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Genetic and Environmental Influences on the Junior Temperament and Character Inventory in a Preadolescent Twin Sample

Joshua D. Isen¹, Laura A. Baker, Adrian Raine, and Serena Bezdjian

University of Southern California

Abstract

This study evaluated the genetic and environmental structure of personality variables from the Junior Temperament and Character Inventory (JTCI), in 605 pairs of 9 and 10-year old twins. There is a paucity of information on the biometric structure of temperament and character traits in preadolescent children. Latent factor models were fit to the subscales/items of each trait as a method of estimating genetic and environmental effects on true score variance, especially since internal consistency and reliability were moderate or low for some scales (particularly Reward Dependence and Persistence). Shared environmental influences on Cooperativeness were substantial. Significant heritability estimates were obtained for Self-directedness and Harm Avoidance, but not Novelty Seeking, Reward Dependence or Persistence. With the exception of Harm Avoidance, each of the scales failed to show measurement invariance with respect to sex, suggesting these scales may differ in meaning for boys and girls at this age.

Keywords

JTCI; personality; twins; preadolescence; measurement invariance

The junior version of the Temperament and Character Inventory (TCI) is an extension of Cloninger's personality system that was adapted for children. The psychometric properties of the JTTCI were first reported in a community sample of preadolescents (Luby et al. 1999), and have since been investigated in clinically referred children as well as community samples (Copeland et al. 2004; Lyoo et al. 2004). The TCI is comprised of four temperament scales (Novelty Seeking, Harm Avoidance, Reward Dependence, and Persistence) and three character scales (Self-directedness, Cooperativeness, and Self-transcendence). Independent neurobiological systems are believed to underlie each of the temperament traits, which are also assumed to be biologically organized early in life. The character dimensions, on the other hand, are thought to unfold epigenetically until maturity (Cloninger et al. 1993). In addition to genetic factors, family-wide environmental influences are hypothetically important for character development, due to the role of cultural practices in shaping self-concepts of personal efficacy and altruism.

Biometrical genetic analyses have demonstrated a strong heritable component for temperament as well as for character in adults. Contrary to expectations, there is little evidence for shared environmental influences on character (Ando et al. 2004; Gillespie et al. 2003). This finding is perhaps less puzzling in light of the disproportionate reliance on adult participation in

¹To whom correspondence should be addressed at Department of Psychology, SGM 501, University of Southern California, Los Angeles CA 90089-1061. Phone: 213 821-2867. Fax: 213 746-9082. Email: isen@usc.edu.

personality research (Heiman et al. 2004). Very few twin studies have evaluated Cloninger's personality model in childhood, a time at which character has not yet crystallized.

If the literature on cognitive abilities serves as a guide, shared environmental factors may be more important in childhood than adulthood (McGue et al. 1993). Heritability of IQ increases with age due to the fact that, as twins approach adulthood, IQ resemblance specifically declines among fraternal twins. Consequently, while shared environmental influences are on an equal footing with genetic influences during early childhood, they cease to account for the IQ variance by adulthood. This developmental trend may extend to personality, although the limited information that is available fails to demonstrate age-related increases in the heritability of temperament styles (McCartney et al. 1990).

Understanding the etiology of personality differences is crucial to the early intervention of Axis II disorders. The JTIC may prove an important instrument in the assessment of risk for personality disorder in children. It has successfully discriminated among children treated for various behavioral problems (Shmeck & Poustka 2001). For example, individuals exhibiting conduct disorder symptoms have high Novelty Seeking scores, while those with emotional problems have elevated Harm Avoidance ratings. Novelty Seeking and Harm Avoidance are differentially associated with externalizing and internalizing problems, respectively (Copeland et al. 2004). These results are consistent with the construct validity of the TPQ (Tridimensional Personality Questionnaire), a precursor to the TCI, in adults and adolescents (Kuo et al. 2004). Correlations between TPQ scales and comparison questionnaires indicate that Novelty Seeking is related to behavioral hostility, while Harm Avoidance is related to cognitive and affective manifestations of hostility (Giancola et al. 1994).

The clinical utility of the TCI has been demonstrated in adult patients suffering from Axis II disorders. Cloninger (1993) introduced his three character dimensions in order to improve diagnoses of personality disorder. Namely, character traits were intended to determine the presence or absence of personality disorder, with temperament traits serving to distinguish the subtype. Self-directedness, in particular, appears to predict diagnoses of personality disorder (Svrakic et al. 1993; de la Rie et al. 1998). This is in line with findings from adolescent samples, in which juveniles with disruptive behavior problems and psychiatric disorders score low on Self-directedness (Schmeck & Poustka 2001; Richter et al. 2002). Low character ratings, coupled with high Harm Avoidance or Novelty Seeking scores, may be especially indicative of children who experience social maladjustment and academic failure (Copeland et al. 2004). For example, social anxiety is characterized by low Self-directedness and high Harm Avoidance scores, while a combination of low Self-directedness and high Novelty Seeking is implicated in ADHD (Cho et al. 2008).

Moderate heritability for Cloninger's personality system is consistently found across a broad range of ages. In female subjects between 55 and 80, there are no cross-sectional age differences in the genetic and environmental structure of the TPQ (Heiman et al. 2003). Moreover, the proportion of genetic and environmental influences on the TCI in young Japanese adults (Ando et al. 2004) parallels that in aging Australians (Gillespie et al. 2003). The heritability ranges from 30%–50%, and the role of the shared environment in explaining personality differences is negligible.

To our knowledge, the genetic and environmental etiology of Cloninger's character traits has yet to be examined in childhood. The JTIC was explored by Heiman et al. (2004) using two age-cohorts of adolescent twins, but items concerning character were omitted. The younger set of twins (aged 11 to 15) completed an abridged version of the JTIC, while the older (16–18 year old) twins completed the adult TPQ. Biometrical twin models indicated that additive genetic effects (with estimates ranging from .28 to .36) were significant for three of the

temperament traits, except for Persistence, which received contributions from a shared environmental source (Heiman et al. 2004). The results were consistent across age-cohort, suggesting that the genetic and environmental dynamics behind personality development may be similar across adolescence.

The present study evaluates the environmental and genetic structure of the JTICI in a sample of preadolescent children. The questions of this study are two-pronged. First, are there genetic as well as shared environmental influences on child personality? As mentioned previously, there is a gap in the literature regarding the heritability of character dimensions in childhood. Secondly, is measurement of the JTICI unbiased with respect to sex? Given that there are well-documented sex differences in psychopathological outcomes, it is important to examine whether the predisposing personality traits are measurement invariant. That is, are the JTICI subscales measuring the same construct in boys and girls? If measurement invariance is not tenable, then differences in the mean and/or etiology of a trait are less interpretable (Derks et al. 2007).

Method

Participants

The subjects were participants in a longitudinal twin study of risk factors for antisocial behavior (see Baker et al., 2006, for a detailed description of the study). The total sample included 605 sets of twins or triplets ($n=1219$ children) age 9–10 years old. The present analyses were based on 1156 children (comprising 551 twin pairs) for whom the JTICI was completed. (Fifty-four children did not complete the JTICI due to time constraints during the laboratory visit.) The children were recruited from schools located throughout Greater Los Angeles. The ethnic distribution of the sample is representative of local demographics: 37% Hispanic, 27% Caucasian, 14% Black, 4% Asian, and the remaining 17% of mixed/other heritage. (All subjects were proficient in the English language). Zygosity determination was based on DNA microsatellite analysis. The breakdown of our sample in terms of gender and zygosity are as follows: MZ male ($N=121$), MZ female ($N=127$), DZ male ($N=77$), DZ female ($N=94$), and DZ opposite-sex ($N=132$).

Instrument

The JTICI contains 105 questions that assess personality via four temperament scales and three character scales. A total of 55 items comprise the temperament scales—Novelty Seeking (18 items), Harm Avoidance (22 items), Reward Dependence (9 items), and Persistence (6 items). Self-directedness and Cooperativeness are composed of 20 questions apiece. The third character scale, Self-transcendence (10 items), displays poor internal consistency (Copeland et al. 2004) and does not appear to be a valid personality construct in childhood (Luby et al. 1999). The developmental continuity has yet to be assessed, but it seems that Self-transcendence items may hold less meaning for individuals who lack an intimate understanding of the life cycle (Cloninger et al. 1993).

For the purposes of investigating invariance of the factor structure across sex, as well as managing the error variance, items were further organized into subscales. Many items were borrowed verbatim from the adult TCI, while others were simply downward extensions of the original items. The JTICI items were summed to form the appropriate subscales based on the TCI scoring manual (Cloninger et al. 1994).

Novelty Seeking contains four subscales: exploratory excitability, impulsiveness, extravagance, and disorderliness. Harm Avoidance also contains four subscales: anticipatory worry, fear of uncertainty, shyness, and fatigability. Reward Dependence is represented on the

JTCI by sentimentality and attachment. Persistence was formerly a subscale of Reward Dependence on the TPQ, but is presently a separate scale. Self-directedness contains five subscales: responsibility, purposefulness, resourcefulness, self-acceptance, and enlightened second nature. Cooperativeness is also composed of five subscales: social acceptance, empathy, helpfulness, compassion, and pure-hearted conscience.

Procedure

JTCI self-ratings were collected in interview format, with children orally responding true or false to 95 questions assessing six of the seven personality variables. The character dimension, Self-transcendence, was omitted due to doubts regarding its validity in preadolescent children (Copeland et al. 2004; Luby et al. 1999; Cloninger et al. 1993). Each JTCI scale was formed by summing the number of endorsed items. Fifty-three subjects were administered the questionnaire twice, separated by a six-month interval. As it is unlikely that longitudinal change can be detected after only six months, the correlation between the two occasions constitutes the test-retest reliability of the JTCI. (Data from the second measurement were only used to calculate the test-retest correlations, and were omitted from all other analyses.)

Families came into the laboratory for a full day. The purpose of the visit was to investigate the antecedents and correlates of antisocial behavior. The day-long visit was divided into two sessions that alternated between siblings. During a behavior assessment session, lab assistants administered neuropsychological tests and several questionnaires, including the JTCI. Items were orally dictated to each twin, with subjects responding 'true' or 'false'. This procedure was implemented in order to prevent reading ability from affecting comprehension of the items, as well as to ensure that subjects did not skip items.

Biometric Analysis

Relative effects of genes and environment were estimated at the latent variable level, rather than based on the observed sumscore of each scale. We ran a common factor model for each trait (i.e. each JTCI scale was treated as a latent factor), on which the relevant subscales were permitted to load. In the cases of Persistence and Reward Dependence (which contain an inadequate number of subscales), the individual items were allowed to load on the latent factor. The adoption of a latent factor analysis was done for two reasons. First, there was concern that the measurement error would be substantial, given the young age of this sample and the different manner of administering the JTCI (i.e. the interview format). Latent variable models are optimal when dealing with measurement error, as the residual (error) variance of the manifest variables is separable from the common factor variance (Bentler, 1980). Secondly, when using latent variable models, the factorial structure can be compared across sexes for the purposes of testing for measurement invariance.

If the measurement of JTCI scales is biased across subsamples, then the constructs are not comparable across groups, and consequently the interpretation of mean differences becomes problematic (see Van der Sluis et al. 2006, for an excellent discussion regarding this topic). Furthermore, unbiasedness is a prerequisite to understanding potential differences in the genetic/environmental structure of a trait (Lubke, Dolan, & Neale, 2004). A major criterion of measurement invariance is factorial invariance which, at a very minimum, ensures that a given construct possesses similar factor patterns across groups (Meredith, 1993; Meredith & Teresi, 2006). We tested for pattern invariance by constraining the factor loadings to be equal across boys and girls.

Pattern invariance is a necessary, but not adequate, step in demonstrating measurement invariance. As a result, we examined more rigorous criteria to insure that any potential sex differences were purely due to differences in the distribution (mean and variance) of the latent

trait, rather than due to differences in the subscale-specific properties. A detailed presentation of the steps for examining measurement invariance—including strong and strict factorial invariance—can be found in Van der Sluis et al. (2006) and Dolan et al. (2006). Strong factorial invariance requires that the specific factor means (i.e. measurement intercepts) are identical across sex (Meredith, 1993; Meredith & Teresi, 2006). This insures that any observable sex differences are solely due to differences in common factor means. Strict factorial invariance additionally requires that the residual variances are identical across sex.

Finally, we sought to determine which sources of covariance—additive genetic effects (A) and/or shared environmental effects (C)—best accounted for individual differences in each JTIC latent trait. Variance that was not explained by these parameters was attributed to non-shared environmental influences (E). The choice of various submodels was informed by the structural equation procedures of Neale & Cardon (1992). The goodness of fit of these models was evaluated using chi-square statistics (or, more specifically, the difference between log likelihood values for nested models) and Akaike's Information Criterion (AIC).

All analyses were performed on the item means for each subscale using maximum likelihood techniques in the Mx GUI program (Neale, 1994). The common pathway model described previously was fit to the raw subscale scores. Since the subscale-specific variances largely consisted of measurement error, it was not meaningful to decompose the specific variances into genetic and environmental sources. We examined heterogeneity of effects across the sexes using a standard sex-limitation model. This allowed us to test whether the factor structure as well as the relative magnitude of genetic/environmental variances was similar for boys and girls.

Figure 1 depicts the biometrical model employed in the present analyses. The genetic and environmental components of the common variance are indicated in variables A, C, and E, with respective effects on the latent trait (e.g., Self-directedness) for Twin 1 (SD_1) and Twin 2 (SD_2) in parameters a , c , and e . We initially allowed these effects to differ between males (m) and females (f), which is illustrated in Figure 1 via an opposite-sex pair of twins. The factor pattern coefficients are denoted r , and the specific variance of each subscale is represented as s .

Results

Phenotypic Analyses

There were significant associations among all of the JTIC scales (see Table I) except for the relation between Novelty Seeking and Harm Avoidance. Reward Dependence and Persistence were positively correlated with character dimensions, whereas Novelty Seeking and Harm Avoidance were negatively correlated with character. The phenotypic correlation matrix was very similar for boys and girls.

We tested for mean sex differences by performing paired-samples t tests on the opposite-sex twins. This is the most valid method of testing for sex differences because it is immune to confounding family-wide variables (e.g. families with girls may have higher divorce rates). Mean JTIC scores are presented for each sex in Table II. Girls obtained significantly higher scores than their twin brother on Harm Avoidance, Reward Dependence, and Cooperativeness.

The six-month test-retest correlation (r) ranged from .40 to .56 (see Table III). Reward Dependence and Persistence exhibited poor internal consistency, with Cronbach's alpha coefficients below .40 in both boys and girls. This was paralleled by the weak twin resemblance for Persistence and Reward Dependence ratings (see Table IV). [Given that the intrapair correlations and reliability coefficients for these traits are low, caution is in order when

proceeding with biometrical analyses]. Moreover, one could infer an absence of genetic influence on Novelty Seeking, since the MZ intraclass correlations failed to systematically exceed the DZ correlations. Twin correlations for Self-Directedness and Cooperativeness, on the other hand, were significant across all five zygosity/sex groups. In the cases of Self-directedness and Harm Avoidance, there was informal support for an additive genetic component, as the MZ intraclass correlations were higher than the DZ correlations.

Biometric Model-fitting

In a saturated model, the means and variances of each subscale were successfully constrained to be equal across co-twins and zygosity groups (results not shown). However, the covariance structure was freely estimated in each of the zygosity groups. Next, we fit a more parsimonious model to the data, in which a common factor was assumed to be responsible for individual differences (Model 1). This common pathway model, in which a latent factor received contributions from additive genetic (A) as well as shared environmental (C) and unique environmental (E) sources of variance, served as the standard against which specific submodels were evaluated. (For the purposes of identification/scaling, we fixed the unique environmental variance to 1). Non-additive genetic effects were not included in any of the structural equation models, as the observed MZ intraclass correlations were never larger than twice that of DZ pairs (see Table IV). A description of our submodels is detailed below, and the results of the model-fitting procedure are presented in Table V.

In the first submodel (Model 2), we tested for pattern invariance by constraining the factor loadings to be equal for males and females. If this produced a negligible change in fit, we proceeded to examine invariance of the subscale-specific properties. Thus, we constrained the subscale-specific means (measurement intercepts) to be equal in boys and girls (Model 3). In multiple-group analyses, this is achieved by fixing to zero the factor mean in a reference group (e.g. females), while freely estimating the mean in the remaining group(s) (Bollen, 1989). The estimate in males would thus be expressed as the relative difference from females. By allowing for group differences in the factor mean, we can examine whether the measurement intercepts are equivalent across sex. In the subsequent model (Model 4), we tested for strict factorial invariance by examining whether the residual variances were similar across sex. When all three criteria are met (i.e. equal loadings, intercepts, and residual variances), we can be confident that the construct is comparable between boys and girls.

If measurement invariance is tenable, then it becomes possible to investigate whether there are sex differences in the mean and variance of the common factor. However, if Models 2–4 fail, then the common factor is not comparable across sex, rendering it meaningless to examine whether the genetic and environmental sources of variance are equivalent. Rather, the genetic and environmental effects would have to be estimated separately in each sex. (At this stage, we freely estimated the unique environmental variance, and fixed one of the regression paths to 1). The significance of genetic or shared environmental parameters was tested by constraining their coefficient to 0. If there was no resulting loss of fit, Akaike's Information Criterion (AIC) decided the competition between models on the basis of parsimony. For the sake of brevity, only the best-fitting submodels are reported in Table V. Standardized genetic and environmental parameters from the best-fitting submodel are presented in Table VI.

Novelty Seeking

The factor loadings could be constrained to equality across sex ($p = .19$). However, the measurement intercepts were significantly different (Model 3 vs. Model 2; $p < .01$). In order to explore the source of this sex difference, we ran four models in which we systematically constrained the intercepts of three subscales to be the same, while allowing the remaining (fourth) intercept to vary across sex. The only model that provided an acceptable fit was one

in which the constraint on the Exploratory Excitability (NS1) facet was released ($p = .07$). Boys had higher residual scores for this subscale, which includes items such as, “Even if I know I could get hurt, I can easily do things that are scary and dangerous”. In other words, boys’ relative score on the Novelty Seeking factor (which we had estimated by fixing the factor mean in girls to zero) was not high enough to account for the observed mean difference in Exploratory Excitability. Intercepts of the three other subscales – Impulsiveness, Extravagance, and Disorderliness – were equivalent across sex. Previous investigators of the TCI have noted problems with the position of Exploratory Excitability, which appears to correspond better to Harm Avoidance than to Novelty Seeking (Hansenne et al., 2001; Ando et al., 2004).

Although the tenability of strong factorial invariance was ambiguous, we resumed the model-fitting process using the revised model (Model 3a). The residual variances were found to be equivalent across sex ($p = .08$). Furthermore, the mean of the common factor did not differ between the sexes ($p = .41$). After successfully constraining the genetic (A) and shared environmental (C) variances to be the same in Model 6, we had poor resolution to decide between an AE and CE model (as both provided a satisfactory fit). However, there was still evidence for twin resemblance, as the simultaneous deletion of A and C led to a deterioration in fit; $\Delta\chi^2(2) = 7.39$, $p = .02$. The most parsimonious model was CE, under which shared environmental influences were estimated at 29% (95% CI = 13 – 52%).

Harm Avoidance

In support of strict factorial invariance, the factor loadings, measurement intercepts, and residual variances were equivalent across boys and girls (see Models 2–4). Boys had a significantly lower score on the Harm Avoidance factor. When running Models 3–4, we observed that the estimate of the factor mean in boys was negative (i.e. lower than the female group’s mean, which had been fixed to zero.) When the factor means were fixed to zero in both groups, there was a significant loss in fit (Model 5 relative to Model 4; $p < .01$). However, the factor variance did not differ, and the magnitude of genetic and environmental variances was similar across sex. An AE model fully accounted for the data, yielding a heritability estimate in the moderate range (95% CI = 41 – 61%).

Reward Dependence & Persistence

Both of these temperament traits were severely limited in their internal consistency, which probably explains why the factor loadings were not equivalent across sex (see Model 2). Twin resemblance was lacking altogether, such that A and C effects could be dropped simultaneously. However, a major caveat is that, in contrast to other scales, we were forced to conduct analyses at the item level instead of the subscale level.

Self-Directedness

The pattern of loadings significantly differed between boys and girls (Model 2; $p < .01$). However, we had prior reasons to suspect that the Self-acceptance subscale (SD4) was a source of bias. Lyoo et al. (2004) had shown that SD4 loads poorly on Self-directedness, and inspection of our standardized regression coefficients indicated that the loading was somewhat lower in boys (.32) than girls (.54). We considered the possibility that, due to gender norms, boys and girls may have interpreted some of the Self-acceptance items differently (e.g. “I really wish that I had special powers, like Superman”). Indeed, relaxation of the constraint on Self-acceptance produced a satisfactory fit (Model 2a relative to Model 1; $p = .07$).

Assuming that pattern invariance was now tenable, we found that the intercepts of the other subscales – Responsibility, Purposefulness, Resourcefulness, and Enlightened Second Nature – could be equated (Model 3 vs. Model 2a; $p = .06$). However, the residual variances significantly differed across sex ($p < .01$), which reinforced our impression that Self-

directedness is not measurement invariant. As the construct may carry different meaning for boys and girls, we decomposed the variance into genetic and environmental components in each sex separately. In both cases, an AE model prevailed. The heritability was quite similar in boys and girls, with point estimates of .69 and .65, respectively. The precision of this estimate was poorer in boys, however.

Cooperativeness

Pattern invariance was not tenable for this trait ($p = .01$). Therefore, we estimated the genetic and environmental effects in each sex separately. In both cases, a CE model was viable. In boys, the power to distinguish between an AE model and CE model was poor, although CE was better-fitting. In girls, an AE model led to a significant loss in fit relative to the full ACE model; $\Delta\chi^2(1) = 4.50$, $p = .03$. Standardized estimates of C were .49 and .58 in boys and girls, respectively.

In sum, strict factorial invariance was unequivocally found for Harm Avoidance. The remaining traits failed to demonstrate measurement invariance at one point or another. Although boys and girls may have interpreted some of the dimensions differently, the relative effects of genes and environment were similar across sex. For example, Self-directedness was substantially heritable in both boys and girls, whereas nongenetic models best accounted for the variance in Cooperativeness within both sexes.

Estimates of A and C for the two character traits – Cooperativeness and Self-directedness – were rather high. These estimates were derived from a common pathway model, and thus reflect familial aggregation of true scores for each JTIC scale. Nevertheless, it appears that the measurement error in Reward Dependence and Persistence was too great to be overcome by our common pathway approach. It is also worth noting that the common factor model, when compared with a saturated model, failed to present a satisfactory fit for any of the scales ($p < .02$). This is likely a result of the low to moderate internal consistency for the JTIC scales in this young sample, and could suggest that the JTIC traits may not be unidimensional at this age.

Discussion

Substantial genetic influences on Cloninger's temperament traits have been observed in a wide range of age groups, spanning adolescence (Heiman et al. 2004), young adulthood (Ando et al. 2004), and older adulthood (Heiman et al. 2003; Stallings et al. 1996). This study explored the biometric architecture of Cloninger's personality system in a preadolescent sample. To our knowledge, it is also the first study to examine whether (J)TIC scales are measurement invariant with respect to sex. The pattern of heritability reported so often in other studies of temperament did not emerge. Among JTIC temperament traits, only Harm Avoidance was moderately influenced by genetic factors in this pre-adolescent sample of twins. Furthermore, strict factorial invariance was tenable only for Harm Avoidance.

Girls had higher scores than boys on the latent Harm Avoidance factor. This is an interesting finding, given that sex differences in internalizing problems largely emerge after puberty (Achenbach & Rescorla, 2006). The present results suggest that elevated behavioral inhibition in girls may represent a latent liability for internalizing psychopathology that does not manifest itself until adolescence. However, not all studies indicate that girls score higher on Harm Avoidance (Lyyo et al. 2004; Luby et al. 1999). In a cross-sectional study of children aged 11–18, the sex difference in Harm Avoidance was most pronounced in late adolescence (Heiman et al. 2004). In adults, women consistently outscore men on Harm Avoidance (Miettunen et al. 2007). Females may compensate for this by having more mature character development (e.g. higher Cooperativeness) that protects them from internalizing problems, at least in

preadolescence. There was some evidence that girls scored higher than boys on the character dimensions (both on Cooperativeness and Self-directedness), which might reflect their greater social and emotional maturity. Unfortunately, neither Cooperativeness nor Self-directedness was measurement invariant, rendering it difficult to assess mean sex differences in these constructs.

Factorial invariance was only partially supported for Novelty Seeking. Boys had higher scores on the Exploratory Excitability facet, which was disproportionately high relative to their scores on the other Novelty Seeking subscales; the mean of the latent factor did not significantly differ across sex. Measurement invariance was rejected in the cases of Reward Dependence and Persistence, but the appalling internal consistency likely played a role in these failures. In general, Reward Dependence shows the most robust sex difference on the TCI, with an average effect size of 0.63 in favor of women (Miettunen et al. 2007). In fact, we are unaware of a single study that has failed to detect a significant sex difference in JTCI Reward Dependence. However, the present study casts doubt on the comparability of this construct across sex, and underscores the need to establish unbiasedness before jumping to conclusions about mean differences. Gender bias may especially plague the Sentimentality subscale of Reward Dependence, as the items appear to reflect feminine stereotypes. It is not inconceivable that males would be more hesitant to admit to certain items (e.g. “I usually cry when I see sad movies”) due to gender role considerations.

Among the two character traits examined, only Self-directedness was significantly heritable. This fits well with the consensus that genetic influences on self-esteem are substantial during childhood (Neiss et al. 2002). In female preadolescent twins, for example, Hur et al. (1998) found that genetic, but not shared environmental, factors were significant for several domains of self-concept. Self-directedness, in the present study, similarly failed to show evidence of shared environmental influence. On the other hand, there was evidence of shared environmental influences on Cooperativeness. This is not surprising, as Altruism, which is a closely related characteristic, is probably also influenced by shared environmental factors (Koenig et al. 2007). Indeed, Ando et al. (2004) found that shared environmental factors explained a significant proportion (0.27) of the variance in the Empathy subscale of Cooperativeness.

These findings partially support Cloninger’s (1993) speculation that character is shaped by genes as well as between-family environments. More specifically, our results suggest that Cooperativeness and Self-directedness have a different genetic/environmental architecture in childhood (particularly for girls). It appears that children’s self-concepts of personal effectiveness are largely heritable, whereas children’s orientation towards others (e.g. social acceptance and helpfulness) is more influenced by the family-wide environment. The young age and ethnic diversity of our sample may have contributed to this finding. Children might be particularly sensitive to religious and parental views concerning social tolerance. Also, mean differences in Cooperativeness between ethnic groups could account for some of the shared environmental variance. Given the purported influence of sociocultural learning on character development, the multicultural composition of our sample is not inappropriate.

An important caveat is that the constructs of Self-directedness and Cooperativeness may have different meaning in boys and girls. We decomposed the variance in each sex separately because the latent factors were not comparable across sex. Familial aggregation of character was unusually high in both sexes (50 – 70%). This is doubtlessly a by-product of our latent variable approach, in which the subscale-specific measurement error was effectively removed from the common variance of each trait.

Phenotypic correlations between JTCI scales departed slightly from the adult pattern. There are modest correlations between Harm Avoidance and Novelty Seeking on the adult TCI (see

Miettunen et al. 2008). In the present study, however, there was no association between Harm Avoidance (HA) and Novelty Seeking (NS). Furthermore, the remaining JTCI scales (i.e. Reward Dependence, Persistence, Self-directedness, and Cooperativeness) comprised a mutually positive cluster of traits that was negatively correlated with both HA and NS. This correlation structure has appeared in other investigations of the JTCI (Lyyo et al. 2004; Copeland et al. 2004), suggesting that elevated HA and NS scores independently predict poor character development in children.

A major limitation to the generalizability of our results is the unusual way in which the questionnaire was administered. Since items were orally dictated to the subjects who, in turn, directly verbalized their responses to the tester, there may have been attenuation in reliability and/or increases in social desirability. However, the problems with the JTCI may be intrinsic to this age group. It is likely that children aged 9–10 are not reliable informants, and that the JTCI is a poor instrument for measuring personality in middle childhood. The preliminary work by Luby et al. (1999) suggested that the JTCI is appropriate for children aged 9–13, but this is somewhat misleading, as older children were oversampled (nearly half were aged 13).

Persistence and Reward Dependence, in particular, suffered from an unacceptably low internal consistency. This is an inconvenience that often plagues Persistence on account of its small number of items. For example, Schmeck et al. (2001) obtained reliability coefficients of .48 and .51 for Persistence and Reward Dependence, respectively, within a sample of adolescents. It is possible that the reliability of these scales may improve with age. Indeed, reliability data was available for 400 participants from the present study who were administered the JTCI again at age 14. Cronbach's alpha for Persistence and Reward Dependence was higher during adolescence, with coefficients of .53 and .63, respectively.

In general, poor measurement properties deflate the magnitude of twin covariance. Since the relative effects of A and C are likely to be underestimated when measurement error is not adequately addressed, we employed a common pathway model as a starting base for the model-fitting procedure. Unfortunately, in all cases, a single latent factor rendered a poor fit when compared to a saturated model. This suggests the possibility that the JTCI scales may not be unidimensional in this age group. A revision of the JTCI may be necessary to improve its psychometric qualities.

On top of this, our power to resolve between the various sources of twin covariance (i.e. A and C) may have been limited due to our relatively small sample size. For example, the intraclass correlations were sufficiently similar across MZ and DZ twins to suggest the presence of shared environmental (C) effects on Cooperativeness. Yet the power of detecting significant C effects on the latent trait of Cooperativeness was only .38 in boys. Nearly thrice the current sample size ($N = 1719$ pairs) would be required to achieve a power of .80. Furthermore, our estimates of A and C do not precisely capture the broad influences that they purport to measure. For example, the effect of C might be masked by genetic non-additivity. In the absence of alternative designs (e.g. measured genotypes or twins separated at birth), it is impossible to accurately state the mechanisms involved.

Other studies have not been hampered by small sample sizes, and have often obtained results that sharply differ from the present estimates. In fact, one large study exploited a more powerful design (i.e. extended sibships of twins) to detect the effects of genetic non-additivity on TCI traits (Keller et al. 2005). In contrast to our finding of limited familial influences (and, in fact, modest C effects) on Novelty seeking, they found evidence of non-additive genetic variation in Novelty Seeking as well as Reward Dependence and Persistence. However, the disparity in results cannot simply be attributed to differences in design, as the subjects used by Keller et al. (2005) were older (i.e. post-adolescent).

In the present study, the absence of familial influences on Persistence and Reward Dependence can easily be attributed to poor measurement properties, but the lack of heritability for Novelty Seeking is less explicable. Cronbach's alpha for Novelty Seeking was approximately .60, which although sub-optimal, is comparable to the .66 coefficient obtained by Heiman et al. (2004) in twins aged 11–18. The heritability estimate in the latter group was 36%, and was obtained via self-report. The discrepancy between the present results and those of Heiman et al. (2004) is perhaps linked to the fact that Novelty Seeking scores are much lower in preadolescents. It is possible that the genetic predisposition for Novelty Seeking does not fully emerge until adolescence, when risk-taking behavior becomes more normative. Alternatively, the present subjects may have responded to the items differently due to the peculiar method in which the JTCT was administered.

Despite these limitations, these results are the first to demonstrate that Cloninger's Self-directedness scale is heritable in both males and females during childhood. Deficient levels of Self-directedness may serve as genetically-mediated risk factors for various types of child psychopathology. Of the four temperament traits, only Harm Avoidance was found to be heritable. This is in contrast to studies of older children and adults, in which genetic influences on Novelty Seeking have consistently been found. It remains to be seen how these characteristics and their genetic and environmental architecture develop over time in future assessments within this longitudinal project.

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Figure 1.

Common Pathway diagram. A common underlying trait (e.g., Self-directedness) is assumed to account for the five observed subscales in Twin 1 (male) and Twin 2 (female), with separate paths in males (m) and females (f). Common additive genetic factors (A), shared environmental factors (C), and non-shared environmental factors (E) are depicted in circles. Ovals denote the latent phenotype (SD), while the measured variables (P1–P5) are depicted in rectangles.

Table 1
Phenotypic Correlations among JTCI scales (Males above diagonal; females below diagonal)

	NS	HA	RD	P	SD	C
NS	-----					
HA	.04	.02	-.11	-.28	-.32	-.47
RD	-.25	-----	-.19	-.19	-.42	-.17
P	-.24	-.24	-----	.09	.21	.17
SD	-.33	-.48	.15	-----	.31	.29
C	-.43	-.25	.35	.34	-----	.44
			.39	.29	.53	-----

Note: Correlations in boldface are significant ($p < .05$)

Table IIJTICI scores (mean $\pm$ SD) among 132 pairs of opposite-sex twins

	Males	Females	t
Novelty Seeking	4.79 $\pm$ 3.14	4.17 $\pm$ 2.77	1.89
Harm Avoidance	10.18 $\pm$ 4.13	11.26 $\pm$ 4.87	-2.12 [*]
Reward Dependence	4.15 $\pm$ 1.75	4.77 $\pm$ 1.73	-3.09 ^{**}
Persistence	4.08 $\pm$ 1.25	4.13 $\pm$ 1.45	-0.31
Self-directedness	12.96 $\pm$ 3.27	13.65 $\pm$ 3.59	-1.95
Cooperativeness	15.34 $\pm$ 2.73	16.13 $\pm$ 2.63	-2.83 ^{**}

*
p<.05**
p<.01

Table III**Reliability Coefficients**

	Cronbach α Boys (N=558)	Cronbach α Girls (N=598)	Test-retest correlation (N=53)	Number of items in scale
Novelty Seeking	.63	.59	.40	18
Harm Avoidance	.74	.76	.56	22
Reward Dependence	.31	.38	.49	9
Persistence	.27	.31	.43	6
Self-directedness	.65	.72	.53	20
Cooperativeness	.64	.63	.48	20

Note: Test-retest interval for the 53 subjects was approximately six months

Table IV

Twin Correlations

	NS	HA	RD	P	SD	C
MZ Male N=121	.18*	.31**	.29**	.03	.46**	.37**
MZ Female N=127	.22*	.42**	.11	.23	.50**	.45**
DZ Male N=77	.37**	.18	.18	.17	.36**	.33**
DZ Female N=94	.05	.23*	.20	.13	.31	.39
DZ Male-Female N=132	.19*	.17	.14	.02	.30**	.27**

* p<.05

** p<.01

Table V

Model-fitting Results

Novelty Seeking		-2LL	df	AIC	$\Delta\gamma^2$	Δdf	p Δ
1	Full ACE	-1370.85	4536	-10442.85			
2 vs. 1	Pattern Invariance	-1364.66	4540	-10444.66	6.19	4	.19
3 vs. 2	Strong Factorial Invariance	-1337.70	4543	-10423.70	26.96	3	<.01
3a vs. 2	Strong Factorial Invariance, bar NS1	-1359.33	4542	-10443.33	5.33	2	.07
4 vs. 3a	Strict Factorial Invariance	-1351.11	4546	-10443.11	8.22	4	.08
5 vs. 4	Factor mean $\phi^2 = \bar{\phi}^2$	-1350.42	4547	-10444.42	.69	1	.41
6 vs. 5	ACE $\phi^2 = \bar{\phi}^2$	-1349.58	4549	-10447.58	.84	1	.36
6a vs. 6	CE	-1349.56	4550	-10449.56	.02	1	.89
Harm Avoidance							
1	Full ACE	-108.99	4536	-8963.01			
2 vs. 1	Pattern invariance	-111.90	4540	-8968.10	2.91	4	.57
3 vs. 2	Strong factorial invariance	-118.16	4543	-8967.84	6.26	3	.10
4 vs. 3	Strict factorial invariance	-123.38	4547	-8970.62	5.22	4	.27
5 vs. 4	Factor Mean $\phi^2 = \bar{\phi}^2$	-136.08	4548	-8959.92	12.70	1	<.01
6 vs. 4	ACE $\phi^2 = \bar{\phi}^2$	-125.96	4549	-8972.04	2.58	2	.28
6a vs. 6	AE	-125.96	4550	-8974.04	0	1	
Reward Depend.							
1	Full ACE	-19223.03	10211	-1198.97			
2 vs. 1	Loadings $\phi^2 = \bar{\phi}^2$	-19318.62	10220	-1117.38	95.59	9	<.01
1a vs. 1	A=C=0 ϕ^2	-19226.60	10213	-1199.40	3.57	2	.17
1b vs. 1	A=C=0 $\bar{\phi}^2$	-19223.24	10213	-1202.76	0.21	2	.90
Persistence							
1	Full ACE	-13006.02	6806	-605.98			
2 vs. 1	Loadings $\phi^2 = \bar{\phi}^2$	-13170.10	6812	-453.90	164.1	6	<.01
1a vs. 1	A=C=0 ϕ^2	-13006.02	6808	-609.98	.00	2	
1b vs. 1	A=C=0 $\bar{\phi}^2$	-13006.05	6808	-609.95	.03	2	
Self-directedness							
1	Full ACE	-77.67	5671	-11264.33			
2 vs. 1	Pattern invariance	-92.81	5676	-11257.82	15.14	5	.01
2a vs. 1	Pattern invariance, bar SD4	-86.34	5675	-11261.77	8.67	4	.07
3 vs. 2a	Strong Factorial Invariance, bar SD4	-93.72	5678	-11262.28	7.38	3	.06
4 vs. 3	Strict Factorial Invariance, bar SD4	-113.97	5682	-11250.03	20.25	4	<.01
1a vs. 1	AE ϕ^2	-78.31	5672	-11265.69	.64	1	.42
1b vs. 1	AE $\bar{\phi}^2$	-77.75	5672	-11266.25	.08	1	.78
Cooperativeness							
1	Full ACE	-2153.84	5671	-13495.84			
2 vs. 1	Pattern Invariance	-2139.00	5676	-13491.00	14.84	5	.01
1a vs. 1	CE ϕ^2	-2151.61	5672	-13495.61	2.23	1	.14
1b vs. 1	CE $\bar{\phi}^2$	-2153.82	5672	-13497.82	.02	1	.89

A = additive genetic effects; C = shared environmental effects; E = unique environmental effects

NS1 = Exploratory Excitability subscale; SD4 = Self-acceptance subscale

Table VI

Standardized estimates of the genetic and environmental variance components

JTICI Scale	A	C	E
Novelty Seeking	-----	.29 (.13, .52)	.71 (.49, .94)
Harm Avoidance	.51 (.41, .61)	-----	.49 (.40, .59)
Reward Dependence	-----	-----	1
Persistence	-----	-----	1
Self-directedness ♂	.69 (.48, .91)	-----	.31 (.10, .52)
Self-directedness ♀	.65 (.47, .84)	-----	.35 (.18, .51)
Cooperativeness ♂	-----	.49 (.36, .61)	.51 (.40, .63)
Cooperativeness ♀	-----	.58 (.47, .70)	.42 (.30, .54)