Aggen, Jacobson, & Neale, 2003). To our knowledge, no studies have examined quantGxE for adult personality traits as a function of moderators measured in adulthood. Potential biometric moderators of the genetic and environmental variance in personality should ideally be contextual variables that are most relevant to an adult's characteristic pattern of thinking, feeling, and behavior.

Personality and Relationship Satisfaction

The search for quantGxE in adult personality has to date lagged behind other phenotypes (e.g., psychopathology). This is surprising, given certain known factors about personality development. We know that there is substantial evidence of significant GxE for various forms of psychopathology (Dick, 2011; Young-Wolff, Enoch, & Prescott, 2011), which are highly correlated with personality (S.C. South, Eaton, & Krueger, 2010). We also know that personality changes over time in adulthood (Roberts & DelVecchio, 2000), and this change is most likely due to continuous transactions between the person and the environment (Hutteman, Hennecke, Orth, Reitz, & Specht, 2014). Behavior genetic methods have been used to examine personality development over time, in which case it is possible to have completely different influences on personality stability and personality change. From these investigations, we know that 1) there is a strong genetic foundation for personality stability, 2) there are increasing nonshared environmental influences on personality across the lifespan, and 3) genetic and environmental contributions to personality *change* may vary by trait (Bleidorn, Kandler, & Caspi, 2014). Thus, while genetic influences are operating on personality at all points across the lifespan, there is good evidence to suggest that there are environmental contexts unique to each twin that serve as a source of personality change in adulthood.

One likely candidate for an "environmental context" that might have an effect on the etiology of personality is the quality of an individual's intimate romantic relationship. There is strong evidence that subjective ratings of romantic relationship quality are correlated with self- and partner-reported personality traits. Individuals who report less satisfying romantic relationships (often marriages) also tend to be higher on the personality traits of neuroticism, negative affect, and negative emotionality, and lower on the traits of extraversion, agreeableness, conscientiousness, positive affect, and positive emotionality (B. M. Donnellan, Conger, & Bryant, 2004; Stroud, Durbin, Saigal, & Knobloch-Fedders, 2010; Watson, Hubbard, & Wiese, 2000). Much of the research linking personality to relationship satisfaction is cross sectional (but see Karney & Bradbury, 1997), although researchers often operate from the standpoint that the direction of effect is from personality to relationship satisfaction.

There is evidence, however, to suggest that relationship experience can affect personality. Establishing a long-term, committed romantic relationship (i.e., marriage), is a normative developmental task that requires certain experiences and skill sets that could help explain personality change during the period of early adulthood (Hutteman et al., 2014). The social investment principle suggests that attainment of age-graded roles, like marriage or a similar bond, may play a role in motivating adults toward greater maturity; individual differences in how much a person invests in these roles should logically be related to differences in personality change in adults (Roberts & Wood, 2006). For example, marriage is associated with decreases in adult antisocial behavior, and the marriage itself, not just selection processes, appears to inhibit the antisocial behavior (Burt et al., 2010). Romantic relationships may, in fact, compensate for less-than-ideal upbringings and aid in resilience to negative outcomes, like psychopathology (e.g., Collishaw et al., 2007). Research suggests that entering into a romantic relationship has an impact on one's personality. In a study using a young adult German sample (mean age at baseline=24.4 years, range 18–30) followed over eight years, the authors found that entry into a first romantic relationship led to decreases in neuroticism and shyness and increases in extraversion, self-esteem, and conscientiousness (Neyer & Lehnart, 2007).

Above and beyond the benefits of entering into a committed romantic relationship, the quality of that relationship seems to have a lasting influence on personality. Robins and colleagues (2002) found that personality traits measured at age 18 and age 26 predicted relationship experiences (i.e., quality, conflict, abuse) at age 26 and changes in relationship experiences from age 21 to 26; further, they found that relationship experiences at age 21 predicted personality change from 18 to 26. For instance, there was a positive correlation between conflict and abuse at age 21 and an increase in negative emotionality from 18 to 26.

Finally, there is longitudinal evidence suggesting that a distressed romantic relationship in adulthood can increase the likelihood of subsequent psychopathology, such as depression and substance use (Mark A. Whisman & Uebelacker, 2009; M. A. Whisman, Uebelacker, & Bruce, 2006). Given the strong links between personality and psychopathology (S.C. South et al., 2010), it is reasonable to hypothesize that relationship satisfaction may moderate the etiology of personality in the same way that studies have shown it works to moderate genetic and environmental influences on psychopathology (Jarnecke & South, 2014; S.C. South &

Krueger, 2008). Indeed, GxE interaction processes would fit well within the social investment principle, providing an explanation for how individual differences in (successfully or unsuccessfully) accomplishing role transitions in young and middle adulthood can have differential impact on personality (Bleidorn, Kandler, & Caspi, 2014).

Current Study

In the current study, we examined whether relationship satisfaction moderated the genetic and environmental influences on adult personality. We build on previous phenotypic work examining the association between personality and relationship satisfaction (e.g., Malouff, Thorsteinsson, Schutte, Bhullar, & Rooke, 2010), and a small but burgeoning literature examining the genetic and environmental influences on relationship satisfaction. Intimate relationship satisfaction is similar to other measures that are frequently labeled “environmental”, including parent-child relationships, peer groups, and traumatic events (Kendler & Baker, 2007), in that it has a non-zero heritability estimate (S.C. South & Krueger, 2008; E. L. Spotts et al., 2004); further, work has shown that the genetic influences on relationship quality overlap with personality (E.L. Spotts et al., 2005). In previous research we have shown that romantic relationship quality can moderate the proportion of genetic and environmental variance contributing to adult mental (Jarnecke & South, 2014; S.C. South & Krueger, 2008) and physical (S.C. South & Krueger, 2013) health; here, we extend that work to adult normative personality.

We hypothesized that the satisfaction with one’s relationship will moderate genetic and environmental influences on normal adult personality traits. There are three possible patterns of results, each of which generally matches with a widely accepted paradigm of development. First, it is possible that genetic variance on personality will be greatest at the lowest end of relationship satisfaction. This would suggest a *diathesis-stress* model of personality, in which genetic influences are expressed in the “riskiest” environment (Monroe & Simons, 1991). Second, genetic variance could be highest at the most extremely positive end of relationship satisfaction. This would support a *bioecological* or *social push* model: in the absence of environmental risk, variance in a phenotype is influenced to a greater degree by genetic differences between people (Bronfenbrenner & Ceci, 1994; Raine, 2002). Finally, the differential susceptibility or “orchid” model would be supported if genetic variance was highest at both extremes of relationship satisfaction (Belsky & Pluess, 2009; Ellis & Boyce, 2008). The interpretation of this model is that like the notoriously picky orchid, some individuals need the precise environmental conditions to thrive.

Method

Participants and Procedure

Participants for the current study were drawn from the Minnesota Twin Family Study (MTFS; Iacono, Carlson, Taylor, Elkins, & McGue, 1999). The MTFS is a longitudinal, community-based study designed to examine the development of substance use and related psychopathology. The MTFS consists of two cohorts of twins: one initially recruited at approximately age 11 and one at age 17. To recruit twins and their families, same-sex twin births from 1971 through 1985 were located using birth records and public databases. Twins were excluded from enrolling in the study if they lived more than a day's drive from the laboratory at the University of Minnesota, if they had a cognitive or physical disability that would prevent them from completing the day-long, in person assessment, or if one member of the twin pair was no longer living. A total of 90% of twin births from the identified years were found and 83% of eligible families agreed to participate. Participating and non-participating families were not appreciably different in terms of socioeconomic status or self-reported mental health problems, although parents from families that agreed to participate had slightly more years of education than parents from families that did not participate. Consistent with the population from which the families were recruited, approximately 98% of the participants were Caucasian. Parents provided informed consent with children provided assent. All study procedures were approved by the University of Minnesota IRB.

At intake, the 11-year old cohort consisted of 756 same-sex, reared together monozygotic (MZ) and dizygotic (DZ) twin pairs: 376 male (253 MZ, 123 DZ) and 380 female (233 MZ, 147 DZ). The 17-year old cohort at intake consisted of 626 same-sex, reared together monozygotic (MZ) and dizygotic (DZ) twin pairs: 289 male (190 MZ, 99 DZ) and 337 female (226 MZ, 111 DZ). Twin participants in both cohorts were followed longitudinally approximately every three years: for the younger cohort, this meant they were assessed at target ages of 11, 14 (follow-up 1), 17 (follow-up 2), 20 (follow-up 3), 24 (follow-up 4), and 29 (follow-up 5), while assessments for the older cohort were at target ages of 17, 20 (follow-up 1), 24 (follow-up 2), and 29 (follow-up 3). Thus, there was overlapping data for both cohorts at ages 17, 20, 23, and 29.

For the current analyses, we only used data from the age 29 assessment, in order to maximize the proportion of participants who had entered into a cohabiting or marriage-like relationship. The personality inventory was administered to all participants who agreed to complete the age 29 assessment. From the total initial sample size of 2,764 (both cohorts at intake), personality data (on some if not all of the MPQ scales) was available on 2,440 participants at the age 29 assessment. The relationship satisfaction measure was administered at the age 29 assessment to twin participants who were (1) currently married, (2) living together with someone, or (3) currently dating the same person for at least 3 months. We limited our sample to those who were currently married (1,246) or cohabitating with a significant other (383), eliminating those twins who were currently only dating[1]. This left a total of 1,629 individual twins (from 1,057 twin pairs) with data on personality and relationship quality. The moderator model that tests for GxE used in the current analyses requires data from both twins on the moderator (here, relationship satisfaction); thus, the final sample size for the biometric moderation models was reduced to 572 twin pairs, 246 male twin pairs (176 MZ and 70 DZ) and 326 female twin pairs (214 MZ and 112 DZ). The

[1]The relationship satisfaction measured that participants completed did not directly ask participants the gender and/or sexuality of the romantic partner they were completing the measure regarding. For the 1246 participants who indicated they were married, it is doubtful that many were same sex couples, as same-sex marriage was not legal in Minnesota at the time of data collection (although it was legal in a few states at that time and some twins may have married in one of those states). We did ask twin participants at the age 29 follow-up about sexual behavior using the following item: "please circle the number that best describes your sexual experiences during the past two years" (1=exclusively heterosexual, 4=equally heterosexual/homosexual, 7=exclusively homosexual). Of the 1210 married twins who completed this item, 5 rated the answer a "6" or "7" (none answered with a 5); of the 346 cohabitating twins who answered this question, 20 rated the answer a "6" or "7" (none responded with a 5).

final sample of 1,144 (572 twin pairs) was significantly different than the twins from the full sample (of 2,440) who were not included in the moderation models on 11 of the 14 personality scales used in the biometric moderation modeling; however, the magnitude of these differences was small, ranging from d=.11 (Well-being) to .25 (Constraint). The average age of participants was 29.45 (SD=.65) when they completed the assessments used in the current analyses. The average length of marriage (available for 1,240 of 1,246 married twin participants) was 4.60 years (SD=2.56), and the average length of cohabitation (available for 381 of 383 participants) was 31.24 months (SD=35.42).

Zygosity in the MTFS was determined using three methods: agreement by parents on a standard zygosity questionnaire; evaluation by MTFS staff on twins' physical similarity, including hair color, visage, and face and ear shape; and comparison on measures of ponderal and cephalic indices and fingerprint ridge count. When there is disagreement among these three estimates, blood samples are requested and a serological analysis is performed.

Measures

Personality—All participants completed a shortened version of the Multidimensional Personality Questionnaire (MPQ; Tellegen & Waller, 2008). The MPQ is a factor-analytically derived inventory designed to assess several basic personality dimensions in a normal population. The version used in the MTFS consisted of 198 items used to form 11 primary personality scales, 10 of which load onto three higher-order factors that were designed to be orthogonal to each other. All 11 scales were used as individual outcomes in the biometric moderation models. Positive Emotionality (PE) is a basic tendency to view life as pleasurable and actively engage in society; it consists of the following primary scales (high scorers described in parentheses): Well-Being (happy, cheerful, feels about the self), Social Potency (likes to influence and lead others, forceful), Achievement (likes to work hard and strive for goals), and Social Closeness (sociable, affectionate likes others). Negative Emotionality (NE) is the tendency to experience negative mood states and psychological distress; it consists of the primary scales of Alienation (thinks others intend harm, suspiciousness), Aggression (vindictive, hurts others for own advantage), and Stress Reaction (prone to negative emotions, tensions, and mood lability, irritable, easily upset). Finally, Constraint measures a tendency to act in a cautious and restrained manner, avoid thrills, and endorse traditional values; scales from this domain are Control (careful, reflective and planful), Harm Avoidance (avoids danger in favor of safe activities), and Traditionalism (endorses high moral standards, conservative). The final scale, Absorption (responsive to sights and sounds), does not load on the three higher-order factors. Reliability for the MPQ scales is excellent, with internal consistency ranging from .76 to .90 and 30 day test-retest reliability coefficients ranging from .82–.92. Of the final sample of 572 twin pairs (N=1144) used in the biometric moderation models, data for personality was available on 1129–1139 individuals (depending on the scale).

Relationship Satisfaction—Participants completed a shortened version of the Dyadic Adjustment Scale (Spanier, 1976). The full DAS is one of the most widely used measures of relationship satisfaction and demonstrates good internal reliability and measurement invariance across gender (S. C. South, Krueger, & Iacono, 2009). The shortened version used here consisted of 12 items from the full measure. Six items asked about the extent of disagreement (from *Always Agree* to *Always Disagree*) on philosophy of life, demonstrations of affection, aims, goals, and things believed important, sex relations, and amount of time spent; three items asked how often (from *All the time* to *Never*) they and their partner discussed separation, quarreled, got on each other's nerves; three items asked for frequency (from *Never* to *More often* than once a day) of exchanging ideas, calmly discussing, and working together on a project; the last item asked for a global rating of happiness (from *Perfect* to *Extremely Unhappy*). Participants were asked to complete these items focusing on the last 12 months of the relationship. These 12 items were recoded (to bring them in line with scoring on the original DAS) and reversed so that higher scores equaled greater satisfaction. Total scores were calculated if participants completed at least 11 of the 12 items, eliminating 4 individuals. The total possible range for the scale using raw scoring was 0 to 61; actual range our sample was 13 to 61 (M=44.64, SD=6.08). Items were standardized and summed to create a total overall score of satisfaction to use in biometric modeling. Reliability of this scale based on standardized item scores was excellent (internal consistency using the current sample was .84).

Data Analysis

The raw data was fit to biometric moderation models in the Mx software package (Neale, Boker, Xie, & Maes, 2003). Personality scales that were negatively correlated with relationship satisfaction were first reversed so that in every case the moderator could be interpreted in the same direction, with higher scores referring to greater relationship satisfaction. Following standard procedures for twin modeling, age, age^2, age*gender, and age^2*gender were regressed out of the personality scale scores and the z-score composite relationship satisfaction variable(McGue & Bouchard, 1984). The standardized residuals were then entered into the biometric models. Missing data for personality traits was handled using full information maximum likelihood, although the moderator models used in the current analyses required that both twins in the pair have data on the moderator variable, relationship satisfaction.

The bivariate biometric moderation model outlined by Purcell (2002); see Figure 1) estimates genetic, shared, and nonshared variance components of the outcome variable (here, personality) as a function of the moderator variable (here, relationship satisfaction). This model is essentially an extension of the bivariate Cholesky decomposition, which estimates the ACE components unique to each variable and as well as the ACE components shared in common between both variables. As shown in Figure 1, three latent variables (A_u, C_u, E_u) are included to estimate the variance unique to personality after accounting for the variance that is common or shared between personality and satisfaction (A_c, C_c, E_c). The moderation model builds on the Cholesky decomposition by including, for each of the paths affecting the outcome variable, a product term that includes a coefficient indexing moderation of the outcome multiplied by the level of the moderator (e.g., $\beta_{Xau}M$). To determine whether there is significant moderation of the ACE variance components of personality, the fit of this model with all six moderation parameters was compared to a model where the moderation parameters were fixed to 0 (again, equivalent to a bivariate decomposition, except for differences in degrees of freedom because of the way the data is entered into the model). Comparing the full bivariate moderation model to the bivariate model with no moderation is a 6 degrees of freedom test. Following recommendations by van der Sluis, Posthuma, and Dolan (2012), the full bivariate moderation model was run first and resulting parameter estimates were inspected for significant moderation on the common pathways (A_c, C_c, E_c). If no moderation was found on these three parameters, then the extended univariate moderation model outlined by van der Sluis et al. was used, as it has more power to identify moderation confined to the unique parameters (A_u, C_u, E_u). The extended univariate moderation model differs from the bivariate moderation model in that it regresses out the effect of the moderator on the outcome variable, and then estimates moderation on the outcome; thus, it will only have three moderation parameters instead of six.

Model fit was evaluated using the likelihood ratio test (LRT) and Akaike's Information Criterion (AIC; Akaike, 1987). LRT is the difference in −2 times the log likelihood (−2lnL) between two different models and is distributed as chi-square. If the six moderation parameters can be removed without a significant decrease in −2lnL, it suggests that the simpler model without moderation best fits the data. AIC can be used to compare the fit of two alternative models, with the lower value representing better fit.

Results

Descriptives and Twin Correlations

Phenotypic correlations between the personality scales and relationship satisfaction are shown in Table 1, along with means and standard deviations for the sample. As shown, relationship satisfaction was significantly, positively correlated with PEM and CON and negatively correlated with NEM. Among the primary scales, satisfaction was positively correlated with Well-being, Achievement, Social Closeness, Control, Harm Avoidance, and Traditionalism, and negatively correlated with Stress Reaction, Alienation, and Aggression. Relationship satisfaction was not significantly correlated with the primary scales of Social Potency and Absorption. The score for relationship satisfaction was significantly higher among married vs. cohabiting couples ($t=2.39$, $df=1627$, $p<.05$), although the effect size was small (Cohen's *d*=.13).

The within-trait twin correlations are provided in Table 1 for the relationship satisfaction scale and the MPQ personality scales. These correlations provide a rough estimate of genetic influences on the outcome (twice the difference between the MZ and DZ correlation is an estimate of heritability). The twin correlations for relationship satisfaction suggest small to moderate levels of heritability, in line with previous findings. The twin correlations for the personality scales generally mirror what has been found before in the MTFS cohorts and other samples, with moderate heritability; for some scales, however, the MZ correlation was more than twice the DZ correlation, suggesting the possible presence of nonadditive genetic influences. Also provided are the cross-trait, within twin correlations (that is, the correlation between relationship satisfaction and personality within each twin) and the cross-trait, cross-twin correlations (the correlation between relationship satisfaction in Twin 1 and personality in Twin 2, and vice versa). The cross-trait, within twin correlations are roughly comparable to the overall correlations between relationship satisfaction and personality in the total sample. In general, the cross-trait, cross-twin correlations are higher in MZ twins than in DZ twins, indicating genetic overlap between relationship satisfaction and personality.

Biometric Moderation Models

Each of the 11 primary personality scales and the 3 higher-order personality domain scales were entered into a bivariate biometric moderation model (Purcell, 2002) with relationship satisfaction as the moderator, for a total of 14 models with moderation parameters freely estimated. Each of these 14 models was compared to a model where the moderation parameters were set to 0 (a 6 df test), thus removing the estimation of different variance components at different levels of the moderator and providing an empirical test of quantGxE. All fit statistics for these moderation and no moderation models are provided in Table 2. When fit indices suggested that the moderation model should be retained, confidence intervals around the parameter estimates were investigated (see Table 3). In all cases, the parameter estimates for moderation of the common paths between relationship quality and personality (Amc, Cmc, Emc) were not significant. Therefore, following van der Sluis et al. (2012), we ran an extended univariate moderation model. Parameter estimates from the extended univariate moderation model (see Table 3) were used to estimate the variance components; the ACE estimates of the personality traits could conceivably have been estimated for any level of the moderator (here, relationship satisfaction), but for ease of presentation we have chosen to present the variance components at five levels of the moderator (−2, −1, 0, 1, 2 SD). Table 4 presentes both the raw and standardized variance components, and Figure 2 plots the raw (unstandardized) variance components for the personality traits where significant moderation was found. For models where there was no evidence of moderation, variance components from the Purcell (2002) model with moderation parameters fixed to 0 (essentially a bivariate decomposition) are estimated.

Positive Emotionality and Primary Scales—For PEM and its four primary scales, the strongest evidence in favor of biometric moderation was found for the scales of Well-being (X^2=31.41, p<.01, ΔAIC=19.4) and Social Potency (X^2=21.42, p<.01, ΔAIC=9.4). For both, *removing* the six moderation parameters led to a significant increase in the log likelihood and an increase in AIC. When the moderation and no moderation models were compared for PEM (X^2=10.81, p=.09), Achievement (X^2=4.16, p=.65), and Social Closeness (X^2=4.59, p=.60), fit indices supported no moderation.

Variance estimates for Well-being were plotted from very low (−2 SD) to very high (+2 SD) levels of relationship satisfaction (see Table 4 and Figure 2). As shown, the raw genetic variance decreased from low to high levels of satisfaction. This was accompanied by a large increase in shared environment and a drop in nonshared environmental variance from low to high levels of satisfaction, resulting in the highest heritability (h^2=.36) of Well-Being among those least satisfied in their relationships and the lowest heritability (h^2=.00) among those with the most satisfying relationships. For Social Potency, genetic variance also decreased from low to high levels of satisfaction, but nonshared environmental variance increased, and shared environment remained low across all levels of satisfaction. As a result, heritability of

Social Potency was highest (h^2=.75) in the most distressed relationships, but the nonshared environment was highest (e^2=.64) in the most satisfied relationships.

Parameter estimates from the no moderation models were used to compute ACE components for PEM, Achievement and Social Closeness. Proportions of variance due to genetic influences ranged from .41 (Achievement) to .47 (PEM), with most of the rest of the variance coming from nonshared environmental influences.

Negative Emotionality and Primary Scales—The no moderation model fit better than the moderation model for the primary scale of Stress Reaction (X^2=6.35, p=.38). Parameter estimates from the no moderation model were used to estimate variance components for Stress Reaction. Genetic influences accounted for 37% of the proportion of variance with the rest due to nonshared environment (63%).

The moderation model fit better than the no moderation model for NEM (X^2=13.24, $p<.05$, ΔAIC=1.2) and its primary scales of Alienation (X^2=17.66, p=.01, ΔAIC=5.7) and Aggression (X^2=25.23, p=.01, ΔAIC=13.2) according to LRT and AIC. The genetic variance in NEM did not change appreciably over the levels of relationship satisfaction, while the shared environmental variance showed a somewhat curvilinear pattern and the nonshared environmental variance decreased from low to high levels of satisfaction. The total variance in NEM was greatest at the most distressed level of relationship quality and lowest among those with average levels of relationship satisfaction. This resulted in an interesting curvilinear pattern for the standardized proportions of variance, with shared environment greatest at the extremes, and genetic and nonshared environment greatest at average levels of satisfaction and dipping at the extremes. In contrast to findings for NEM, the genetic variance for Alienation decreased from low to high levels of satisfaction with a corresponding decrease in nonshared environmental variance. This resulted in heritability of Alienation decreasing from a high of .42 at −2SD to a low of .20 at +2SD, while the proportion of variance due to shared environment increased dramatically from .05 (−2SD) to .40 (+2SD). When the parameter estimates for Aggression were plotted, the genetic variance increased from low to high levels of relationship satisfaction, shared environmental variance decreased substantially and nonshared environmental variance essentially stayed the same. The proportion of variance due to genetic influences was greatest at the highest levels of satisfaction (h^2=.52 at +2 SD) and the proportion of total variance due to shared environment was greatest at the lowest levels of satisfaction (c^2=.53 at −2 SD).

Constraint and its Primary Scales—The no moderation model fit better for the primary scales of Control (X^2=5.23, p=.51) and Harm Avoidance (X^2=1.48, p=.96) according to all measures of fit. The parameter estimates from the no moderation models for Control and Harm Avoidance revealed a heritability of .27 for Control and .49 for Harm Avoidance, while nonshared environment was .72 for Control and .50 for Harm Avoidance.

The moderation model for CN (X^2=15.45, $p<.05$, ΔAIC=3.5) and Traditionalism (X^2=15.03, $p<.05$, ΔAIC=3) fit significantly better than the no moderation model according to LRT and AIC. When parameter estimates for CN were plotted for different levels of the moderator, genetic variance and nonshared environmental variance increased substantially from low to high levels of satisfaction while shared environmental variance decreased. Thus, similar to what was found for Aggression, heritability of CN was greatest at the highest levels of satisfaction (h^2=.58 at +2 SD), the proportion of total variance due to shared environment was greatest at the lowest levels of satisfaction (c^2=.42 at −2 SD) and nonshared environmental variance was greatest at average levels of satisfaction (e^2=.51 at 0 SD). The heritability of Traditionalism also increased from low (h^2=.12) to high (h^2=.48) levels of relationship satisfaction. Unlike Aggression and CN, however, the proportion of variance in Traditionalism due to nonshared environment decreased from low (e^2=.54) to high (e^2=.27) levels of satisfaction.

Discussion

The goal of the current study was to examine quantGxE for adult personality traits. As the moderator of interest, we focused on romantic relationship quality. Given the importance of romantic relationships as a developmental task related to personality (Hutteman et al., 2014), the significant associations between relationship satisfaction and personality in adults (Malouff et al., 2010), and the importance of relationship functioning generally for well-being and mental health (M. A. Whisman, 2013), it is reasonable to hypothesize that quality of one's intimate romantic relationship in adulthood may have an effect on the etiology of personality. We used a large sample of married or cohabitating twins at the average age of 29 who completed measures of personality and relationship quality to estimate the presence of quantGxE using standard modeling procedures. Moderation was found for 8 of the 14 personality scales examined, but there were differences in the pattern of findings across these personality traits. Below we outline the major findings from this study and their implications.

We replicated phenotypic associations between relationship quality and adult personality traits. Previous work in a sample of adult couples (average age of 27 for women and 29 for men) found that communal positive emotionality and constraint were significantly, positively related to one's own relationship quality, while negative emotionality was negatively related to relationship quality (M. B. Donnellan, Assad, Robins, & Conger, 2007). In our sample of twins assessed at an average age of 29, we found that Positive Emotionality (and subscales of Well-Being, Social Potency, and Social Closeness) and Constraint (and two subscales of Control and Traditionalism) were significantly and positively related to relationship satisfaction, and Negative Emotionality and all of its subscales were negatively related to quality of the relationship. Even though two of the personality scales (Social Potency and Absorption) did not show significant phenotypic main effects with relationship satisfaction, we submitted them to biometric moderation; previous work on quantGxE has shown that moderation can be found even in the absence of main effects (Tucker-Drob & Harden, 2013), and indeed, we found moderation for those two scales.

The pattern of biometric moderation found for three of the personality traits, Well-Being, Social Potency, and Alienation, were indicative of a diathesis-stress pattern of quantGxE. In every case, the genetic variance and the heritability of the personality scale was greatest at the lowest levels of relationship satisfaction. This is evidence of, and very much in line with, the diathesis-stress theory, which suggests that in context of an environmental "trigger"—here, an unsatisfying and/or distressed romantic relationship—genetic influences on personality will be expressed. Similar biometric moderation results have been found for relationship satisfaction and internalizing psychopathology, a domain encompassing symptoms of depression, anxiety, and the personality trait of neuroticism (S.C. South & Krueger, 2008). Well-Being is a tendency to experience positive emotions, and may be similar to the concept of positive affect that has been articulated for the mood and anxiety disorders (Clark, 2005; Clark, Watson, & Mineka, 1994), while Alienation is a primary scale under the domain of Negative Emotionality, a construct that is similar to the trait of neuroticism included, along with mood and anxiety disorders, in the domain of internalizing psychopathology (Hettema, Neale, Myers, Prescott, & Kendler, 2006).

For three personality scales—Aggression, CN, and Traditionalism—biometric moderation suggested evidence for the bioecological or social push model. For all three, genetic variance (and heritability) were highest in the most advantaged environmental context (here, a happy and satisfying relationship free of distress and conflict). This is in line with the bioecological model, which posits that in an enriched environment, genetic influences "will out"; in other words, a genetic predisposition (here, toward self-control or lack of self-control) is expressed in the right environmental conditions. We would note that Aggression is a primary scale of NEM, and similar results were found for NEM previously in our MTFS sample when examining adolescent personality (i.e., average age 17) as a function of the parent-child relationship (R.F. Krueger & Johnson, 2008). In that study, the heritability of NEM reached its peak at the highest levels of parental regard. However, the results found here may be better compared to work that has found evidence of social push using quantGxE modeling for antisocial behavior (Tuvblad, Grann, & Lichtenstein, 2006). It may be that among people with happy and satisfying relationships, the etiology of aggression (or being able to inhibit impulses) may depend more on genetic influences than among people in unhappy, distressed marriage, where aggression/restraint is highly influenced by the environment (both shared and nonshared).

How do we reconcile our pattern of findings across the different traits of the MPQ, with some evidence of diathesis-stress, some evidence of the bioecological model, and no evidence of the differential susceptibility model? Our phenotypic findings are in line with the social investment principle, which posits that *psychologically* investing in normative social roles (not just obtaining that role) like a committed romantic relationship should be related to increases in social dominance, agreeableness, conscientiousness, and emotional stability. The way that those traits are related to each other may help to put our findings in context. Markon and colleagues (2005) found that multivariate personality space using multiple personality measures (including the MPQ) could be explained at several different levels, including what look like the Five Factor Model domains at the five factor level. At the two-factor level, they recovered two factors, which Digman (1997) referred to as alpha (reversed Neuroticism plus Disinhibition) and beta (Positive Emotionality, or Extraversion and Openness) factors and De Young (2006) calls stability and plasticity, respectively. Markon et al. also found that NEM had a non-negligible loading on the beta/plasticity factor. Turning back to the findings from the current study, the three scales which demonstrated evidence of diathesis-stress were two PEM scales (Well-Being and Social Potency) and a NEM scale (Alienation) and the three scales which aligned with the bioecological model were a NEM scale (Aggression) and CN and its scale of Traditionalism. It may be that genetic influences on personality traits related to socialization, social interest, and stability in emotional and motivational domains (alpha/stability) are best expressed in the context of a positive form of socialization (i.e., happy romantic relationship), but for personality traits related to personal growth and the tendency and ability to explore novel situations (beta/plasticity) a distressed romantic relationship can trigger genetic risk (i.e., for low levels of these positive traits). Thus, we can tentatively conclude that relationship satisfaction enhanced genetic effects on alpha/stability personality traits and relationship distress magnified genetic effects on beta/plasticity personality traits.

The pattern of findings for NEM and Absoprtion were not supportive of any of our a priori models of GxE. For both, the proportion of variance due to genetic and nonshared environmental variance was somewhat curvilinear, reaching a peak at average or slightly above average levels of relationship satisfaction before dipping back down. However, for NEM, the change in heritability actually masked genetic variance that was constant at all levels of satisfaction, while the genetic variation in Absorption did increase slightly from low to high levels, speaking to the importance of reporting both unstandardized and standardized variance components. Particularly for NEM, it is unclear why this pattern would be found, in light of findings from Alienation in this study and for previous work on internalizing (S.C. South & Krueger, 2008); however, one of the few studies to examine quantGxE for personality also found no moderation of neuroticism as a function of family dysfunction (Kendler et al., 2003). One possibility is that moderation is less likely to occur on the personality traits that tend to saturate the stability and plasticity factors; neuroticism is the strongest loading on stability and extraversion the strongest indicator of plasticity (DeYoung, 2006), and in the current study we found no moderation of PEM and no change in genetic variance of NEM across levels of relationship satisfaction.. Another possibility is that the extended univariate moderation model used to estimate the variance components in the current study was better able to identify the source of the moderation as coming from the shared environment.

A final intriguing aspect of our results involves the estimate of environmental influences. For all but one of the personality traits where moderation was found, the proportion of variance attributed to the shared environment was non-zero for at least a few levels of the moderator. For some traits (i.e., Aggression, Constraint, and Absorption), shared environment was greatest at extremely low levels of satisfaction, but for others the shared environment was close to zero at low levels of satisfaction (i.e., Well-Being and Alienation). Finding substantial non-zero estimates of the shared environment is rare in adult phenotypes and suggests that the impact of the family environment on adult personality may only become apparent at extreme levels of the environmental context. Not surprisingly, the nonshared environment was a consistently large proportion of the total variance of all the traits; even so, there were certain traits in which the nonshared environment was elevated at certain levels of relationship satisfaction. For instance, the nonshared environment was particularly important for social potency at the high end of relationship satisfaction. It is tempting to interpret this finding as suggesting that the nonshared environment was the romantic relationship; however, it is important to recognize there are other nonshared environmental influences on adult personality besides one's romantic relationship, including other family members, occupational demands, and friends and other social groups (Bleidorn et al., 2014).

This study is not without limitations. First, even though we had strong a priori reasons for examining relationship satisfaction as a moderator of genetic and environmental effects on personality, we must acknowledge that it is possible that personality may in fact moderate the genetic and environmental influences on satisfaction and future research should examine this direction of effect. We had only the twin's self-report of relationship satisfaction and it will be important to incorporate partner reports of relationship satisfaction (E.L. Spotts et al., 2005). The relationship satisfaction measure was a shortened version of the Dyadic Adjustment Scale and the validity of this scale has not been established; the internal reliability of this measure, however, is excellent, and heritability estimates of satisfaction using this scale were comparable to what has been found previously (E. L. Spotts, Prescott, & Kendler, 2006). We also used a sample of twins at the average age of 29 who were either cohabiting or married; this meant a loss of almost 800 twins from those who provided personality data. Ideally, we would utilize a sample of adult twins assessed later in their 30s and 40s to capture everyone who might conceivably marry or enter into a long-term monogamous cohabiting relationship. Of course, by combining cohabiting and married twins we may have missed potential differences between twins from these different populations. We also note that our results can only generalize to the population of individuals in an intimate romantic relationship (either cohabitating or married), and not to all persons. In order to be included in our sample, it was necessary for the participant to be in an intimate romantic relationship, and it is possible that other genetically-influenced variables, like attachment, may create covariance between personality traits and relationship satisfaction. We did not have direct information on whether the twins in our sample were reporting on a same-sex or opposite-sex relationship, although there is evidence to suggest that a large majority of participants were most likely in opposite-sex relationships, suggesting the need for future research using same-sex couples.

As with any twin study, our results are constrained by the sample; we estimated genetic and environmental components of variance at five different standard deviation units of the sample, and a sample with greater extremes in relationship satisfaction may result in a different pattern of findings. In a related vein, we note that for every personality trait analyzed, we were able to exclude moderation on the covariance paths between relationship satisfaction and personality. This allowed us to use an extended univariate moderation model, which has better power to detect moderation. Purcell's (2002) full bivariate moderation model may produce false positive findings when the moderator is correlated between twins and when the moderator and the outcome are correlated (as was the case in the current study). Our sample of 572 twins was fairly large for the use of these types of models in the literature; but the use of a larger sample may have resulted in finding significant moderation on the covariance paths, thus we urge replication of our findings in larger samples of twins in romantic relationships.

In conclusion, we found that romantic relationship satisfaction moderated the genetic and environmental components of variance of adult personality. For several personality traits, high levels of relationship satisfaction allowed for the expression of greater genetic influences on personality; whereas for other traits, genetic influences were expressed when relationships were highly distressed. This supports the finding that the etiology of adult personality is not 'static' (Hopwood et al., 2011), and that an important environmental context for etiological change is whether or not one is happy with a current intimate romantic partner. Future research would do well to examine these questions among even older adult samples (e.g., middle-age and late-adulthood) and with different measures of personality (i.e., maladaptive personality domains).

Acknowledgments

This work was supported in part by United States Public Health Service Grants AA09367 to Matthew McGue, DA05147 to William G. Iacono, and DA038065 to Irene Elkins

References

Akaike H. Factor analysis and AIC. Psychometrika. 1987; 52:317–332.

Belsky J, Pluess M. Beyond diathesis stress: Differential susceptibility to environmental influences. Psychological Bulletin. 2009; 135:885–908. [PubMed: 19883141]

Bleidorn W, Kandler C, Caspi A. The behavioural genetics of personality development in adulthood--classic, contemporary, and future trends. European Journal of Personality. 2014; 28:244–255.

Boomsma D, de Geus E, van Baal G, Koopmans J. A religious upbringing reduces the influence of genetic factors on disinhibition: Evidence for interaction between genotype and environment on personality. Twin Research. 1999; 2:115–125. [PubMed: 10480746]

Bouchard TJ Jr, Loehlin JC. Genes, evolution, and personality. Behavior Genetics. 2001; 31:243–273. [PubMed: 11699599]

Bronfenbrenner U, Ceci SJ. Nature-nurture reconceptualized in developmental perspective: A bioecological model. Psychological Review. 1994; 101:568–586. [PubMed: 7984707]

Burt SA. Gene-environment interactions and their impact on the development of personality traits. Psychiatry. 2008; 7(12):507–510.

Burt SA, Donnellan BM, Humbad MN, Hicks BM, McGue M, Iacono WG. Does marriage inhibit antisocial behavior? An examination of selection vs. causation via a longitudinal twin design. Archives of General Psychiatry. 2010; 67(12):1309–1315. [PubMed: 21135331]

Caspi A, McClay J, Moffitt T, Mill J, Martin J, Craig IW, Poulton R. Role of genotype in the cycle of violence in maltreated children. Science. 2002; 297(5582):851–854. [PubMed: 12161658]

Caspi A, Sugden K, Moffitt TE, Taylor A, Craig IW, Harrington H, Poulton R. Influence of life stress on depression: Moderation by a polymorphism in the 5-HTT gene. Science. 2003; 301(5631):386–389. [PubMed: 12869766]

Clark LA. Temperament as a unifying basis for personaltiy and psychopathology. Journal of Abnormal Psychology. 2005; 114:505–521. [PubMed: 16351374]

Clark LA, Watson D, Mineka S. Temperament, personality, and the mood and anxiety disorders. Journal of Abnormal Psychology. 1994; 103(1):103–116. [PubMed: 8040472]

Collishaw S, Pickles A, Messer J, Rutter M, Shearer C, Maughan B. Resilience to adult psychopathology following childhood maltreatment: Evidence from a community sample. Child Abuse & Neglect. 2007; 31(3):211–229. http://dx.doi.org/10.1016/j.chiabu.2007.02.004. [PubMed: 17399786]

Costa, PT.; McCrae, RR. Revised NEO Personality Inventory (NEO-PI-R) and NEO Five-Factor Inventory (NEO-FFI) professional manual. Odessa, FL: Psychological Assessment Resources; 1992.

de Moor MHM, Costa PT, Terracciano A, Krueger RF, de Geus EJC, Toshiko T, Boomsma Dl. Meta-analysis of genome-wide association studies for personality. Molecular Psychiatry. 2012; 17(3): 337–349.10.1038/mp.2010.128 [PubMed: 21173776]

DeYoung CG. Higher-order factors of the Big Five in a multi-informant sample. Journal of Personality and Social Psychology. 2006; 91(6):1138–1151.10.1037/0022-3514.91.6.1138 [PubMed: 17144770]

Dick DM. Gene-environment interaction in psychological traits and disorders. Annual Review of Clinical Psychology. 2011; 7:383–409.

Digman JM. Higher-order Factors of the Big Five. Journal of Personality and Social Psychology. 1997; 73:1246–1256. [PubMed: 9418278]

Donnellan BM, Conger RD, Bryant CM. The Big Five and enduring marriages. Journal of Research in Personality. 2004; 38:481–504.

Donnellan MB, Assad KK, Robins RW, Conger RD. Do negative interactions mediate the effects of negative emotionality, communal positive emotionality, and constraint on relationship satisfaction? Journal of Social and Personal Relationships. 2007; 24:557–573.

Ellis BJ, Boyce WT. Biological sensitivity to context. Current Directions in Psychological Science. 2008; 17:183–187.

Finkel D, McGue M. Sex differences and nonadditivity in the heritability of the Multidimensional Personality Questionnaire scales. Journal of Personality and Social Psychology. 1997; 72(4):929–938. [PubMed: 9108705]

Hettema JM, Neale MC, Myers JM, Prescott C, Kendler KS. A population-based twin study of the relationship between neuroticism and internalizing disorders. American Journal of Psychiatry. 2006; 163:857–864. [PubMed: 16648327]

Hopwood CJ, Donnellan MB, Blonigen DM, Krueger RF, McGue M, Iacono WG, Burt SA. Genetic and environmental influences on personality trait stability and growth during the transition to adulthood: A three-wave longitudinal study. Journal of Personality and Social Psychology. 2011; 100:545–556.10.1037/a0022409 [PubMed: 21244174]

Hutteman R, Hennecke M, Orth U, Reitz AK, Specht J. Developmental tasks as a framework to study personality development in adulthood and old age. European Journal of Personality. 2014; 28:267–278.

Iacono WG, Carlson SR, Taylor J, Elkins IJ, McGue M. Behavioral disinhibition and the development of substance use disorders: Findings from the Minnesota Twin Family Study. Developmental Psychopathology. 1999; 11:869–900.

Jang KL, Dick DM, Wolf H, Livesley WJ, Paris J. Psychosocial adversity and emotional instability: An application of gene-environment interaction models. European Journal of Personality. 2005; 19:359–372.

Jang KL, Livesley WJ, Vernon PA, Jackson DN. Heritability of personality disorder traits: A twin study. Acta Psychiatrica Scandinavica. 1996; 94:438–444. [PubMed: 9020996]

Jang KL, McCrae RR, Angleitner A, Riemann R, Livesley W. Heritability of facet-level traits in a cross-cultural twin sample: Support for a hierarchical model of personality. Journal of Personality and Social Psychology. 1998; 74:1556–1565. [PubMed: 9654759]

Jarnecke AM, South SC. Genetic and environmental influences on alcohol use: Moderation by some, but not all, forms of social support. Alcoholism: Clinical and Experimental Research. 2014; 38:367–375.

Karney BR, Bradbury TN. Neuroticism, marital interaction, and the trajectory of marital satisfaction. Journal of Personality and Social Psychology. 1997; 72:1075–1092.10.1037/0022-3514.72.5.1075a [PubMed: 9150586]

Kendler KS, Aggen SH, Jacobson KC, Neale MC. Does the level of family dysfunction moderate the impact of genetic factors on the personality trait of neuroticism? Psychological Medicine. 2003; 33:817–825. [PubMed: 12877396]

Krueger, RF.; Johnson, W. Behavioral genetics and personality: A new look at the integration of nature and nurture. In: John, OP.; Robins, RW.; Pervin, LA., editors. Handbook of Personality: Theory and Research. 3. New York: Guilford; 2008. p. 287-310.

Krueger RF, South SC, Johnson W, Iacono W. The heritability of personality is not always 50%: Gene-environment interactions and correlations between personality and parenting. Journal of Personality. 2008; 76:1485–1522. [PubMed: 19012656]

Lemery-Chalfant K, Kao K, Swann G, Goldsmith HH. Childhood Temperament: Passive Gene-Environment Correlation, Gene-Environment Interaction, and the Hidden Importance of the Family Environment. Development and Psychopathology. 2013; 25(1):51–63.10.1017/S0954579412000892 [PubMed: 23398752]

Livesley, WJ.; Jackson, DN. Manual for the Dimensional Assessment of Personality Pathology-Basic Questionnaire. Port Huron, MI: Sigma Press; 2001.

Malouff JM, Thorsteinsson EB, Schutte NS, Bhullar N, Rooke SE. The Five-Factor Model of personality and relationship satisfaction of intimate partners: A meta-analysis. Journal of Research in Personality. 2010; 44:124–127.

Markon KE, Krueger RF, Watson D. Delineating the structure of normal and abnormal personality: An integrative hierarchical approach. Journal of Personality and Social Psychology. 2005; 88:139–157. [PubMed: 15631580]

McGue M, Bouchard TJ. Quality of twin data for the effects of age and sex. Behavior Genetics. 1984; 14:325–343. [PubMed: 6542356]

Moffitt TE, Caspi A, Rutter M. Measured gene-environment interactions in psychopathology: Concepts, research strategies, and implications for research, intervention, and public understanding of genetics. Perspectives on Psychological science. 2006; 1:5–27. [PubMed: 26151183]

Monroe SM, Simons AD. Diathesis-stress theories in the context of life stress research: Implications for the depressive disorders. Psychological Bulletin. 1991; 110:406–425. [PubMed: 1758917]

Neale, MC.; Boker, SM.; Xie, G.; Maes, HH. Mx: Statistical modeling. 6. Richmond, VA: Department of Psychiatry, Virginia Commonwealth University; 2003.

Neyer FJ, Lehnart J. Relationships matter in personality development: Evidence from an 8-year longitudinal study across young adulthood. Journal of Personality. 2007; 75(3):535–568. [PubMed: 17489891]

Purcell S. Variance components models for gene-environment interaction in twin analysis. Twin Research. 2002; 5:554–571. [PubMed: 12573187]

Raine A. Biosocial studies of antisocial and violent behavior in children and adults: A review. Journal of Abnormal Child Psychology. 2002; 30:311–326. [PubMed: 12108763]

Roberts BW, DelVecchio WF. The rank-order consistency of personality traits from childhood to old age: A quantitative review of longitudinal studies. Psychological Bulletin. 2000; 126:3–25.10.1037/0033-2909.126.1.3 [PubMed: 10668348]

Roberts, BW.; Wood, D. Personality development in the context of the neo-socioanalytic model of personality. In: Mroczek, DK.; Little, TD., editors. Handbook of personality development. Mahwah: Erlbaum; 2006.

Robins RW, Caspi A, Moffitt TE. It's not just who you're with, it's who you are: Personality and relationship experiences across multiple relationships. Journal of Personality. 2002; 70(6):925–964. [PubMed: 12498360]

South, SC.; Eaton, NR.; Krueger, RF. The connections between personality and psychopathology. In: Millon, T.; Krueger, RF.; Simonsen, E., editors. Contemporary directions in psychopathology: Scientific foundations of the DSM-V and ICD-11. New York: Guilford Press; 2010. p. 242-262.

South SC, Krueger RF. Marital quality moderates genetic and environmental influences on the internalizing spectrum. Journal of Abnormal Psychology. 2008; 117:826–837. [PubMed: 19025229]

South SC, Krueger RF. Marital satisfaction and physical health: Evidence for an Orchid effect. Psychological Science. 2013

South SC, Krueger RF, Iacono WG. Factorial invariance of the Dyadic Adjustment Scale across gender. Psychological Assessment. 2009; 21(4):622–628. [PubMed: 19947795]

Spanier GB. Measuring dyadic adjustment: New scales for assessing the quality of marriage and similar dyads. Journal of Marriage and the Family. 1976; 38:15–28.

Spotts EL, Lichtenstein P, Pedersen N, Neiderhiser JM, Hansson K, Cederblad M, Reiss D. Personality and marital satisfaction: A behavioural genetic analysis. European Journal of Personality. 2005; 19:205–227.

Spotts EL, Neiderhiser JM, Towers H, Hansson K, Lichtenstein P, Pedersen NL, Reiss D. Genetic and environmental influences on marital relationships. Journal of Family Psychology. 2004; 18:107–119. [PubMed: 14992614]

Spotts EL, Prescott C, Kendler KS. Examining the origins of gender differences in marital quality: A behavior genetic analysis. Journal of Family Psychology. 2006; 20:605–613. [PubMed: 17176195]

Stroud K, Durbin CE, Saigal SD, Knobloch-Fedders LM. Normal and abnormal personality traits are associated with marital satisfaction for both men and women: An actor-partner interdependence model analysis. Journal of Research in Personality. 2010; 44:466–477.

Tellegen, A.; Waller, NG. Exploring personality through test construction: Development of the Multidimensional Personality Questionnaire. In: Boyle, GJ.; Matthews, G.; Saklofske, DH., editors. Handbook of personality theory and testing: Vol.II. Personality measurement and assessment. Thousand Oaks, CA: Sage; 2008. p. 261-292.

Tucker-Drob EM, Harden KP. Gene-by-preschool interaction on the development of early externalizing problems. Journal of Child Psychology and Psychiatry. 2013; 54:77–85. [PubMed: 22780450]

Turkheimer E. Three laws of behavior genetics and what they mean. Current Directions in Psychological Science. 2000; 9:160–164.

Tuvblad C, Grann M, Lichtenstein P. Heritability for adolescent antisocial behavior differs with socioeconomic status: Gene-environment interaction. Journal of Child Psychology and Psychiatry. 2006; 47:734–743. [PubMed: 16790008]

van der Sluis S, Posthuma D, Dolan CV. A note on false positives and power in G X E modelling of twin data. Behavior Genetics. 2012; 42:170–186. [PubMed: 21748401]

Watson D, Hubbard B, Wiese D. General traits of personality and affectivity as predictors of satisfaction in intimate relationships: Evidence from self- and partner-ratings. Journal of Personality. 2000; 63:413–449. [PubMed: 10831308]

Whisman MA. Relationship discord and the prevalence, incidence, and treatment of psychopathology. Journal of Social and Personal Relationships. 2013; 30(2):163–170.

Whisman MA, Uebelacker LA. Prospective associations between marital discord and depressive symptoms in middle-aged and older adults. Psychology and Aging. 2009; 24:184–189. [PubMed: 19290750]

Whisman MA, Uebelacker LA, Bruce ML. Longitudinal association between marital dissatisfaction and alcohol use disorders in a community sample. Journal of Family Psychology. 2006; 20:164–167. [PubMed: 16569102]

Young-Wolff KC, Enoch M, Prescott CA. The influence of gene-environment interactions on alcohol consumption and alcohol use disorders: A comprehensive review. Clinical Psychology Review. 2011; 31:800–816. [PubMed: 21530476]

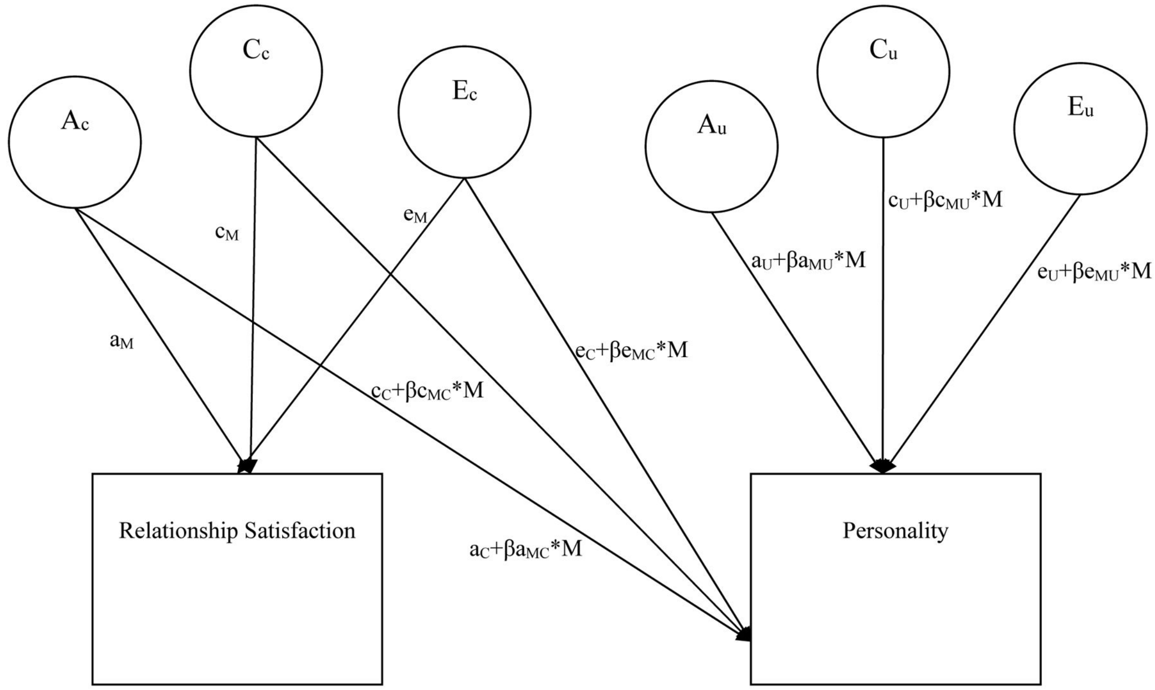
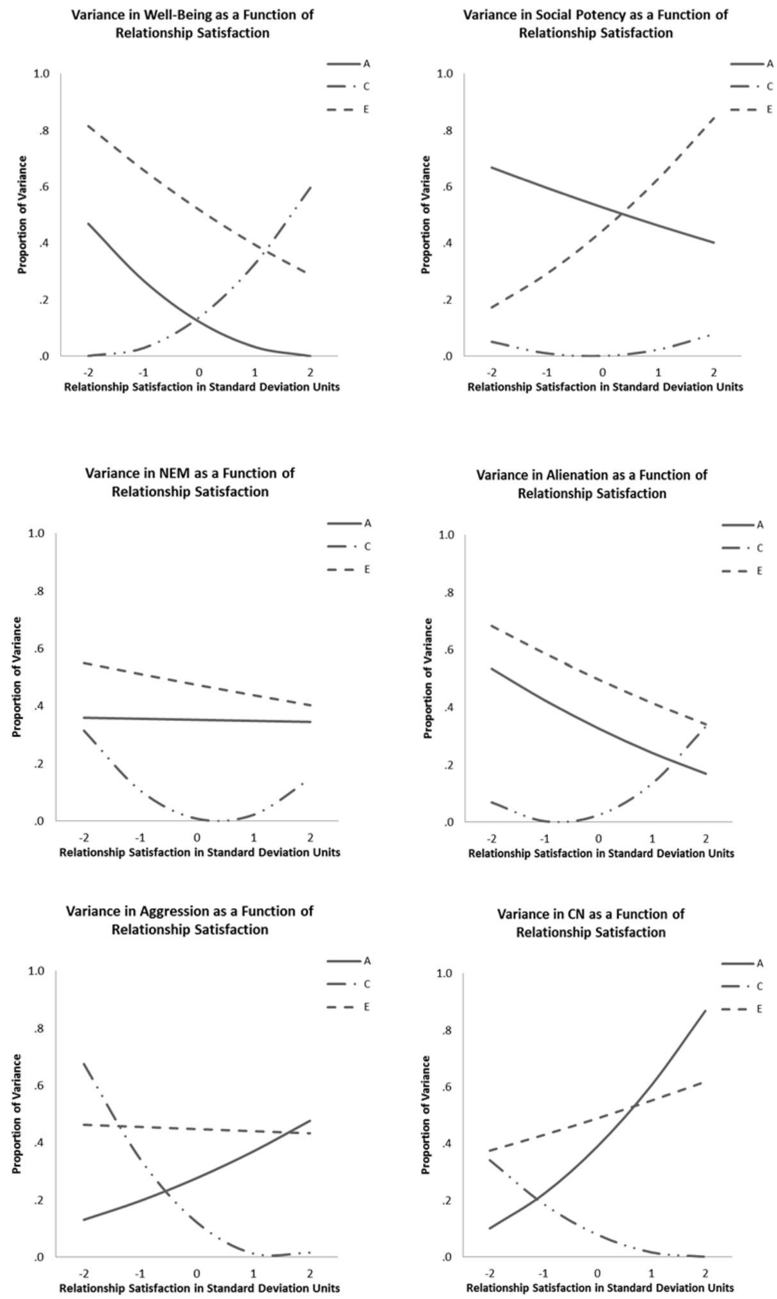


Figure 1.

Bivariate biometric moderation model with relationship variable moderating genetic and environmental effects on the personality variable (model displayed for single member of a twin pair). A=latent factor representing additive genetic influences; C=latent factor representing shared environmental variance; E=latent factor representing nonshared environmental influences. a_C, c_C, and e_C represent common variance shared between the moderator and outcome variables, and a_U, c_U, and e_U signify residual variance in the outcome after accounting for the moderator. The β coefficients index the direction and magnitude of the moderation effect. The total phenotypic variance in personality can be calculated by squaring and summing all of the paths leading to it, P= $(a_C+\beta a_{MC}M)^2$ + $(c_C+\beta c_{MC}M)^2$+ $(e_C+\beta e_{MC}M)^2$ + $(a_U+\beta a_{MU}M)^2$ + $(c_u+\beta c_{MU}M)^2$ + $(e_u+\beta e_{MU}M)^2$.


Variance in Well-Being as a Function of Relationship Satisfaction
Variance in Social Potency as a Function of Relationship Satisfaction
Variance in NEM as a Function of Relationship Satisfaction
Variance in Alienation as a Function of Relationship Satisfaction
Variance in Aggression as a Function of Relationship Satisfaction
Variance in CN as a Function of Relationship Satisfaction
A
C
E
Proportion of Variance
Relationship Satisfaction in Standard Deviation Units
1.0
.8
.6
.4
.2
.0
-2
-1
0
1
2

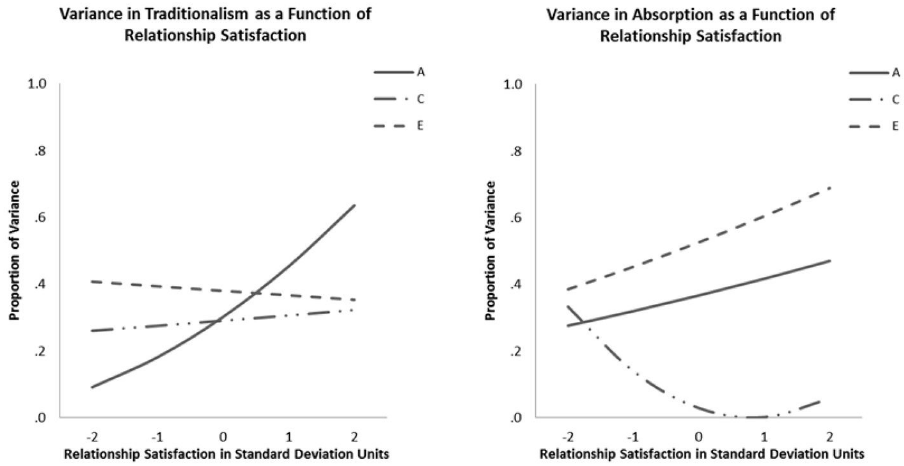


Figure 2.

Plot of the moderation of personality scales by increasing relationship satisfaction. Values are estimates from the extended univariate moderation model. A=additive genetic; C=shared environment; E= nonshared environment. Values shown are standardized (i.e., proportion of total variance due to genetic or environmental variance).

Table 1

Correlations and descriptives for study variables

	Correlation with DAS[a]	Mean	SD	Within Trait Twin Correlations		Cross Trait, Within Twin Correlations				Cross Trait, Cross-Twin Correlations			
				MZ	DZ	MZ		DZ		MZ		DZ	
						T1	T2	T1	T2	T1-T2	T2-T1	T1-T2	T2-T1
Relationship Satisfaction (DAS)													
Raw Scale Score	-	44.64	6.08	-	-	-	-	-	-	-	-	-	-
Z-score composite	-	0.00	7.25	0.19	0.02	-	-	-	-	-	-	-	-
Postive Emotionality	**0.23**	122.77	13.14	0.49	0.16	0.29	0.25	0.35	0.19	0.10	0.18	0.06	−0.11
Well-being	**0.38**	56.25	7.51	0.37	0.24	0.43	0.40	0.40	0.32	0.14	0.23	0.03	−0.07
Social Potency	0.04	44.44	8.86	0.53	0.18	0.04	0.09	0.19	0.04	−0.01	0.05	0.10	−0.19
Achievement	**0.09**	51.78	8.00	0.46	0.19	0.12	0.06	0.17	0.09	0.09	0.09	−0.01	−0.10
Social Closeness	**0.23**	54.87	8.35	0.40	0.23	0.24	0.24	0.18	0.18	0.11	0.11	0.10	−0.03
Negative Emotionality	**−0.33**	78.33	13.33	0.43	0.21	0.35	0.30	0.19	0.31	0.18	0.09	0.02	0.04
Stress Reaction	**−0.27**	39.49	9.25	0.37	0.15	0.29	0.25	0.22	0.32	0.09	0.01	−0.01	0.02
Alienation	**−0.29**	29.11	7.86	0.44	0.22	0.30	0.29	0.19	0.27	0.23	0.10	0.07	−0.05
Aggression	**−0.27**	30.25	7.47	0.49	0.25	0.32	0.23	0.20	0.16	0.19	0.14	−0.10	0.07
Constraint	**0.12**	144.99	15.10	0.45	0.28	0.08	0.06	0.19	0.01	0.07	0.03	−0.08	0.08
Control	**0.15**	52.78	7.36	0.26	0.16	0.14	0.09	0.16	0.11	0.10	0.03	−0.13	0.14
Harm Avoidance	**0.06**	52.32	10.97	0.49	0.26	−0.01	0.04	0.04	−0.03	0.03	0.02	0.03	0.07
Traditionalism	**0.09**	52.95	7.03	0.59	0.49	0.07	0.08	0.22	0.02	0.02	−0.02	0.00	−0.05
Absorption	−0.03	37.92	9.35	0.44	0.11	−0.03	0.00	−0.04	0.07	−0.00	−0.07	−0.02	−0.02

Note. The correlations in the first column are given for the Relationship Satisfaction (Dyadic Adjustment Scale, DAS) z-score composite sum and the raw personality scale scores from the Multidimensional Personality Questionnaire (MPQ). For the 11 MPQ primary scales, Means and SDs are for the raw scores, ranging from 18–72. Scores for Positive Emotionality, Negative Emotionality, and Constraint are optimally weighted composites of raw primary-scale scores derived from factor analysis. Sample size for the correlations with relationship satisfaction, means and SDs is 1629 (from 676 MZ and 381 DZ twin pairs). Twin correlations (N=572) are Pearson correlations, using the age- and gender-regressed z-score for Relationship Satisfaction and the age- and gender-regressed z-scores for all 14 personality scales; these z-scores are used in the biometric moderation models. T1-T2 indicates Twin 1's DAS score and Twin 2's personality score, and T2-T1 indicates Twin 2's DAS score and Twin 1's personality score. Note than twin correlations for Negative Emotionality and its subscales are positive, because they have been reversed for use in the biometric moderation models, but should be interpreted in the same direction as shown in the first column.

[a]Significant correlations shown in bold. Correlations > .06 significant at p<.01; correlations > .09 significant at p<.0001.

Table 2

Fit statistics for biometric moderation models

	−2lnL	df	X^2	*p*	AIC
PEM					
Full ACE Moderation	6151.57	2256			1639.57
No Moderation	6162.38	2262	10.81	0.09	**1638.38**
Well-Being					
Full ACE Moderation	6122.29	2266			**1590.29**
No Moderation	6153.70	2272	31.41	**0.00**	1609.70
Social Potency					
Full ACE Moderation	6245.03	2265			**1715.03**
No Moderation	6266.45	2271	21.42	**0.00**	1724.45
Achievement					
Full ACE Moderation	6260.93	2265			1730.93
No Moderation	6265.09	2271	4.16	0.65	**1723.09**
Social Closeness					
Full ACE Moderation	6286.35	2266			1754.35
No Moderation	6290.94	2272	4.59	0.60	**1746.94**
NEM					
Full ACE Moderation	6131.80	2256			**1619.80**
No Moderation	6145.04	2262	13.24	**0.04**	1621.04
Stress Reaction					
Full ACE Moderation	6208.84	2266			1676.84
No Moderation	6215.19	2272	6.35	0.38	**1671.19**
Alienation					
Full ACE Moderation	6174.70	2266			**1642.70**
No Moderation	6192.36	2272	17.66	**0.01**	1648.36
Aggression					
Full ACE Moderation	6156.57	2265			**1626.57**
No Moderation	6181.79	2271	25.23	**0.00**	1639.79
CN					

	−2lnL	df	X^2	*p*	AIC
Full ACE Moderation	6253.25	2256			**1741.25**
No Moderation	6268.70	2262	15.45	**0.02**	1744.70
Control					
Full ACE Moderation	6353.39	2265			1823.39
No Moderation	6358.62	2271	5.23	0.51	**1816.62**
Harm Avoidance					
Full ACE Moderation	6242.56	2265			1712.56
No Moderation	6244.05	2271	1.48	0.96	**1702.05**
Traditionalism					
Full ACE Moderation	6140.65	2258			**1624.65**
No Moderation	6155.68	2264	15.03	**0.02**	1627.68
Absorption					
Full ACE Moderation	6258.57	2265			**1728.57**
No Moderation	6272.08	2271	13.52	**0.04**	1730.08

Note. N=572 twin pairs. −2lnL=−2 log likelihood; df=degrees of freedom; X^2=difference in −2 log likelihood between full moderation and no moderation models; the difference in df between full moderation and no moderation models is 6 for all personality traits; p=probability value; AIC=Akaike Information Criterion, with smaller values indicating better model fit (shown in **bold**).

Table 3

Parameter estimates from best-fitting models

	a_M	a_C	a_U	βa_{MC}	βa_{MU}	c_M	c_C	c_U	βc_{MC}	βc_{MU}	e_M	e_C	e_U	βe_{MC}	βe_{MU}
PEM															
No Moderation	0.34	0.44	0.52			−0.20	0.13	0.00			0.88	0.16	0.70		
95% CI	.06, .50	.12, .76	−.70, .70			−.42, .42	−.42, .42	−.39, .39			.83, .94	.09, .22	.65, .75		
Well-being															
Bivariate	0.39	0.54	0.01	0.01	−0.26	−0.12	0.31	0.00	0.05	0.00	0.88	0.27	0.71	0.03	−0.09
95% CI	.19,.49	.25,.68	−.49,.49	−.20,.24	−.36,.36	−.35,.35	−.53,.53	−.51,.51	−.34,.34	−.35,.35	.83,.94	.19,.35	.66,.77	−.05,.10	−.16, −.03
Univariate	-	-	0.35	-	−0.17	-	-	0.37	-	0.20	-	-	0.72	-	−0.09
Social Potency															
Bivariate	0.37	0.08	0.72	0.14	−0.05	−0.13	0.08	0.00	0.05	0.00	0.89	0.09	0.66	−0.01	0.12
95% CI	−.49,.49	−.78,.78	−.79,.79	−.25,.25	−.22,.22	−.44,.44	−.38,.38	−.36,.36	−.24,.24	−.23,.23	.83,.94	.01,.16	.62,.72	−.07,.08	.06,.18
Univariate	-	-	0.73	-	−0.05	-	-	0.03	-	0.13	-	-	0.67	-	0.13
Achievement															
No Moderation	0.32	0.42	0.49			−0.24	0.21	0.00			0.89	0.02	0.73		
95% CI	.04, .49	.02, .73	−.72,.72			−.42, .42	−.47, .47	−.40, .40			.83, .94	−.05, .09	.68, .78		
Social Closeness															
No Moderation	0.40	0.24	0.61			0.00	0.02	0.00			0.88	0.13	0.76		
95% CI	−.50, .50	−.71, .71	−.69, .69			−.42, .42	−.50, .50	−.49, .49			.83, .94	.06, .20	.71, .82		
NEM															
Bivariate	0.39	0.31	0.56	−0.18	0.06	0.05	−0.10	0.00	0.14	0.00	0.89	0.22	0.69	0.07	−0.03
95% CI	−.50,.50	−.70,.70	−.65,.65	−.32,.32	−.30,.30	−.42,.42	−.49,.49	−.48,.48	−.33,.33	−.32,.32	.83,.94	.14,.29	.64,.75	−.02,.14	−.09,.04
Univariate	-	-	0.59	-	0.00	-	-	0.09	-	−0.24	-	-	0.69	-	−0.03
Stress Reaction															
No Moderation	0.40	0.11	0.59			0.00	0.00	0.00			0.88	0.24	0.75		
95% CI	−.50, .50	−.65, .65	−.66, .66			−.42, .42	−.45, .45	−.43, .43			.83, .94	.17, .31	.70, .80		
Alienation															
Bivariate	0.35	0.52	0.32	−0.17	0.15	−0.18	0.20	0.00	0.07	0.00	0.89	0.14	0.70	0.06	−0.06
95% CI	.08,.50	.10,.71	−.63,.63	−.31,.16	−.32,.32	−.40,.40	−.48,.48	−.48,.48	−.33,.33	−.31,.31	.83,.94	.07,.22	0.65,.76	−.03,.13	−.13,.01
Univariate	-	-	0.57	-	−0.08	-	-	0.16	-	0.21	-	-	0.71	-	−0.06

	a_M	a_C	a_U	βa_{MC}	βa_{MU}	c_M	c_C	c_U	βc_{MC}	βc_{MU}	e_M	e_C	e_U	βe_{MC}	βe_{MU}
Aggression															
Bivariate	0.38	0.39	0.41	0.05	0.06	−0.11	0.26	−0.23	−0.09	0.20	0.89	0.15	0.67	0.00	−0.01
95% CI	.03,.49	−.04,.71	−.67,.67	−.18,.26	−.30,.30	−.41,.41	−.58,.58	−.58,.58	−.32,.32	−.32,.32	.83,.95	.08,.23	.62,.73	−.07,.08	−.07,.06
Univariate	-	-	0.53	-	0.08	-	-	0.35	-	−0.24	-	-	0.67	-	−0.01
CN															
Bivariate	0.40	0.10	0.63	−0.06	0.15	0.00	−0.16	−0.21	0.09	0.11	0.88	0.05	0.70	0.02	0.04
95% CI	−.50,.50	−.73,.73	−.75,.75	−.23,.24	−.27,.27	−.43,.43	−.53,.53	−.53,.53	−.27,.27	−.27,.27	.83,.94	−.03,.13	.65,.76	−.06,.09	−.02,.11
Univariate	-	-	0.62	-	0.15	-	-	0.28	-	−0.15	-	-	0.70	-	0.04
Control															
No Moderation	0.40	0.17	0.50			−0.05	0.12	0.00			0.88	0.07	0.85		
95% CI	−.50, .50	−.60, .60	−.61, .61			−.42, .42	−.51, .51	−.51, .51			.83, .94	−.01, .14	.80, .91		
Harm Avoidance															
No Moderation	0.39	0.04	0.69			0.08	0.12	0.00			0.88	−0.02	0.70		
95% CI	−.50, .50	−.75, .75	−.77, .77			−.43, .43	−.48, .48	−.46, .46			.83, .94	−.09, .04	.65, .75		
Traditionalism															
Bivariate	0.37	0.23	0.52	0.04	0.12	−0.14	0.53	0.00	0.01	0.00	0.89	0.09	0.62	−0.02	−0.01
95% CI	−.49,.49	−.72,.72	−.73,.73	−.12,.21	−.23,.23	−.42,.42	−.68,.68	−.67,.67	−.17,.17	−.18,.18	.83,.94	.02,.16	.57,.66	−.08,.05	−.06,.04
Univariate	-	-	0.55	-	0.12	-	-	0.54	-	0.01	-	-	0.62	-	−0.01
Absorption															
Bivariate	0.40	−0.07	0.62	−0.21	−0.03	0.00	0.00	0.00	0.00	0.00	0.88	0.02	0.72	0.07	0.05
95% CI	.02,.50	−.65,.25	−.69,.69	−.31,.07	−.18,.13	−.40,.40	−.45,.45	−.44,.44	−.27,.27	−.25,.25	.83,.94	−.05,.10	.67,.78	−.00,.12	−.01,.11
Univariate	-	-	0.61	-	0.04	-	-	0.17	-	−0.20	-	-	0.73	-	0.05

Note. a_M, genetic path estimate for relationship quality; c_M, shared environmental path estimate for relationship quality; e_M, nonshared environmental path estimate for relationship quality; a_C, genetic path estimate common to relationship quality and personality; c_C, shared environmental path estimate common to relationship quality and personality; e_C, nonshared environmental path estimate common to relationship quality and personality; a_U, genetic path estimate unique to personality; c_U, shared environmental path estimate unique to personality; e_U, nonshared environmental path estimate unique to personality; β_{aMC}, moderator of common genetic path to personality; β_{cMC}, moderator of common environmental path to personality; β_{eMC}, moderator of nonshared environmental path to personality; β_{aMU}, moderator of unique genetic path to personality; β_{cMU}, moderator of unique environmental path to personality; β_{eMU}, moderator of unique nonshared environmental path to personality. No Moderation=estimates from model with moderation parameters set to 0. Bivariate=estimates from Purcell's (2002) bivariate moderation model; 95% confidence intervals are for bivariate moderation. Univariate=parameter estimates from Van der Sluis et al. (2012) extended univariate moderation model, which only allows for moderation on the unique path to the outcome.

Table 4

Estimates of unstandardized and standardized variance components for models

	Variance components			Total Variance	Proportions of variance		
	A	C	E		A(%)	C(%)	E(%)
PEM	0.46	0.02	0.51	0.99	0.47	0.02	0.52
Well-Being							
−2	0.47	0.00	0.82	1.28	0.36	0.00	0.63
−1	0.27	0.03	0.66	0.95	0.28	0.03	0.69
0	0.12	0.14	0.52	0.78	0.16	0.18	0.67
1	0.03	0.33	0.39	0.75	0.04	0.43	0.52
2	0.00	0.60	0.29	0.88	0.00	0.67	0.33
Social Potency							
−2	0.67	0.05	0.17	0.89	0.75	0.06	0.19
−1	0.59	0.01	0.29	0.90	0.66	0.01	0.33
0	0.53	0.00	0.44	0.97	0.54	0.00	0.46
1	0.46	0.02	0.63	1.11	0.41	0.02	0.56
2	0.40	0.08	0.84	1.32	0.30	0.06	0.64
Achievement	0.41	0.04	0.54	0.99	0.41	0.04	0.54
Social Closeness	0.43	0.00	0.60	1.03	0.42	0.00	0.58
NEM							
−2	0.36	0.31	0.55	1.22	0.29	0.26	0.45
−1	0.36	0.11	0.51	0.97	0.37	0.11	0.53
0	0.35	0.01	0.47	0.83	0.42	0.01	0.57
1	0.35	0.02	0.44	0.81	0.43	0.03	0.54
2	0.34	0.15	0.40	0.89	0.39	0.16	0.45
Stress Reaction	0.36	0.00	0.62	0.98	0.37	0.00	0.63
Alienation							
−2	0.53	0.07	0.68	1.29	0.42	0.05	0.53
−1	0.42	0.00	0.59	1.01	0.42	0.00	0.58
0	0.33	0.02	0.50	0.85	0.38	0.03	0.59
1	0.24	0.14	0.42	0.79	0.30	0.17	0.52

	Variance components			Total Variance	Proportions of variance		
	A	C	E		A(%)	C(%)	E(%)
2	0.17	0.33	0.34	0.84	0.20	0.40	0.40
Aggression							
−2	0.13	0.68	0.46	1.27	0.10	0.53	0.36
−1	0.20	0.34	0.46	0.99	0.20	0.34	0.46
0	0.28	0.12	0.45	0.85	0.33	0.14	0.53
1	0.37	0.01	0.44	0.82	0.45	0.02	0.54
2	0.48	0.02	0.43	0.93	0.52	0.02	0.47
CN							
−2	0.10	0.34	0.38	0.82	0.12	0.42	0.46
−1	0.22	0.19	0.43	0.84	0.26	0.22	0.51
0	0.39	0.08	0.49	0.96	0.41	0.08	0.51
1	0.61	0.02	0.55	1.17	0.52	0.01	0.47
2	0.87	0.00	0.62	1.49	0.58	0.00	0.42
Control	0.27	0.01	0.73	1.02	0.27	0.01	0.72
Harm Avoidance	0.48	0.01	0.49	0.98	0.49	0.01	0.50
Traditionalism							
−2	0.09	0.26	0.41	0.76	0.12	0.34	0.54
−1	0.18	0.27	0.39	0.85	0.21	0.32	0.46
0	0.30	0.29	0.38	0.97	0.31	0.30	0.39
1	0.45	0.31	0.37	1.13	0.40	0.27	0.33
2	0.64	0.32	0.35	1.31	0.48	0.25	0.27
Absorption							
−2	0.28	0.33	0.38	0.99	0.28	0.33	0.39
−1	0.32	0.14	0.45	0.91	0.35	0.15	0.50
0	0.37	0.03	0.53	0.92	0.40	0.03	0.57
1	0.42	0.00	0.60	1.02	0.41	0.00	0.59
2	0.47	0.06	0.69	1.22	0.39	0.05	0.57

Note. A=additive genetic; C=shared environment; E=nonshared environment. A(%)=heritability.