Low Extraversion and High Neuroticism as Indices of Genetic and Environmental Risk for Social Phobia, Agoraphobia, and Animal Phobia

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Objective: The authors examined the extent to which two major personality dimensions (extraversion and neuroticism) index the genetic and environmental risk for three phobias (social phobia, agoraphobia, and animal phobia) in twins ascertained from a large, population-based registry.

Method: Lifetime phobias and personality traits were assessed through diagnostic interview and self-report questionnaire, respectively, in 7,500 twins from female-twin, male-twin, and opposite-sex pairs. Sex-limited trivariate Cholesky structural equation models were used to decompose the correlations among extraversion, neuroticism, and each phobia.

Results: In the best-fitting models, genetic correlations were moderate and negative between extraversion and both social phobia and agoraphobia, and that between extraversion and animal phobia was effectively zero. Genetic correlations were high and positive between neuroticism and both social phobia and agoraphobia, and that between neuroticism and animal phobia was moderate. All of the genetic risk factors for social phobia and agoraphobia were shared with those that influence extraversion and neuroticism; in contrast, only a small proportion of the genetic risk factors for animal phobia (16%) was shared with those that influence personality. Shared environmental experiences were not a source of correlations between personality traits and phobias, and unique environmental correlations were relatively modest.

Conclusions: Genetic factors that influence individual variation in extraversion and neuroticism appear to account entirely for the genetic liability to social phobia and agoraphobia, but not animal phobia. These findings underscore the importance of both introversion (low extraversion) and neuroticism in some psychiatric disorders.

(P)hobias run in families, and twin studies suggest that the modest familial aggregation observed in general population samples is mainly due to genetic factors (1). Exactly what is inherited, though, is unclear. In particular, it is of interest to determine to what extent the familial vulnerability to phobias is indexed by basic personality traits, such as extraversion and neuroticism (2, 3). Low extraversion (introversion) and high neuroticism enhance aversive conditioning in laboratory settings (4–6).

Extraversion and neuroticism are found in almost all personality nosologies (7). Extraversion refers to a person's tendency to be venturesome, enigmatic, assertive, and sociable and to experience positive emotions (e.g., joy). Eysenck theorized that introverts have higher levels of activity in the ascending reticular activating system and are more "aroused" than extraverts, in that introverts are more distractible in high-stimulus environments and perform better at prolonged, monotonous tasks (4). Though the physical basis of extraversion remains under investigation (6, 8), there is some empirical support for Eysenck's theory (4, 8). Neuroticism refers to a person's general tendency to experience negative emotions (e.g., nervousness, sadness, and anger). Eysenck theorized that neuroticism reflects a person's characteristic limbic "excitability," based on autonomic activation patterns (4).

The relationship between neuroticism and anxiety/depressive disorders is widely recognized; less well known is the finding that introversion is also consistently associated with some of these conditions. Social phobia and agoraphobia have particularly strong associations with both introversion and neuroticism. In contrast, relationships between these traits and specific phobias (e.g., animal phobia) tend to be relatively weak (10, 11).

Extraversion and neuroticism are moderately heritable (12) and may contribute part of the heritable basis of phobia. A number of family studies have partially and indirectly addressed this hypothesis for social phobia. For example, trait anxiety, harm avoidance, and behavioral inhibition all combine aspects of introversion and neuroticism (5, 13, 14) and appear familiality related to social...
phobia (15, 16). To our knowledge, familial relationships between personality traits and agoraphobia have received less attention; however, agoraphobia appears familial related to behavioral inhibition (17). In contrast, behavioral inhibition does not appear familial related to specific phobias (18); this finding is consistent with weak phenotypic relationships between personality traits and specific phobias.

The extant family studies suggest that introversion and neuroticism may index theheritable liability to social phobia and agoraphobia, and a common specific phobia, animal phobia. On the basis of extant phenotypic and family studies, we predicted that introversion and neuroticism would substantially increase the genetic vulnerability to social phobia and agoraphobia. Also on the basis of extant studies, we expected that the results for animal phobia would contrast with those for social phobia and agoraphobia, in having weaker phenotypic and genetic relationships to personality traits.

Method

Subjects

The twin data in this report derive from two interrelated projects involving participants in the population-based Virginia Twins Registry, details of which are described elsewhere (18, 19, 20). Briefly, twins from female-female pairs were eligible if they were white and born between 1934 and 1971, and twins from male-male and male-female pairs were eligible if they were white and born between 1940 and 1974. The current study utilizes data from the first interview wave of female-female twins and the second interview wave of male-male and male-female twins. In the interviews of female-female twins, 2,163 subjects were interviewed, including 1,023 complete pairs, 58% of which were monogamous and 42% dizygotic; 68% of the subjects were interviewed in person and 32% by telephone. In the interviews of male-male twins, 2,308 subjects were interviewed, including 1,198 complete pairs, 59% of which were monogamous and 41% dizygotic. In the interviews of opposite-sex twins, 2,066 subjects were interviewed, including 1,070 complete pairs. Of the male-male and male-female twins, 80% were interviewed in person and 20% by telephone. Zygosity determinations using scored questions and photographs were validated by using genetic marker data, with an error rate of less than 5% (18). The interviews at these waves utilized identical phobia assessing questions, and the specific phobias were the first time in either study in which the participants were assessed for phobias. The assessments were also comparable in that they employed identical self-administered personality questionnaires.

The average age at interview was 38.1 years (SD 7.6, range 27-53) in the female-female sample and 37.9 years (SD 8.3, range 20-57) in the male-male and male-female twins. Written informed consent was obtained before in-person interviews, and verbal consent was obtained before telephone interviews. The projects were approved by the Committee for the Conduct of Human Research at Virginia Commonwealth University.

Measures

Lifetime phobias were assessed with an adaptation of the Diagnostic Interview Schedule version III-A (19). The assessed social phobias included meeting new people, giving a speech, using public bathrooms, and eating in public. The assessed agoraphobias included going out of the house alone, being in crowds, and being in open spaces, and the assessed animal-related fears included spiders, "bugs," mice, snakes, bats, and other animals. In this study, a phobia was diagnosed if interviewers judged that the particular fear and related avoidance interfered significantly in the respondent's life. The interviews were carefully trained and supervised mental health workers with at least a master's degree or a bachelor's degree and 3 years of clinical experience. Two separate staff members reviewed each interview for completeness and consistency. The members of each twin pair were assessed by different interviewers who were blind to clinical information about the co-twins, and all data were entered twice to minimize data entry errors.

Values indicating test-retest reliability for social phobia, agoraphobia, and animal phobia, based on the current methods, were in the modest to moderate range (for females: 0.47, 0.52, 0.49; for males: 0.72, 0.76, 0.73; correlation for males: 0.72; 0.76; 0.73; 0.72); reliability was unrelated to zygoteness. The lifetime prevalences of social phobia, agoraphobia, and animal phobia in females were 14.1%, 8.1%, and 10.5%, respectively; in males these were 6.2%, 4.0%, and 5.1%, respectively (20, 21).

Extraversion was assessed with eight items and neuroticism was evaluated with 12 items from the short form of the self-administered Iynenck Personality Questionnaire (22). For extraversion, the Cronbach alpha value was 0.61 for the female-female sample and 0.52 for the sample with male-male and male-female twins; the comparable estimates for neuroticism were 0.54 and 0.65, respectively. Internal consistency was considered to be adequate. Personality scores were analyzed as ordinal variables (extraversion range 1-6, neuroticism range 1-12).

Statistical Analysis

We used SASH version 9.1 (SAS Institute, Cary, NC), to calculate polychoric and tetrachoric correlations and SPSS version 12.0 (SPSS, Chicago) in logistic regression analyses. The purpose of including subjects from the comparable female-female and male-male/female samples was to maximize sample size and statistical power. Since it would not be justified to assume genetic homogeneity across sexes, we explicitly tested for global sex differences prior to testing the hypotheses of interest for this study. Specifically, we applied sex-influenced Chaninov structural equation models to the twin data. These allowed us to assess genetic and environmental liabilities shared among extraversion, neuroticism, and each phobia, taking possible sex differences into account (23). The sex-limitation model allowed for two types of possible sex differences: 1) sex-specific genetic effects (which would imply some stochasticity to the genes that influence the pheno-
ypes in men and women); and 2) sex differences in the magnitude of effects of the same underlying latent genetic and environmental factors (quantitative sex differences). The models imposed a specific structure on the latent factors hypothesized to determine the measured phenotypes, with the first group of factors—additive genetic (A), female-specific additive genetic (A), shared common

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RISK FOR SOCIAL PHOBIA, AGORAPHOBIA, AND ANIMAL PHOBIA

FIGURE 1. Trivariate Cholesky Model of Latent Factors Hypothesized to Determine Extraversion, Neuroticism, and Phobia

The top panel represents one twin and a single genetic set of "fac- tors," though the full model included three sets for males and four sets for females, i.e., additive genetic (A), female-specific additive genetic, shared (or common) environmental (C), and unique environmental, latent variables appear in circles, while observed (mea- sured) variables appear in rectangles. The bottom panel shows par- ticular factors and paths of interest for hypothesis testing, referred to in the methods section. Path 1 represents additive genetic effects that influence both extraversion and phobia; path 2 represents add- ditive genetic effects that influence both neuroticism and phobia; path 3 represents additive genetic effects that influence only pho- bia; path 4 represents shared environmental effects that influence both extraversion and phobia; and path 5 represents shared environ- mental effects that influence both neuroticism and phobia.

environmental (C), and unique environmental (D)—influencing extraversion, neuroticism, and the phobia; the second group of factors—A1, A2, C1, and D1—influencing only neuroticism and the phobia; and the third group—A3, A4, C3, and D3—influencing only the phobia. The specific ordering of extraversion and neuroticism was arbitrary and not of particular interest, we chose to include the phobias last since we were particularly interested in whether or not there were genetic influences that were unique to each phobia, not shared with those that influence extraversion or neuroticism. The model is illustrated in simplified form in the top part of Figure 1.

We fit models to the raw data using the Mx program (20). Model testing began with each full model, including all of the above men- tioned sources of variance. Thresholds for personality traits and phobias were allowed to differ between males and females, given set differences in means and prevalences, respectively. Model pa- rameters and indices that characterized the fit of each full model were calculated, and then the full models were compared with nested submodels created by eliminating or constraining parameters in a stepwise fashion. The goal was to identify the most par- simonious model that sufficiently described the data. The fit of nested submodels was compared by taking the difference be- tween negative two times the log likelihood of the data (-2LL) for each full model and respective submodels under certain regular- ity conditions, these differences follow a chi square distribution, with degrees of freedom equal to the difference in degrees of freed- om between the two models. More parsimonious models (i.e., those with fewer parameters) are considered preferable if they do not provide a significantly worse fit to the data. To operationalize this, we used the Akaike information criterion (AIC) statistic, cal- culated as the model chi square value minus two times the de- grees of freedom. Lower AIC values suggest a better balance of ex- planatory power and complexity.

We modeled each phobia separately. Prior to hypothesis test- ing, we created simplified sex-limited "baseline" models. In a stepwise fashion, we: 1) eliminated the sex-specific additive genetic parameters, 2) equated the sex non-shared and shared additive genetic parameters across sexes, and 3) equated the sex con- trolled shared environmental parameters across sexes, in models, for each phobia, each of those changes resulted in a favor- able balance of model fit and parsimony (lower AIC). However, for each phobia, when we also attempted to equate the sex unique environmental paths across sexes, there was a significant loss of fit. Equating unique environmental paths across sexes forced the proportion of genetic variance to be identical across sexes, al- though in this study, cross-sexes, within-trait correlations for fe- male monozygotic twins were larger than the corresponding cor- relations for male monozygotic twins for all phenotypes except animal phobia (see table in online data supplement, correlations in blue). That is, there was evidence for global quantitative sex differences (the same genes having larger effects in women). We corrected for this by allowing separate unique environmental parameters for each sex in our hypothesis-testing models.

Results

Table 1 shows polygenic and tetralectic correlations for extraversion, neuroticism, and phobia in monozy- gotic and dizygotic twins. First, note the substantial negative within-person correlation between extraversion and social phobia and the positive within-person correlation between neuroticism and social phobia. These phenotypic correlations are consistent with prior observations, i.e., persons with social phobia are typically low in extra- version and/or high in neuroticism. Next, note that cross- twin correlations between extraversion and social phobia and between neuroticism and social phobia are larger in absolute value in monozygotic versus dizygotic twins. This suggests that genetic factors that affect extraversion and those that affect neuroticism also affect social phobia.

For agoraphobia, the pattern is similar to that for social phobia. In contrast, animal phobia was not at all phenotypically related to extraversion, and it was relatively weakly related to neuroticism. Since agoraphobia typically affects a different set of behaviors and contexts than social phobia, this pattern suggests that agoraphobia is a distinct phobia.

Table 2 shows the results of our model-fitting proce- dures (again, separate for each phobia). Model 1, our "baseline" model, includes the sex limitation of the unique environmental parameters specified earlier. In model 2, we set the additive genetic paths between extraversion and each phobia (path 1 in the lower part of Figure 1) to zero. For the social phobia and animal phobia models, this change resulted in a substantial loss of fit (higher AIC val-
TABLE 1. Polychoric and Tetrachoric Correlations for Extraversion, Neuroticism, and Phobias in Twins and Twin Pairs From a Large, Population-Based Registry

<table>
<thead>
<tr>
<th>Variable(s)</th>
<th>Within-Person, Cross-Trait Correlation (all subjects)</th>
<th>Cross-Twin, Within-Trail Correlation</th>
<th>Cross-Twin, Cross Trail Correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personality and phobia</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extraversion and social phobia</td>
<td>-0.243</td>
<td>-0.158</td>
<td>-0.049</td>
</tr>
<tr>
<td>Neuroticism and social phobia</td>
<td>0.322</td>
<td>0.419</td>
<td>0.049</td>
</tr>
<tr>
<td>Extraversion and agoraphobia</td>
<td>-0.161</td>
<td>-0.172</td>
<td>0.094</td>
</tr>
<tr>
<td>Neuroticism and agoraphobia</td>
<td>0.420</td>
<td>0.238</td>
<td>0.075</td>
</tr>
<tr>
<td>Extraversion and animal phobia</td>
<td>0.000</td>
<td>-0.036</td>
<td>-0.014</td>
</tr>
<tr>
<td>Neuroticism and animal phobia</td>
<td>0.229</td>
<td>0.202</td>
<td>0.017</td>
</tr>
<tr>
<td>Single personality trait or phobia</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extraversion</td>
<td>0.420</td>
<td>0.095</td>
<td></td>
</tr>
<tr>
<td>Neuroticism</td>
<td>0.433</td>
<td>0.564</td>
<td></td>
</tr>
<tr>
<td>Social phobia</td>
<td>0.281</td>
<td>0.130</td>
<td></td>
</tr>
<tr>
<td>Agoraphobia</td>
<td>0.372</td>
<td>0.134</td>
<td></td>
</tr>
<tr>
<td>Animal phobia</td>
<td>0.388</td>
<td>0.045</td>
<td></td>
</tr>
</tbody>
</table>

TABLE 2. Fitting of Sex-Limited Trivariate Cholesky Structural Equation Models of Extraversion, Neuroticism, and Phobias to Data of Twin Pairs From a Large, Population-Based Registry

<table>
<thead>
<tr>
<th>Social Phobia</th>
<th>Agoraphobia</th>
<th>Animal Phobia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model 1: base line</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\chi^2$</td>
<td>df</td>
<td>p</td>
</tr>
<tr>
<td>Model 2: drop path 3</td>
<td>20.14</td>
<td>1.9</td>
</tr>
<tr>
<td>Model 3: drop path 2</td>
<td>12.12</td>
<td>1.9</td>
</tr>
<tr>
<td>Model 4: drop path 2</td>
<td>12.12</td>
<td>1.9</td>
</tr>
<tr>
<td>Model 5: drop paths 4 and 5</td>
<td>20.51</td>
<td>2.1</td>
</tr>
</tbody>
</table>

*(Model 1) fit the animal phobia data well, suggesting that extraversion and animal phobia are genetically unrelated. In model 3, we set the additive genetic effects of these phobias (path 3 in Figure 1) to zero, and there was substantial worsening of fit in every case. This indicates that neuroticism and all three phobias share a significant portion of genetic determinants, separate from those of extraversion. In model 4, we dropped the phobia-specific additive genetic paths (path 3 in Figure 1), with a substantial improvement in fit for social phobia and agoraphobia, but not animal phobia. In model 5, we set the common environmental paths between extraversion and each phobia and between neuroticism and each phobia (paths 4 and 5 in Figure 1) to zero. In each case, these changes produced further improvements in the AIC (lower values), suggesting that environmental experiences shared by twins contribute little to the covariation between these personality traits and phobias.*

Suggesting that environmental experiences shared by twins contribute little to the covariance between these personality traits and phobias.

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TABLE 3. Genetic and Unique Environmental Correlations, and Phobia-Specific Variance, in the Baseline and Best-Fitting Models of Extraversion, Neuroticism, and Phobias in Twin Pairs From a Large, Population-Based Registry

<table>
<thead>
<tr>
<th>Phobia Type and Model</th>
<th>Additive Genetic Factors</th>
<th>Unique Environmental Factors</th>
<th>Phobia-Specific Variance (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Extraversion</td>
<td>Neuroticism</td>
<td>Male</td>
</tr>
<tr>
<td>Social phobia</td>
<td>-0.47</td>
<td>0.96</td>
<td>-0.18</td>
</tr>
<tr>
<td>Best-fitting model</td>
<td>-0.52</td>
<td>0.94</td>
<td>-0.18</td>
</tr>
<tr>
<td>Agoraphobia</td>
<td>-0.52</td>
<td>0.93</td>
<td>-0.12</td>
</tr>
<tr>
<td>Baseline model</td>
<td>-0.48</td>
<td>0.95</td>
<td>-0.13</td>
</tr>
<tr>
<td>Animal phobia</td>
<td>0.08</td>
<td>0.30</td>
<td>0.02</td>
</tr>
<tr>
<td>Best-fitting model</td>
<td>-0.40</td>
<td>0.84</td>
<td>0.04</td>
</tr>
</tbody>
</table>

1 Baseline model is model 1 in Table 2; best-fitting model is model 5 in Table 2.

TABLE 4. Odds Ratios for a Co-Twin’s Phobia Given a Subject’s Extraversion or Neuroticism Score, With and Without Adjustment for the Subject’s Phobia or Recent Panic Attack/Occur, in Twin Pairs From a Large, Population-Based Registry

| Odds Ratio for Co-Twin’s Phobia, Given a Point Higher Personality Trait Score in Subject |
|-----------------------------------------------|-------------------------------------------------|-----------------------------------------------|
| Type of Twins and Subject’s Personality Trait | Social Phobia | Agoraphobia | Animal Phobia |
| Monozygotic pairs                             | Unadjusted | Adjusted for Subject’s Social Phobia | Unadjusted | Adjusted for Subject’s Agoraphobia | Unadjusted | Adjusted for Subject’s Recent Panic | Unadjusted | Adjusted for Subject’s Animal Phobia |
| Subject’s extraversion                        | 0.88 | 0.91 | 0.98 | 0.93 | 0.93 | 0.98 | 0.98 |
| Subject’s neuroticism                        | 1.16 | 1.14 | 1.16 | 1.13 | 1.13 | 1.13 | 1.13 |
| Subject’s phobia                             | 1.06 | 1.07 | 1.03 | 1.05 | 1.05 | 1.04 | 1.02 |
| Subject’s neuroticism                        | 1.04 | 1.03 | 1.03 | 1.05 | 1.05 | 1.04 | 1.02 |

1 Extraversion range: 0–6; neuroticism range: 0–13.
2 Panic attacks or spells in the last year (spontaneous attacks of fear, extreme discomfort, palpitations, faintness, or shortness of breath that interfered with daily life and were not likely due to a physical illness or medication).
3 Panic and agoraphobia are particularly strongly correlated heritable conditions.

Social phobia-specific and agoraphobia-specific genetic variance was 0%, while the estimate of animal phobia-specific genetic variance was greater than 99%.

Since having a phobia or recent panic might affect personality measures (27), we conducted logistic regression analyses to determine the extent to which a subject’s phobia or panic could confound the relationship between the subject’s personality traits and her or his co-twin’s phobia. As shown in Table 4, accounting for a subject’s phobia or panic had little effect on these relationships (the odds ratios were comparable when a subject’s phobia or panic was taken into account). Note that these analyses likely overcontrol for psychopathology, since high neuroticism and behavioral inhibition appear to predict later onset of panic, social phobia, and perhaps agoraphobia (14, 28, 29).

Discussion

Our results suggest that the familial co-occurrence of certain personality traits and phobias has a genetic, not a shared environmental, basis. Further, genetic factors that influence individual variation in extraversion and neuroticism appear to account entirely for the genetic liability to social phobia and agoraphobia, but not animal phobia. Finally, our results indicate the importance of both introversion and neuroticism as personality endophenotypes for social phobia and agoraphobia. Though genetics often seek a single basic dimension for an endophenotype, our results suggest that the greatest genetic risk for social phobia or agoraphobia involves genetic liability to both low extraversion and high neuroticism.

The extent to which introversion and neuroticism index the genetic vulnerability to social phobia and agoraphobia here is particularly noteworthy (estimated at 100%). For comparison, when we used this cohort and similar methods, estimates of the extent to which neuroticism indexes the genetic vulnerability to major depressive disorder, generalized anxiety disorder, and panic disorder were 30% (12% = 0.69, 59% = 0.77, and 41% = 0.65, respectively) (30): none of these conditions was associated with introversion (31). As expected, personality traits indexed only a small portion of the heritable basis of animal phobia in this study. The heritable basis of animal phobia may involve "preparedness" for aversive conditioning to specific stimuli (32), which neither affects nor is affected by personality to a substantial degree.

In a previous multivariate twin study of neuroticism and internalizing disorders, we reported results for two broad

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genetic factors, one that influenced neuroticism and each disorder and a second, independent of neuroticism, that influenced major depression, generalized anxiety disorder, and panic disorder (the phobias did not have substantial loadings on this second factor). The current study suggests that if a third genetic factor linked to extraversion were added to the earlier model, this third factor would account for the remaining genetic variance of social phobia and agoraphobia, through not animal phobia.

To our knowledge, this is the first study to demonstrate genetic overlap between introversion and psychiatric disorders. Notably, the phenotypic and genetic correlations between extraversion and social phobia or agoraphobia were smaller in absolute value than those for neurotics here. This contrasts with results from another general population study (11) in which we used a different personality measure (33) and psychiatric diagnoses. In that study, these phobias were more strongly related to introversion than to neuroticism. Thus, had we used an alternative measure of extraversion in this study (e.g., one that explicitly includes positive emotionality), the genetic correlations with social phobia or agoraphobia might have been larger in absolute value.

Some have argued that combining introversion with neuroticism, as in trait anxiety (5) or harm avoidance (13), provides a more parsimonious construct to describe the presumed temperament vulnerability to anxiety and depressive disorders. However, since introversion is not consistently associated with all of these disorders (18, 11, 31), it seems useful to consider extraversion and neuroticism separately. It remains an open question whether the physical bases of neuroticism and introversion are most fully construed as constituting a single neurobiological system (5, 13) or two interacting systems (4).

Our results have obvious relevance for molecular genetics. As in other anxiety and depressive disorders, finding genes that influence neuroticism should be valuable in determining the etiology of phobias. Several groups are currently searching the genome for loci that influence neuroticism (for instance, see references 34 and 35). Our results suggest that determining the genetic basis of introversion/extraversion should also be valuable in determining the etiologies of social phobia and agoraphobia. We know of no current systematic studies to identify genetic loci that influence introversion/extraversion, though candidate gene studies exist for this phenotype (for instance, see reference 36). We hope that our findings stimulate further genetic research on extraversion.

While considering the implications of our study for clinical practice, prevention, and research, the limitations of our cross-sectional method should be borne in mind. That is, though our statistical model specifies that latent factors affect all of the phenotypes of interest directly (i.e., there are no causal arrows between the measured variables), it is conceivable that this is not the case. For example, it is possible that genetic and unique environmental factors affect personality traits directly and that introversion and/or neuroticism are themselves true risk factors for social phobia or agoraphobia. This would be consistent with theories regarding the effects of introversion and neuroticism on aversive conditioning (e.g., in the context of social evaluation; noisy, close, or exposed environments; and/or anxiety or panic symptoms) (4, 5) and with theories that relate extraversion to reward-seeking behavior (5) (i.e., extraverts should find venturing into unfamiliar or bustling public environments pleasurable). However, the hypothesis that personality traits mediate genetic risk for phobias and alternatives (e.g., personality traits are simply markers of genetic risk for social phobia or agoraphobia) are difficult to test with cross-sectional data when patterns of heritability are similar across phenotypes, as in the current study (25); a longitudinal study would be more appropriate (for instance, see reference 37). The results in Table 4 suggest that "state" and/or state effects could not account for much of the observed covariance in this study; nevertheless, a conservative conclusion is that low extraversion and high neuroticism are powerful indices of genetic risk for social phobia and agoraphobia in adults.

Second, our models require several assumptions (25), including the absence of assortative mating (likely minimal for the phenotypes considered here (12, 38) and the independence and additivity of the latent variables. Gene-environment interactions could affect twin similarity in either direction, depending on whether both twins are exposed to the specific environmental factor in question; to our knowledge, gene-environment interactions and correlations have yet to be demonstrated for the phenotypes studied here. It is important that the assumption of equal relevant shared environmental experiences for monozygotic and dizygotic twins appears valid here (22, 23, 39).

Third, though nonadditive genetic effects have been detected for personality traits (15), we did not model these here. Given the inclusion of binary phenotypes (phobias), we had inadequate power to discriminate nonadditive from additive genetic effects.

Fourth, unique environmental effects and measurement error are confounded in our models; this may bias our unique environmental correlation estimates downward. Nevertheless, our low unique environmental correlations for personality traits and phobias parallel the low unique environmental correlation for avoidant personality traits and social phobia in the study by Jek更能 et al, which appears elsewhere in this issue of the Journal. In both studies, unique environmental experiences mainly seem to account for phenotypic differences in persons with similar genetic vulnerabilities.

Fifth, our samples were made up entirely of Caucasian twins born in Virginia. Thus, our results may not generalize to individuals from other backgrounds.

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