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Circadian and seasonal variability of resting frontal EEG asymmetry

Carly K. Peterson *, Eddie Harmon-Jones

Texas A&M University, Department of Psychology, 4235 TAMU, College Station, TX 77843, United States

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ABSTRACT

Asymmetrical frontal cortical activity at resting baseline relates to important aspects of personality and psychopathology. However, some research has failed to replicate these relationships, perhaps because of situational influences. The present research investigates two situational variables, circadian and seasonal variability. These variables affect basal cortisol levels and mood, which have also been found to relate to resting asymmetrical frontal activity. Results of two correlational studies revealed that relative right frontal activity was greatest during fall mornings. These results suggest the importance of assessing time of day (TOD) and time of year (TOY) effects on resting frontal EEG asymmetry, which could reflect circadian and seasonal influences, but also selection effects when participants are free to select among study session times.

Asymmetrical frontal cortical activity at resting baseline is related to important aspects of personality and psychopathology (Coan and Allen, 2004; Harmon-Jones, 2003). For example, greater relative right frontal activity has been related to more depression. Methodological and conceptual questions have emerged about the status of the relationship between individual differences and asymmetrical frontal cortical activity. On the conceptual front, research has compared a valence model with a motivational direction model. In response, research has supported the motivational direction model, which suggests that relative left frontal activity is related to approach motivation, whereas relative right frontal activity is related to withdrawal motivation (Peterson et al., 2008; van Honk and Schutter, 2006). On the methodological front, some have questioned the replicability of the relationship between emotive individual differences and resting, baseline frontal asymmetry (Reid et al., 1998). In response, research has suggested that when examining individual differences in frontal asymmetry, multiple recording sessions are necessary, because only half of the variance in a resting session is due to trait influences (Hagemann et al., 2002, 2005). However, to date, little research has investigated the role of state influences on resting, baseline asymmetrical frontal activity (see Hagemann, 2004). The present research sought to fill this gap.

Two variables present in every study session that may influence baseline asymmetrical frontal activity are time of day (TOD) and time of year (TOY). Yet, all past research has failed to control for these variables. Importantly, both variables have been found to relate to other measures that are related to asymmetrical frontal cortical activity.

The first variable, TOY, influences basal cortisol and mood. With cortisol, levels are highest in fall and winter and lowest in spring (King et al., 2000; Walker et al., 1997). With mood, depression is more likely in fall or winter and remits in spring (Nayyar and Cochrane, 1996). These changes in mood range from normal variations in sadness experienced by most individuals (Nayyar and Cochrane, 1996) to severe variations such as Seasonal Affective Disorder (SAD; e.g. Partonen and Lönnqvist, 1998). Treatment for depression is also more effective in the spring compared to the fall and winter (Wirz-Justice, 2005). More recent research has shown that an individual's seasonality (i.e. seasonal changes in mood and behavior) relates to non-seasonal depression and anxiety, and that even individuals with low to moderate seasonality show a modest increase in depressive symptoms during the winter (Oyane et al., 2008).

Research stemming from seasonal variations of mood has found that TOY also affects the P3 (P300) event-related brain potential (Polich and Geisler, 1991). This research demonstrated that P3 amplitude, which is hypothesized to reflect updating of working memory (Donchin and Coles, 1988; Donchin et al., 1986), is greatest in the spring and summer months (Polich and Geisler, 1991). Recently, P3 amplitude over the frontal cortical regions has been linked to approach sensitivity, suggesting that this ERP may hold similar qualities as EEG alpha power (Peterson et al., 2008). Based on this research and research linking cortisol and mood with TOY, we predicted that season might affect frontal EEG asymmetry.

* Corresponding author. Tel.: +1 979 458 4056; fax: +1 979 845 4727.
E-mail addresses: carlypeterson@gmail.com (C.K. Peterson), eddiehj@gmail.com (E. Harmon-Jones).

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More specifically, we predict that relative right frontal activity will be greater in the fall than in the spring.

The second variable present in every study is TOD. Basal cortisol levels follow a circadian rhythm, with higher levels appearing following awakening, and then decreasing throughout the rest of the day, with lowest levels at night (King et al., 2000; Van Cauter, 1989). Also, greater basal cortisol levels have been found to correlate directly with relatively greater right than left frontal cortical activity (Buss et al., 2003; Kalin et al., 1998; Rilling et al., 2001). Importantly, both variables relate to withdrawal motivation. Greater relative right frontal activity is associated with withdrawal-related emotions such as fear (Tomarken et al., 1990), disgust (Davidson et al., 1990), anxiety (Davidson et al., 2000) and depression (Henriques and Davidson, 1991). Similarly, cortisol potentiates fear (Schulkin et al., 1998), and higher levels have been associated with shyness (Schmidt et al., 1997) and anxious depression (Schulkin et al., 1998). Interestingly, mood is also affected by circadian cycles, so that we tend to wake up in a slightly negative mood, but as the day goes on our moods become more positive (Wirz-Justice, 2005). This pattern is consistent with the idea of greater right frontal activity in the mornings developing into greater left frontal activity later in the day. Thus, we predicted that relative right frontal activity at resting baseline might be greatest in the morning. Finally, it is possible that TOD interacts with season to predict relative right frontal activity, such that fall mornings may be associated with greater relative right frontal activity as compared to other times.

As noted above, all past studies on resting frontal asymmetry have not controlled for TOD or season. That is, studies could have been conducted during morning or afternoon only, during fall or spring only, or during all parts of the day and all seasons. Also, in studies conducted during all parts of the day and all seasons, participants could chose when to participate, and researchers did not statistically control for TOD or season. Thus, in the current study, we sought to examine whether these ever-present and freely floating variables may have affected past participants' resting frontal asymmetries by examining the effect of TOD and season on frontal asymmetry. Because we wanted our study to be similar to past studies on resting frontal asymmetry, our participants were not randomly assigned to the TOD or season. What we wanted to examine is whether or not there is variability in resting frontal asymmetry related to TOD and/or TOY (or perhaps participants' selection of such times) that could assist in explaining why some past studies failed to replicate relationships between frontal asymmetry and other individual difference characteristics (for a review, see Coan and Allen, 2004). Of course, this renders the present studies correlational ones (like all past studies on resting baseline frontal asymmetry). Because both circadian rhythms and seasons have been found to influence variables related to asymmetrical frontal cortical activity, we speculated that TOY might moderate the effects of TOD on relative right frontal activity at baseline. Specifically, relative right frontal activity may be at its greatest in fall mornings as compared to fall afternoons and spring mornings and afternoons.

Additionally, it may be that these predicted effects could also be found over the parietal region. Although parietal asymmetry is typically only examined in a comparative nature (e.g. Schaffer, Davidson et al., 1983), research has demonstrated that anxious-depressed individuals evidence greater relative right parieto-temporal activity compared to nonanxious-depressed individuals (Bruder et al., 1997). Therefore, given the associations between anxiety, depression and cortisol (Schulkin et al., 1998), it may be possible that relative right parietal activity will also show circadian and/or seasonal variability.

1. Study 1

1.1. Method

1.1.1. Participants and materials

One hundred and eleven (91 female[1]) introductory psychology students at Texas A&M University (Latitude 30.61N, Longitude −96.32W) participated in exchange for course credit; 33 participants were run in the spring and summer months (12 before 12:00 p.m., 21 after 12:00 p.m.), and 78 were run in the fall and winter months (19 before 12:00 p.m., 59 after 12:00 p.m.)[2].

Seventy-two of the participants completed the revised Interpersonal Adjective Scales (IAS-R; Wiggins et al., 1988) prior to EEG collection. The IAS-R is a broad measure of personality composed of eight variables arranged in a circular ordering around the underlying dimensions of nurturance and dominance. It is made up of single adjectives rated on an eight-point scale ranging from "extremely inaccurate" to "extremely accurate." The 64 items comprise eight scales: Assured-Dominant, Arrogant-Calculating, Cold-hearted, Aloof-Introverted, Unassured-Submissive, Unassuming-Ingenuous, Warm-Agreeable, and Gregarious-Extraverted.

1.1.2. Data collection and reduction

To record EEG, 27 tin electrodes mounted in a stretch-lycra electrode cap (Electro-Cap, Eaton, OH) were placed on the participant's head. The ground electrode was mounted in the cap on the mid-line between the frontal pole and the frontal site. The reference electrode was placed on the left ear, and data were also acquired from an electrode on the right ear, so that an off-line, averaged ears' reference could be computed. All electrode impedances were under 5000 Ω, and homologous sites were within 1000 Ω of each other. Vertical and horizontal eye movements (EOG) were also recorded to facilitate artifact correction of the EEG. EEG and EOG were amplified (an analog 60 Hz notch filter was enabled) with Neuroscan Synamps (El Paso, TX), bandpass filtered (0.1–100 Hz) and digitized at 500 Hz. Four minutes of resting data were acquired; 2 min eyes open (O) and 2 min eyes closed (C). Two sequences were used, O–C–C–O and C–O–O–C, and they alternated by participant.

Following data acquisition, the signals were visually scored and portions of the data that contained artifacts were removed. Then, a regression-based eye movement correction was applied (Semlitsch et al., 1986) after which the data were again visually inspected, to insure that proper correction was done. All epochs 1.024 s in duration were extracted through a Hamming window. A fast Fourier transform was used to calculate the power spectra, which were averaged across epochs of each resting minute. Total power within the alpha band (8–13 Hz) was obtained. Asymmetry indexes were created for homologous frontal sites (F3/4, F7/8) and parietal sites (P3/4; for comparison purposes) by taking natural log right minus natural log left. Because alpha power is inversely related to cortical activity, higher asymmetry scores indicate greater relative left than right activation (Davidson et al., 2000).

2. Results

To examine the effect of TOD and TOY on resting asymmetry, both variables were centered and entered into a regression

[1] For both studies, additional analyses were conducted in which sex of participant was included as a predictor of resting asymmetry. No significant Sex × TOD × TOY interactions were found ($ps > .26$), and all TOD × TOY interactions remained significant ($ps < .05$). Also, in both studies, after baseline EEG data were collected, participants performed one of four separate studies not relevant to the present concerns; most of those data are currently being analyzed but data from one study is published (Peterson et al., 2008).

[2] Breakdown of participants run by month: March, 11; April, 10; May, 3; June, 5; July, 2; August, 2; September, 29; October, 33; November, 15; December, 1.