The Generalizability of Trait and State-Manipulated Frontal EEG Asymmetry

James A. Coan, John J.B. Allen and Patrick E. McKnight
University of Arizona

Abstract

Generalizability ("G") theory (Cronbach et al., 1972) provides empirical tests of the degree to which sources of variance contributing to a given measure are independent (i.e., generalizable across) of other sources of variance. For this report, G-theory was applied to frontal EEG asymmetry data collected during manipulations of emotional state. Results indicated that trait-specific influences, state-specific influences, and the interaction of trait and state influences, each independently accounted for approximately 10% of the overall variance in frontal EEG asymmetry. Results suggested that trait predispositions exert only moderately stable influences across emotional states, though emotional states exert highly reliable influences across most individuals. The Spearman-Brown prophecy formula was used to estimate the optimal number of recording sessions for a reliable trait estimate of frontal EEG asymmetry. Results indicated that four occasions of measurement should yield an optimally stable estimate of trait-specific variance. Other sources of variance, such as specific frontal region and reference scheme, are also discussed.

Introduction

Frontal EEG Asymmetry in Emotion

- In 40 published studies, trait measures of frontal EEG asymmetry (typically recorded from individuals at "rest") are used to predict other measures of temperament, indicators of psychopathology, or individual differences in emotional reactivity thought to underlie "affective style."
- Over 25 studies have sought to measure state changes in frontal EEG asymmetry that occur concomitantly with state changes in emotional behavior, including subjective emotional experience.

The Approach/Withdrawal Model

- In trait studies, relative left frontal EEG *activity* is thought to be associated with trait predispositions toward approach (e.g., behavioral activation, aggression and affective positivity) or withdrawal (e.g., depression, anxiety, shyness) tendencies.
- In state studies, relative left frontal EEG *activation* is thought to be associated with the occurrence and experience of positive emotions, plus anger, while relative right frontal EEG activation is thought to be associated with the occurrence and experience of negative emotions, excluding anger.

Sources of Unreliability in Frontal EEG Asymmetry

- Measures of frontal EEG asymmetry typically show excellent internal consistency reliability and acceptable test retest reliability. Little is known about how well single measures of frontal EEG asymmetry generalize across specific sources of unreliability, such as:
- **Reference Scheme**: Researchers have found that a potentially major source of unreliability in frontal EEG asymmetry is the reference scheme used (e.g., Hagemann, et al., 2001; Reid, et al., 1998). *How much does reference scheme affect the reliability of frontal EEG asymmetry measures?*
- **Particular Frontal Region**: Researchers have reported frontal asymmetry effects in different frontal regions, such as the mid-frontal region, the lateral-frontal region and the frontal-temporal-central region. *Is the particular frontal region a meaningful source of variance, or are all frontal regions equally likely to show effects?*
- **Trait Variance**. *Do individual trait differences decrease the reliability of state measurements of frontal EEG asymmetry?*
- **State Variance**. *Do state -dependent sources of variance in frontal EEG asymmetry decrease the reliability of trait measures of frontal EEG asymmetry?*

Study Hypotheses

1. **State changes in frontal EEG asymmetry will be reliable across traits, reference schemes and specific frontal regions.**
2. **Trait variance in frontal EEG asymmetry will be preserved within frontal EEG asymmetries during emotional states.**

Method

State Asymmetries: Manipulating Emotion with the Directed Facial Action Task.

- 36 Psychology 101 Participants
- 2 Minutes of EEG recorded for each of 5 Emotions: Fear, Sadness, Disgust, Anger, Joy. (For details, see Coan, Allen & Harmon-Jones, 2001)

Resting Asymmetry

- 33 Psychology 101 Participants (From the same sample as above).
- 8 minutes of resting EEG recorded during eyes opened-eyes closed counterbalanced

Procedural Details

•Assessment of EEG

EEG was recorded at sites F3, F4, F7, F8, Fz, FTC1, FTC2, C3, C4, T3, T4, TCP1, TCP2, T5, T6, P3, P4, Pz, O1, O2, Oz, A1 and A2, referenced online to Cz. Interelectrode impedances were reduced to less than 5 Kohms. All sites were amplified 20,000 with AC differential amplifiers (bandpass 0.1 and 100 Hz), and digitized continuously at 2048 Hz. In addition to Cz-referenced data, two offline montages involving computer-linked mastoids and the average reference were also created. Three regions were used for these analyses. They were: the Mid-Frontal region, the lateral-frontal region and the frontal-temporal-central region.

EEG Alpha Asymmetry Score

ln(right) - ln(left) alpha was derived using homologous sites
(higher scores = greater relative left activity or activation)

Generalizability Theory

Generalizability Theory (Cronbach, et al., 1972), or "G-Theory," allows researchers to estimate the **Generalizability** and **Dependability** of different sources of variance contributing to any given measure. Generalizability Theory also allows for the estimation of variance components associated with each source of variance and all interactions among different sources of variance.

The Generalizability Coefficient, or ρ^2: A reliability coefficient summarizing the preservation of the relative positions of scores within a *given* source of variance. When this number is close to one, the relative positions of scores with that source of variance are preserved across other sources of variance.

The Dependability Coefficient, or Φ: A measure of the reliability of the absolute score attributable to a given source of variance. When this number is close to one, the absolute levels of scores within one source of variance are preserved across other sources of variance.

Variance Components can be used to estimate the percent of total explained variance accounted for by any given source of variance (see "A Simple Generalizability Model," below). Variance components can be calculated for single sources of variance as well as all interactions between unique sources of variance.

A Simple Generalizability model

$$\sigma^2_y = \sigma^2_t + \sigma^2_s + \sigma^2_{ts}$$

σ^2_y = Total variance in frontal EEG asymmetry
σ^2_t = Trait variance
σ^2_s = State Variance
σ^2_{ts} = Trait by State interaction variance

Results

Measuring Frontal EEG Asymmetry *At Rest*

- Trait variance alone accounted for approximately 15% of the variance in frontal EEG asymmetry, and showed moderate generalizability and dependability across region and reference scheme simultaneously.
- Alone, neither specific frontal region nor reference scheme accounted for any noteworthy variance, and their reliabilities were in any case very low.
- The trait by reference scheme interaction accounted for approximately **44%** of the variance, with the remainder of the variance unexplained. **This interaction can be interpreted to mean that the effect of reference scheme was idiosyncratic to each participant.**

	% Explained Variance	Generalizability	Dependability
Trait (N=33)	14.78%	0.44	0.43
Region (N=3)	0.07%	0.08	0.04
Reference Scheme (N=3)	0.00%	0.00	0.00
Trait by Region	0.00%		
Trait by Reference Scheme	44.33%		
Region by Reference Scheme	1.24%		
Trait by Region by Reference Scheme, error	39.59%		

Measuring Frontal EEG Asymmetry *During Emotional States*

- **Trait variance** alone accounted for approximately 8% of the variance in state frontal EEG asymmetry, and showed low generalizability and dependability across all of other sources of variance simultaneously.
- **Emotional states** accounted for approximately 10% of the explained variance and showed extremely high relative and absolute reliabilities across each all other sources of variance simultaneously.
- Neither **region**, nor **reference scheme** accounted for significant proportions of variance, and while generalizability coefficients for both reference scheme and region were comparable to that of trait variance, their dependability scores were very low.
- Other sources of variance tended to interaction with trait, with **trait by region** and **trait by state** interactions each accounting for 12%, and trait by reference accounting for 17% of the explained variance.
- Interestingly, the largest proportion of variance, 20%, was accounted for by a **trait by region by state interaction**. This suggest that the impact of specific frontal regions on emotional states are idiosyncratic to each person.

	% Explained Variance	Generalizability	Dependability
Trait (N=36)	8.23%	0.32	0.28
Region (N=3)	0.49%	0.36	0.09
Emotional State (N=3)	9.79%	0.92	0.83
Reference Scheme (N=3)	1.33%	0.61	0.22
Trait by Region	11.57%		
Trait by State	11.42%		
Trait by Reference Scheme	16.62%		
Region by State	0.46%		
Region by Reference Scheme	0.22%		
State by Reference Scheme	0.46%		
Trait by Region by State	19.73%		
Trait by State by Reference Scheme	3.79%		
Trait by Region by Reference Scheme	11.75%		
Region by State by Reference Scheme	0.15%		
Trait by State by Region by Reference Scheme, error	3.98%		

Specific Trait and State Reliabilities in State Measurements

- Using data from state recordings of frontal EEG asymmetry, the table below presents reliability coefficients for both state and trait asymmetries across other sources of variance ***specifically*.**
- **Notice that reliability coefficients for trait asymmetries increase dramatically when calculated for one specific other source of variance at a time!**

	Generalizability	Dependability
Trait Across Reference Scheme only	0.60	0.58
Trait Across Region Only	0.68	0.67
Trait Across Emotional State Only	0.68	0.54
State Across Reference Scheme only	0.98	0.94
State Across Region Only	0.98	0.97
State Across Trait Only	0.97	0.95

State Changes in Frontal EEG Asymmetry are Highly Reliable

- When state changes in frontal EEG asymmetry occur as a function of emotion, they tend to reliably occur in the same ways across individuals, reference schemes, and even specific frontal regions.

Trait Frontal EEG Asymmetry is Moderately Reliable

- Trait frontal EEG asymmetry shows moderate to low generalizability and dependability when extracted from measurements of frontal EEG activity occurring during emotional states.
- When specifically tested across emotional states only, however, trait variance is highly reliable (approx. 0.70), suggesting that **trait variance is likely to be preserved, in both relative and absolute terms, during emotional states**, other sources of unreliability notwithstanding.
- **Trait variance in frontal EEG asymmetry appears to be more reliable when recorded at rest.**

Reference Scheme Affects Trait More Strongly Than State

- Reference scheme accounted for very little systematic variance on its own during state manipulations, but did interact with trait in an idiosyncratic fashion for each person.
- In emotional state recordings, the relative reliability of reference scheme effects is fairly high, while the absolute reliability of reference scheme is very low.
- In sum, these results suggest that **reference scheme effects are 1) a function of individual participants, 2) reliable within individuals and emotional tasks, and 3) relatively random in absolute terms**--that, is their effects are random across individuals and states, but stable within individuals and states.

For More Reliable Trait Frontal EEG Asymmetry Estimates, Measure During Rest, on Four Measurement Occasions.

- Applied to these coefficients, the Spearman-Brown Prophecy formula suggests that measurements of trait frontal EEG asymmetry should be highly reliable across each of the sources of unreliability assessed here, if averaged across four measurement occasions.
- Specifically, **extracting trait variance from four measurement occasions should increase the generalizability and dependability of trait frontal EEG asymmetries recorded at rest from 0.44 and 0.43 to 0.76 and 0.75, respectively.**
- **Single occasions of measurement are sufficient, however, for reliable estimates of state-dependent frontal EEG effects.**