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Review

The role of asymmetric frontal cortical activity in emotion-related phenomena: A review and update

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ABSTRACT

Conceptual and empirical approaches to the study of the role of asymmetric frontal cortical activity in emotional processes are reviewed. Although early research suggested that greater left than right frontal cortical activity was associated with positive affect, more recent research, primarily on anger, suggests that greater left than right frontal cortical activity is associated with approach motivation, which can be positive (e.g., enthusiasm) or negative in valence (e.g., anger). In addition to reviewing this research on anger, research on guilt, bipolar disorder, and various types of positive affect is reviewed with relation to their association with asymmetric frontal cortical activity. The reviewed research not only contributes to a more complete understanding of the emotive functions of asymmetric frontal cortical activity, but it also points to the importance of considering motivational direction as separate from affective valence in psychological models of emotional space.

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The role of regional cortical activity, particularly hemispheric lateralization, in emotions has been the subject of interest for several decades. Over the last decade, research on asymmetric frontal cortical activation and emotion has flourished. Consequently, this review will focus primarily on this body of work. Other work on the role of asymmetric parietal cortical activation and emotional processes, though not as extensive, will be reviewed briefly. The review will focus primarily on electroencephalographic (EEG) measures of asymmetric cortical activation because these measures have been used most frequently in examinations of lateralizations of emotional functions.

1. Asymmetric frontal cortical activity and the experience of affective valence

The asymmetric involvement of prefrontal cortical regions in positive affect (or approach motivation) and negative affect (or withdrawal motivation) was suggested over 70 years ago by observations of persons who had suffered damage to the right or left anterior cortex (Goldstein, 1939). Later research supported these observations using the Wada test, which involves injecting amytal, a barbiturate derivative, into one of the internal carotid arteries and suppressing the activity of one hemisphere. Amytal injections in the left side produced depressed affect, whereas injections in the right side produced euphoria (Terzian and Cecotto, 1959; Alema et al., 1961; Perria et al., 1961; Rossi and Rosadini, 1967). These effects were interpreted as reflecting the release of one hemisphere from contralateral inhibitory influences. Thus, activation in the right hemisphere, when not inhibited by the left hemisphere, caused depression; an uninhibited left hemisphere caused euphoria.

Subsequent studies appeared to confirm these results, finding that persons who had suffered left hemisphere damage or lesions tended to show depressive symptoms (Black, 1975; Gasparrini et al., 1978; Gainotti, 1972; Robinson and Price, 1982), whereas persons who had suffered right hemisphere lesions tended to show manic symptoms (Gainotti, 1972; Robinson and Price, 1982; Sackeim et al., 1982). Other research has revealed asymmetries underlying appetitive and avoidant behaviors in non-human animals, in species ranging from great apes and reptiles (Deckel et al., 1998; Hopkins et al., 1993) to chicks (Güntürkün et al., 2000), amphibians (Rogers, 2002), and spiders (Ades and Ramires, 2002).

More recent research suggests that in humans these asymmetric activations are often specific to the frontal cortex. This research often uses asymmetric activation in right versus left frontal cortical areas as a dependent variable, usually assessed by EEG recordings. Frontal cortical asymmetry is assessed by comparing activation levels between comparable areas on the left and right sides. Difference scores are widely used in this research, and their use is consistent with the amytal and lesion research described above that suggests that asymmetry may be the key variable with one hemisphere inhibiting the opposite one. Consistent with that view is evidence from studies of transcranial magnetic stimulation, discussed later in the article (Schutter, 2009; Schutter et al., 2001).

Much of this evidence has been obtained with EEG measures of brain activity, or more specifically, alpha frequency band activity derived from the EEG. Research has revealed that alpha power is inversely related to regional brain activity using hemodynamic measures (Cook et al., 1998) and behavioral tasks (Davidson et al., 1990).

2. Trait affective styles and resting asymmetric frontal activity

In the EEG research, depression has been found to relate to resting frontal asymmetric activity, with depressed individuals showing relatively less left than right frontal brain activity (Jacobs and Snyder, 1996; Schaffer et al., 1983), even when in remission status (Henriques and Davidson, 1990). Other research has revealed that trait positive affect is associated with greater left than right frontal cortical activity, whereas trait negative affect is associated with greater right than left frontal activity (Tomarken et al., 1992). In addition, 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).

Although there have been several replications of the above effects (e.g., Allen et al., 1993), there have also been failures to replicate (Reid et al., 1998). In response, research has suggested that half of the variance in a resting session is due to trait influences with the remaining half due to state influences (Hagemann et al., 2002, 2005). Thus, the presence of strong and varying situational influence could cause failures to replicate some trait results.

Two situational variables that may influence baseline asymmetric frontal activity are time of day and time of year. Both variables have been found to relate to other measures that are related to asymmetric frontal cortical activity. First, time of year influences basal cortisol and mood. Cortisol levels are highest in fall and winter and lowest in spring (King et al., 2000; Walker et al., 1997). Depressed mood is higher in fall and winter and lower in spring (Nayyar and Cochrane, 1996; Oyane et al., 2008; Partonen and Lonnqvist, 1998). As noted above, greater depression is associated with lesser left frontal activity. Also, greater basal cortisol levels correlate directly with relatively greater right than left frontal cortical activity measured at resting baseline (Buss et al., 2003; Kalin et al., 1998; Rilling et al., 2001). Higher basal cortisol levels have been associated with shyness (Schmidt et al., 1997) and anxious depression (Schulkin et al., 1998). Second, time of day influences basal cortisol levels, with increased levels in the morning, and then decreasing levels throughout the rest of the day, with lowest levels at night (King et al., 2000; Van Cauter, 1989). Also, mood is affected by circadian cycles, so that moods are more negative in the morning and become more positive as the day goes on (Wirz-Justice, 2005).

Because depressed mood and basal cortisol levels correlate with asymmetric frontal cortical activity at baseline, Peterson and Harmon-Jones (2009) predicted that time of day and time of year may be correlated with asymmetric frontal cortical activity. More specifically, relative right frontal activity at resting baseline may be greatest in fall mornings compared to other times. To test this prediction, we simply assessed the relationship between time of day and time of year on resting asymmetric frontal activity. Results of two studies revealed that relative right frontal activity was indeed greatest during fall mornings. Additional analyses suggested that this relationship was not due to subject selection. These results suggest that time of day and time of year may explain why some past studies failed to replicate relationships between frontal asymmetry and other individual difference characteristics. Also, they suggest that these variables be measured and/or controlled in future studies.

Additional, yet-to-be discovered variables may similarly influence resting baseline asymmetric activity. Based on existing