The Heritability of Frontal EEG Asymmetry: Sex Differences and Non-Additivity

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The heritabilities of frontal EEG asymmetry, and positive and negative emotionality were estimated. Relatively greater right midfrontal EEG asymmetry was associated with higher Negative Emotionality scores in both the Cz and linked mastoid reference schemes in females, but not in males. Midfrontal EEG asymmetry was found to be modestly heritable in females, but not in males. Negative Emotionality demonstrated moderately high heritability in males and females. A bivariate Cholesky model was used to estimate the heritability of the phenotypic correlation between midfrontal EEG asymmetry and Negative Emotionality. According to this model, common genetic effects accounted for approximately 40% of the observed phenotypic correlation between midfrontal EEG asymmetry and Negative Emotionality.

Frontal EEG Asymmetry, Personality and the Cholesky Hypothesis

It was hypothesized that broad personality attributes are in part genetically mediated, and that the genes that influence those personality attributes do so partially via their effects on brain mechanisms indexed by frontal cortical asymmetries in activity.
For the purposes of this study, this hypothesis will be referred to as the "Cholesky hypothesis," after the so-called "Cholesky" models frequently employed to evaluate such relationships (e.g., McGue & Lykken, 1992).

Preconditions of the Cholesky Hypothesis

In order to evaluate the Cholesky hypothesis, several initial criteria need to be evaluated. That is, if the Cholesky hypothesis is true, then…

1. Frontal EEG asymmetry must be correlated with the measures of personality that EEG asymmetry related genetic effects are thought to underlie.
    a. Thus, it was first hypothesized that frontal EEG asymmetry should correlate with Positive and Negative Emotionality, or both.
2. Both frontal EEG asymmetry and those dimensions of personality with which it correlates must to some extent be heritable.

The Cholesky Hypothesis: The bivariate relationships between frontal EEG asymmetry and paper and pencil measures of personality will be partially determined by common genetic influences.

Method

Sample: 125 twin pairs (250 individual participants), 59 male twin pairs (MZ = 29, DZ = 30) and 66 female twin pairs (MZ = 30, DZ 36) were sampled as part of the Minnesota Twin Family Study. The mean age for the sample was 19 years. Zygosity was determined using 3 different procedures: 1) Parents filled out a questionnaire of physical similarity, 2) staff rated the physical similarity of twins, and 3) an algorithm was applied based on ponderal index, cephalic index and finger print ridge count.

Resting Mid-Frontal EEG Asymmetry (cf., Coan & Allen, in press): EEG asymmetries were derived from 5 minutes of resting Cz referenced EEG, recorded simultaneously from each twin pair while they sat with eyes closed in adjacent, identically configured laboratories. Mid-Frontal EEG asymmetry was calculated using the equation Asymmetry Score = ln(right) - ln(left) alpha (cf., Allen, Coan & Nazarian, in press). Higher scores imply greater relative left activity.

Multidimensional Personality Questionnaire (MPQ) (Tellegen, et al., 1998): The MPQ measures 11 personality dimensions and three higher order factors. Only findings from the higher order factors are reviewed here. They are Positive Emotionality (related to Extroversion) and Negative Emotionality (related to Neuroticism).

Results

Mid-Frontal EEG Asymmetry and Personality

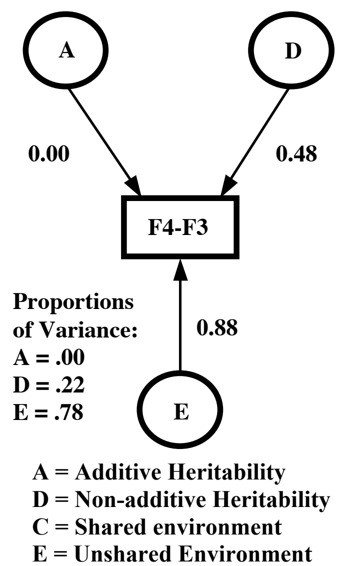
Both positive and negative emotionality measures were negatively correlated with frontal EEG asymmetry in females, suggesting that individuals with greater right frontal activity were also more likely to endorse items and subscales of both positive and negative emotionality.

Table 1. Zero order correlations between mid-frontal EEG asymmetry and the primary and higher order scales of the MPQ.

	Males (N = 118)	Females (N = 132)
Positive Emotionality	-.03	-.21*
Negative Emotionality	.01	-.19*

Heritability Estimates

The heritability of frontal EEG asymmetry was estimated to be 0.22 (see figure to the right) in females. This estimate was derived from an ADE model, χ^2 = 2.80 (df =3), p = .56, AIC = -3.92, and RMSEA = .04. Attempts to fit this and other models to male twins were unsuccessful. Because only females showed evidence of heritability in frontal EEG asymmetry, only a female personality models were run.



Positive Emotionality also fit best to an ADE model, with additive (A), non-additive (D) and unique environment (E) accounting for 21%, 64% and 15%, respectively, of its variance. (χ^2 = 2.80 (df =3), p = .56, AIC = -3.92, and RMSEA = .04).

Negative Emotionality fit best to an AE model, with additive genetic (A), and unique environment (E) accounting for 41% and 59%, respectively, of its variance (χ^2 = 4.43 (df =3), p = .35, AIC = -3.57, and RMSEA = .05).

CHOLESKY MODEL

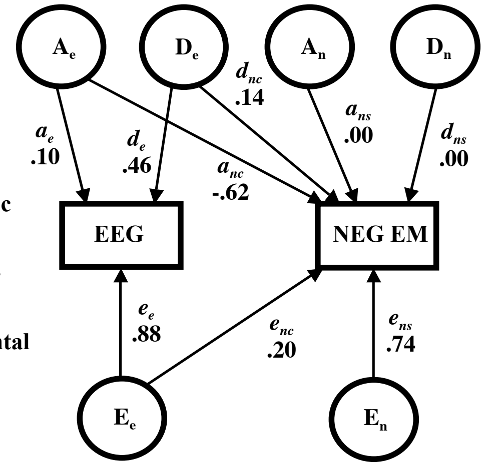
Attempts to fit a Cholesky model to the Positive Emotionality Data were unsuccessful. An ADE Cholesky model was specified for frontal EEG asymmetry and Negative Emotionality (see figure - right), χ^2 = 11.47 (df =11), p = .41, AIC = -10.53, and RMSEA = .04. Because heritability estimates for frontal EEG asymmetry were only available for females, only a female EEG asymmetry/Negative Emotionality Cholesky model was run.

About 22% of the variance in female frontal EEG Asymmetry was attributable to genetic influences. About 41% of the variance in female Negative Emotionality was attributable to genetic influences. About 42% of the covariance between frontal EEG asymmetry and Negative Emotionality was attributable to common genetic influences.

Additive genetic
$a^2_e = .01$
$a^2_{nc} = .39$, $a^2_{ns} = .00$ $\}$ $a^2_n = .39$

Non-additive genetic
$d^2_e = .21$
$d^2_{nc} = .02$, $d^2_{ns} = .00$ $\}$ $d^2_n = .02$

Unique environmental
$e^2_e = .78$
$e^2_{nc} = .04$, $e^2_{ns} = .55$ $\}$ $e^2_n = .59$



CALCULATING THE HERITABILITY OF THE COMMON VARIANCE

$$h_b^2 = \frac{|a_e a_{nc}| + |d_e d_{nc}|}{|a_e a_{nc}| + |d_e d_{nc}| + |e_e e_{nc}|} \qquad h_b^2 = \frac{.062 + .064}{.062 + .064 + .176} = .42$$

Thus: $h^2_{eeg} = .22$ $h^2_{negative\ emotionality} = .41$ $h^2_{bivariate\ correlation} = .42$

DISCUSSION

SEX DIFFERENCES

Dramatic sex differences were found, with relatively greater female, but not male, right mid-frontal EEG asymmetry corresponding to greater Positive and Negative Emotionality, and female, but not male, frontal EEG asymmetry showing modest (h^2 = .22) heritability.

Several possibilities may explain these sex differences. For example, sex differences could be attributable to interactions between genes and sex hormones or sex-specific chromosomal differences, or from sex-specific environmental pressures. For example, one could ask the following questions: 1) Is emotional expressivity culturally constrained in males? 2) Are, females generally more "open" to dysphoric emotions (and their reports) than males (cf., Finkel & McGue, 1997)?

Sex differences in the relationship between mid-frontal EEG asymmetry and Positive and Negative Emotionality may spring from the same source of sex differences in frontal EEG asymmetry found in previous work, such as those found in relationships between frontal EEG asymmetry and measures of defensiveness (Kline, Allen & Schwartz, 1998), those found in state changes in frontal EEG asymmetry in response to EEG hookup procedures (Blackhart, et al., 2002) and those found in state frontal EEG asymmetry responses to incentives (Miller & Tomarken.

THE CHOLESKY HYPOTHESIS

The correlation between female mid-frontal EEG asymmetry and Negative Emotionality represents a small effect ($r \approx .19$, $r^2 \approx .04$). Nevertheless, approximately 42% of that effect is attributable to common additive genetic effects. This is true despite the fact that less than 1% of female mid-frontal EEG asymmetry was attributable to additive genetic effects.

Still, methodological constraints in this study strongly suggest caution. Trait measures of frontal EEG asymmetry are highly sensitive to state and occasion-related influences (Coan & Allen, 2003), and optimal trait measurement is likely to require averaging across up to four measurement occasions (Coan & Allen, in press). In this study, no comparison scalp regions were available, and the sample size was small for a heritability study, especially given the estimation of complex models, where adequate statistical power to reject poorly fitting models is an issue. Nevertheless, this study provides a valuable first look at the heritability of frontal EEG asymmetry and its relationship to other trait measures.

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