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Review

Contributions from research on anger and cognitive dissonance to understanding the motivational functions of asymmetrical frontal brain activity

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Abstract

Research has suggested that approach-related positive emotions are associated with greater left frontal brain activity and that withdrawal-related negative emotions are associated with greater right frontal brain activity. Different explanations have been proposed. One posits that frontal asymmetry is due to emotional valence (positivity/negativity), one posits that frontal asymmetry is due to motivational direction (approach/withdrawal), and one posits that frontal asymmetry is due to a combination of emotional valence and motivational direction (positive-approach/negative-withdrawal). Because research had confounded emotional valence and motivational direction, the theoretical explanation was muddled. Solely supporting the motivational direction model, recent research has revealed that anger and cognitive dissonance, emotions with negative valence and approach motivational tendencies, are related to relatively greater left frontal activity.

Keywords: Frontal EEG asymmetry; Emotion; Anger; Cognitive dissonance

1. Introduction

Over the past two decades, a variety of research approaches have pointed to the importance of the left and right frontal brain regions in emotion and motivation. Research has suggested that left frontal brain activity is associated with positive emotions and approach behavior and right frontal brain activity is associated with negative emotions and withdrawal behavior. This research has created an impression that high levels of left frontal

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activity are preferred to low levels of left frontal activity. Several popular press articles have appeared in the New York Times, Parade Magazine, and other sources echoing the message advanced by several researchers (e.g., Fox et al., 2001; Davidson, 1998) that relatively high left frontal brain activity is more psychologically and physically healthy than relatively less left frontal brain activity. This theoretical model is widely accepted, even among researchers who are not involved in research on the frontal asymmetry (e.g., Oatley and Jenkins, 1996; Zajonc and McIntosh, 1992). Indeed, researchers have begun to use the past findings regarding the association of left frontal activity with more positive outcomes in creating treatment strategies such as biofeedback (e.g., Baehr et al., 1997; Rosenfeld et al., 1995). However, in this article, I review research that casts doubt on the assumption that increased left frontal activity is always beneficial. Although several studies have found left frontal activity to be associated with positive emotions, recent research has indicated that these findings resulted because the past research confounded approach motivation with positive emotional valence. Appetitive motivations are not always associated with positive affects. Anger, greed, lust, and mania are some examples of approach motivations that may have deleterious consequences. In this article, I will briefly review research on the relationship between emotion/motivation and asymmetrical frontal brain activity. I will then describe several theoretical explanations of the research results. After reviewing the various theoretical explanations, I will review recent research on the emotion of anger and the emotive state of cognitive dissonance that has favored the motivational direction view over the other views. Finally, I broadly consider this recent research for theories and research on emotion.

2. Asymmetrical frontal brain activity and emotion

Broadly speaking, research on frontal asymmetry has proceeded along three lines: (1) examinations of the relationship between behavioral or experiential indices of trait affect/motivation and resting electroencephalograph activity (EEG); (2) examinations of the relationship between resting EEG and responses to emotion-eliciting stimuli; and (3) examinations of EEG changes during exposure to emotionally evocative situations.[1] To begin, I will briefly review representative findings from each of these empirical approaches.

[1] Much of the research on asymmetrical frontal brain activity has assessed the activity using alpha frequency band activity derived from the electroencephalograph (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). Additional data from individuals with brain damage supports the research reviewed in this article (e.g., Robinson and Downhill, 1995). Because the majority of research on the frontal asymmetry has used EEG alpha power, the review focuses on this research. In addition, in the review, I use the term brain activity to refer to the inverse of alpha power, as is commonly done in this literature. Moreover, I reserve the use of the term activation to refer to state-induced changes in EEG, whereas activity can refer to state or trait (baseline) EEG. Finally, the term relative left frontal activity (or activation) is used to describe greater left than right frontal activity—a difference or asymmetry score.

3. Examinations of the relationship between indices of trait affect/motivation and resting EEG

3.1. Depression

Depression has been found to relate to resting frontal asymmetrical activity, with depressed individuals showing relatively less left than right frontal brain activity. This relationship between depression and asymmetrical frontal activity has been found in individuals identified by self-report indices of depression (Jacobs and Snyder, 1996; Schaffer et al., 1983), and individuals identified through clinical interviews (Allen et al., 1993). Moreover, relatively less left frontal activity has been found in individuals who were previously clinically depressed but were in remission status (Henriques and Davidson, 1990).

3.2. Positive and negative affect

Other research has revealed that trait positive affect is associated with greater left than right frontal brain activity, whereas trait negative affect is associated with greater right than left frontal brain activity (e.g., Tomarken et al., 1992a). In this past research, trait positive affect and negative affect were assessed using the Positive and Negative Affect Schedule (Watson et al., 1988). These affects are best described as activated positive affect and activated negative affect (Watson et al., 1999), as the measures include words such as interested and active on the positive affect scale, and afraid and distressed on the negative affect scale.

3.3. Behavioral activation/behavioral inhibition

Other research has found that trait behavioral activation sensitivity (BAS) relates to greater left than right frontal brain activity (Coan and Allen, 2003; Harmon-Jones and Allen, 1997; Sutton and Davidson, 1997). In this research, BAS was measured by Carver and White's (1994) behavioral inhibition sensitivity (BIS)/BAS questionnaire, which includes items such as "When I want something, I usually go all-out to get it." Regarding the relationship of behavioral inhibition sensitivity (BIS; "I worry about making mistakes."), studies have produced inconsistent results, with one finding a significant relationship between BIS and greater right than left frontal activity (Sutton and Davidson, 1997) and the two others finding a non-significant relationship (Coan and Allen, 2003; Harmon-Jones and Allen, 1997). It is possible that BIS is not equivalent to withdrawal motivation (see Harmon-Jones and Allen, 1997).

4. Examinations of the relationship between resting EEG and responses to emotion-eliciting stimuli

Resting baseline frontal asymmetrical activity has been found to predict emotional responses. Individuals with relatively greater right than left frontal activity exhibit larger negative affective responses to negative emotion-inducing films (fear and disgust) and smaller

positive affective responses to positive emotion-inducing films (happiness) (Tomarken et al., 1990; Wheeler et al., 1993). In a related vein, research has found that resting baseline frontal asymmetrical activity predicted evaluative responses to merely exposed stimuli (Harmon-Jones and Allen, 2001). That is, individuals with relative right frontal activity reported more favorable attitudes toward familiarized stimuli (safety) than did individuals with relative left frontal activity. Other research has found that relative right frontal activity at baseline predicts crying in response to maternal separation in 10-month-old infants (Davidson and Fox, 1989).

Although these effects are based on correlational evidence and hence subject to alternative explanations, recent research has more strongly suggested that the frontal asymmetry is causally involved in the production of these emotional responses. In this experiment, biofeedback training was used to manipulate the frontal asymmetry (Allen et al., 2001). Participants were randomly assigned to receive biofeedback training designed to increase right frontal relative to left frontal activity or to receive training in the opposite direction. Five consecutive days of biofeedback training provided signals of reward (300 Hz reward tone) or nonreward (150 Hz nonreward tone) depending on whether the difference between right and left frontal activity exceeded a criterion value. Systematic alterations of frontal asymmetry were observed as a function of biofeedback training. Moreover, subsequent self-reported affect in response to emotionally evocative film clips were significantly influenced by the direction of biofeedback training. That is, individuals trained to increase left frontal activity reported more positive affect in response to the happy film clip than individuals trained to increase right frontal activity. These results suggest that the frontal asymmetry can be altered using biofeedback training and that this alteration can affect emotional responses. Taken together with previous research, this experiment suggests that the frontal asymmetry is causally involved in the production of emotional experience.

5. Examinations of EEG activity during exposure to emotionally evocative situations

Research has also demonstrated that asymmetrical frontal brain activity is associated with state emotional responses. For instance, Davidson and Fox (1982) found that 10-month-old infants exhibited increased left frontal activation in response to a film clip of an actress generating a happy facial expression as compared to responses exhibited to a film clip of an actress generating a sad facial expression. Frontal brain activity has been found to relate to facial expressions of positive and negative emotions, as well. For example, Ekman and Davidson (1993) found increased left frontal activation during voluntary facial expressions of smiles of enjoyment (i.e., activation of zygomatic major with concurrent activation of orbicularis oculi, pars lateralis) as compared to voluntary facial expressions of smiles not associated with enjoyment (i.e., activation of zygomatic major without orbicularis oculi, pars lateralis). More recently, Coan et al. (2001) found that voluntary contractions of the facial musculature to form a happy facial expression produced relatively greater left frontal activity, and that voluntary contractions of the facial musculature to form a fearful facial expression produced relatively less left frontal activity.

6. Explanations of the relationship between asymmetrical frontal brain activity and emotion

Primarily, there have been three conceptual models designed to explain the observed results. The first view has posited that the left frontal brain region is involved in the experience and expression of positive emotion and that the right frontal brain region is involved in the expression and experience of negative emotion (e.g., Ahern and Schwartz, 1985; Gotlib et al., 1998; Heller, 1990; Heller and Nitschke, 1998; Silberman and Weingartner, 1986). Indeed, this theoretical model is widely accepted (e.g., Oatley and Jenkins, 1996; Zajonc and McIntosh, 1992). Most of the results can be explained with this model, which I refer to as the valence model.

A second view has posited that the left frontal brain region is involved in expression of approach-related emotions and that the right frontal brain region is involved in expression withdrawal-related emotions (Davidson, 1995; Fox, 1991; Harmon-Jones and Allen, 1997; Sutton and Davidson, 1997). Again, the obtained results can be accommodated by this model, which I refer to as the motivational direction model. That is, the affects and emotions that have been examined in the research are all associated with approach or withdrawal motivation. The approach-related emotions have been found to be associated with relatively greater left frontal activity, whereas the withdrawal-related emotions have been found to be associated with relatively greater right frontal activity.

A third view has posited that the left frontal brain region is involved in the expression and experience of positive, approach-related emotions and that the right frontal brain region is involved in the expression and experience of negative, withdrawal-related emotions (Davidson, 1998; Tomarken and Keener, 1998). The obtained results can also be accommodated by this model, which I refer to as the valenced motivation model. That is, the positive affects and emotions that have been examined in the research are all associated with approach motivation, and the negative affects and emotions that have been examined are all associated with withdrawal motivation.

Because the previously conducted research confounded the valence of the emotion with the direction of motivation, it is unable to address whether the frontal asymmetry reflects the valence of the emotion, the direction of the motivation, or a combination of valence and motivation. Often, positive emotion is associated with approach-related motivation, whereas negative emotion is associated with withdrawal-related motivation. Indeed, most contemporary theories of emotion posit that positive emotion is always associated with approach motivation and that negative emotion is always associated with withdrawal motivation emotion (e.g., Watson, 2000; for a different point of view, see Carver, 2001). However, not all emotions behave in accord with this presumed relationship between the valence of emotion and direction of motivation. Anger is one of the best examples of a violation of the relationship, because anger is negative in valence (e.g., Lazarus, 1991; Watson et al., 1999), but it often evokes approach motivation (e.g., Berkowitz, 1999; Darwin, 1872/1965; Plutchik, 1980; Young, 1943).

To address the primary emotional/motivation functions of asymmetrical frontal brain activity, my colleagues and I have been examining the emotion of anger, as it is often considered a negative emotion that evokes approach motivational tendencies. By examining the

emotion of anger, we are in a position to answer precisely what the emotional/motivational functions of asymmetrical frontal brain activity are.

7. Anger and approach motivation

Before reviewing the research on anger and asymmetrical frontal activity, it is important to consider whether anger is associated with approach motivation. Several lines of research suggest that anger elicits behavioral approach or approach motivation tendencies. In what follows, I briefly review representative research supporting the idea that anger is associated with approach inclinations.

7.1. Behavioral evidence

In the animal behavior literature, a distinction has been made between offensive or irritable aggression and defensive aggression (Flynn et al., 1970; Moyer, 1976). It has been posited that irritable aggression results from anger and that pure irritable aggression "involves attack without attempts to escape from the object being attacked" (Moyer, 1976, p. 187). A number of aggression researchers have suggested that offensive aggression is associated with anger, attack, and no attempts to escape, whereas defensive aggression is associated with fear, attempts to escape, and attack only if escape is impossible (Blanchard and Blanchard, 1984; Lagerspetz, 1969; Moyer, 1976). In demonstrating that organisms evidence offensive aggression and that this is an approach behavior, Lagerspetz (1969) found that under certain conditions mice would cross an electrified grid to attack another mouse.

In other research with adult humans, Baron (1977) demonstrated that angry individuals are reinforced positively by signs of their tormentor's pain. The participants who had been deliberately provoked by another individual had a sanctioned opportunity to assault him in return. Indications that their first attacks were hurting their target led to intensified aggression even though the unprovoked participants reduced the intensity of their punishment at learning of the other's pain. The initial signs of their victim's suffering showed the angry persons they were approaching their aggressive goal and thus evoked even stronger assaults from them. Other research is consistent with these findings (e.g., Berkowitz et al., 1981).

In addition, Lewis et al. (1992) found that infants who expressed anger during extinction maintained interest during subsequent relearning, whereas infants who expressed sadness during extinction evidenced decreased interest during relearning. Thus, subsequent to frustrating events, anger may maintain and increase task engagement and approach motivation.

7.2. Subjective evidence

Additional support for the idea that anger is associated with approach motivation comes from research testing the conceptual model that integrated reactance theory with learned helplessness theory (Wortman and Brehm, 1975). According to this model, how individuals respond to uncontrollable outcomes depends on their expectation of being able to control the outcome and the importance of the outcome. When an individual expects to be able to control outcomes that are important, and those outcomes are found to be uncontrollable,

psychological reactance should be aroused. Thus, for individuals who initially expect control, the first few bouts of uncontrollable outcomes should arouse reactance, a motivational state aimed at restoring control. After several exposures to uncontrollable outcomes, these individuals should become convinced that they cannot control the outcomes and should show decreased motivation (i.e., learned helplessness). In other words, reactance will precede helplessness for individuals who initially expect control. In one study testing this model, individuals who exhibited angry feelings in response to one unsolvable problem had better performance and were presumably more approach motivated on a subsequent cognitive task than did participants who exhibited less anger (Mikulincer, 1988).

Other research has revealed that state anger relates to high levels of self-assurance, physical strength, and bravery (Izard, 1991), inclinations associated with approach motivation. Additionally, Lerner and Keltner (2001) found that anger (both trait and state) is associated with optimistic expectations, whereas fear is associated with pessimistic expectations. Moreover, happiness was associated with optimism, making anger and happiness appear more similar to each other in their relationship with optimism than fear and anger. Although Lerner and Keltner (2001) interpreted their findings as being due to the appraisals associated with anger, it seems equally plausible that it was the approach motivational character of anger that caused the relationship of anger and optimism. That is, anger creates optimism because anger engages the approach motivational system and produces greater optimistic expectations.

7.3. Hormonal and physiological evidence

Further evidence supporting the conceptualization of anger as involving approach and not withdrawal comes from research on testosterone, which has been found to be associated with anger and aggression in humans (e.g., Olweus, 1986). In this research, testosterone treatments have been found to decrease withdrawal (fear) responses in a number of species (e.g., Boissy and Bouissou, 1994; Vandenheede and Bouissou, 1993). Other research has demonstrated that damage to the amygdala, a brain region involved in defensive behavior, has no effect on offensive aggression but reduces reactivity to nonpainful threat stimuli (Blanchard and Takahashi, 1988; Busch and Barfield, 1974).

7.4. Individual differences evidence

Other evidence supporting the idea that anger is associated with an approach-orientation comes from research on bipolar disorder. The emotions of euphoria and anger often occur during manic phases of bipolar disorder (Cassidy et al., 1998; Depue and Iacono, 1989; Tyrer and Shopsin, 1982). Both euphoria and anger may be approach-oriented processes, and a dysregulated or hyperactive approach system may underlie mania (Depue and Iacono, 1989; Fowles, 1993). Research suggests that hypomania/mania involves increased left frontal brain activity and approach motivational tendencies. In this research, it has been found that individuals who have suffered damage to the right frontal cortex are more likely to evidence mania (see review by Robinson and Downhill, 1995). Thus, this research is consistent with the view that mania may be associated with increased left frontal activity and increased approach tendencies, because the approach motivation functions of the left frontal cortex are released and not restrained by the withdrawal system in the right frontal

cortex. Furthermore, lithium carbonate, a treatment for bipolar disorder, reduces aggression (Malone et al., 2000), suggesting that anger and aggression correlate with the other symptoms of bipolar disorder. In addition, trait anger has been found to relate to high levels of assertiveness and competitiveness (Buss and Perry, 1992). These lines of research suggest that anger is associated with a number of approach-related individual differences characteristics.

Recently, two additional individual differences studies were conducted to test the hypothesis that trait anger is related to trait approach motivation, or more specifically, trait BAS (Harmon-Jones, 2003). In both studies, trait BAS, as assessed by Carver and White's (1994) scale, was positively related to trait anger at the simple correlation level, as assessed by the Buss and Perry (1992) aggression questionnaire. One of the two studies found that trait anger also related to trait behavioral inhibition sensitivity at the simple correlation level. In both studies, general negative affect was statistically controlled. This was done because anger's association with general negative affect (Berkowitz, 1999, 2000; Watson, 2000) may cause the association of BIS and anger. That is, the affect of anger has two subcomponents: a nonspecific component that reflects the contribution of general negative affect (Berkowitz, 1999; Watson, 2000) and a more specific component that reflects the unique qualities of anger (Watson, 2000). In other words, at the simple correlation level, anger may be associated with BIS, but when controlling for negative affect, anger will not be associated with BIS but will only be associated with BAS. Results supported this prediction in both studies. Additional results in Study 2 revealed that BAS was positively correlated with physical aggression, and simultaneously regressing aggression onto BAS, BIS, and general negative affect revealed that physical aggression was positively related to BAS, negatively related to BIS, and positively related to negative affect. These results support the hypothesis that anger is related to approach motivation and strongly challenge theoretical models that assume that approach motivation is only associated with positive affect.

7.5. Summary of section

Because of the large body of evidence suggesting that anger is often associated with approach motivation, we examined the relationship between anger and relative left frontal activation to test whether the frontal asymmetry is due to emotional valence, motivational direction, or a combination of emotional valence and motivational direction.

8. Anger and asymmetrical frontal brain activity

8.1. Asymmetrical frontal activity and trait anger

In one of the first studies examining the relationship between anger and asymmetrical frontal brain activity (Harmon-Jones and Allen, 1998), EEG of young adolescents (M age = 13 years) was recorded as they sat quietly for 6 min. Trait anger was measured using the Buss and Perry (1992) aggression questionnaire. Results indicated that trait anger was positively related with relatively greater left than right frontal brain activity. Moreover, additional analyses revealed that high levels of trait anger were associated with increased left frontal

activity and decreased right frontal activity. These results suggest that the frontal asymmetry is associated with motivational direction (approach versus withdrawal) rather than emotional valence. In addition, in this study, general activated positive and negative affect, as assessed by the Positive and Negative Affect Schedule—Children's version (PANAS-C; Laurent et al., 1994), related to the frontal asymmetry in magnitudes similar to those found in previous research (Sutton and Davidson, 1997). That is, positive affect related to relative left frontal activity and negative affect related to relative right frontal activity. Presumably, positive affect and anger related to relative left frontal activity because both emotions are approach-related. Moreover, controlling for positive and negative affect, separately and together, did not alter the magnitude of the anger—frontal asymmetry relationship. These results suggest that anger is related to relative left frontal activity, independent of general activated positive and negative affect.

A second study was conducted to assess the validity of an alternative explanation for the relationship between anger and relative left frontal brain activity (Harmon-Jones, 2004). According to this explanation, individuals with high levels of trait anger might regard anger as a positive emotion, and this positive feeling or attitude toward anger is responsible for anger being associated with relative left frontal activity. To understand why anger might be a positive emotion, it is important to consider what is meant by positivity and negativity of emotion. Emotions can be regarded as positive or negative because of the conditions that evoked the emotion or because of the emotion's subjective feel. The emotion of anger can be viewed as negative when considering the conditions that evoked the emotion, and positive or negative when considering the subjective feel or evaluation of the emotion. Indeed, past writers have suggested in line with this latter definition that some individuals "take considerable pleasure in the experience of anger" (Ekman and Friesen, 1975, p. 81).

To address whether the relationship of anger with increased left frontal activation could be explained by the fact that individuals with high levels of trait anger enjoy the experience of anger more than individuals with low levels of trait anger, studies were conducted to first create and assess the reliability and validity of a scale that would assess attitude toward anger and second to examine the relationship of attitude toward anger with the resting frontal asymmetry (Harmon-Jones, 2004). A reliable and valid measure of feelings toward anger was created, and then it and a measure of trait anger were related to the resting frontal asymmetry. Results indicated that trait anger related to relative left frontal activity[2],

[2] Two other studies have provided additional examinations of the association of anger with the frontal EEG asymmetry. However, the results were not strongly supportive of an anger-left frontal activity relationship. In one of these experiments (Dawson et al., 1992), 21-month-old infants' facial expressions were recorded during emotion-eliciting situations. During expressions of anger, relatively greater left than right frontal activity occurred, and during expressions of sadness, relatively greater right than left activity occurred. However, the frontal asymmetry was significantly different from neutral expressions only for sad expressions and not for angry expressions. In another experiment (Fox and Davidson, 1988), 10-month-old infants evidenced greater left than right frontal activity during angry facial expressions not accompanied by crying, and greater right than left frontal activity during angry facial expressions accompanied by crying. Effects of identical direction occurred for sad facial expressions; that is, greater left than right frontal activity during sad facial expressions not accompanied by crying, and greater right than left frontal activity during sad facial expressions accompanied by crying. Because sadness and anger showed similar relations with the frontal asymmetry, it is difficult to infer from these effects whether the frontal asymmetry reflects valence or direction. Finally, both of these studies were correlational and subject to interpretational difficulties associated with correlational studies.

replicating the previous study (Harmon-Jones and Allen, 1998). Moreover, while trait anger was directly associated with a more positive attitude toward anger, the attitude toward anger did not relate to relative left frontal activity. In addition, statistically controlling for attitude toward anger did not alter the magnitude of the relationship between trait anger and relative left frontal activity. This study suggested that the relationship between trait anger and relative left frontal activity was not due to relative left frontal activity being associated with a more positive feeling toward anger. In addition, this study replicated the results of the previous one, but with a sample of young adults, whereas the first study examined adolescents who might be less controlled and more likely to translate anger into approach behavior. That anger related with relative left frontal activity in young adults (M age 19 years) suggests that the relationship is not limited to young adolescents.

8.2. Asymmetrical frontal activity and state anger

While evidence suggests that anger is a negative and approach-oriented emotion, and that trait anger is related to relative left frontal activity, it is not known how state anger relates to asymmetrical frontal brain activity. Moreover, the trait anger-relative left frontal evidence presented thus far is entirely correlational and subject to the interpretational difficulties associated with correlational results. Because past research has found asymmetrical frontal activity to be responsive to manipulations of positive-approach and negative-withdrawal states (see above review as well as Hagemann et al., 2002), it was therefore important to examine whether manipulated anger would increase relative left frontal activity.

In this state anger research, we also examined the relationship between anger-related asymmetrical frontal activity and aggression. Emotions such as anger can be conceived of as having motivational functions and as generating action tendencies (Brehm, 1999; Frijda, 1986). Of course, emotions may generate action tendencies that may not be manifest in overt behavior. However, anger often generates approach-related action tendencies that are generally aimed at resolving the anger-producing event. In the case of an insult, the action tendency may be aggression. If anger-induced relative left frontal activity is involved in approach motivational processes, then greater anger-induced left frontal activity may relate to increased aggression. Our research on trait aggression and asymmetrical frontal activity has yielded some support for this prediction, in that relative left frontal activity at baseline has been found to relate to somewhat greater self-reported trait aggression (Harmon-Jones and Allen, 1998). To assess the relationship of relative left frontal activity with aggression, we included a behavioral measure of aggression. We predicted that relative left frontal activity in response to an anger-eliciting event would relate to increased aggression.

To test these predictions, participants were randomly assigned to a condition in which they were insulted or not insulted (Harmon-Jones and Sigelman, 2001). They were informed that the study concerned personality, psychophysiology, and perception. They were also told that another participant was in another room with another experimenter, and that the study would be conducted in connection with this other participant's study. Then, they were told that there were two perception studies, the first involving person perception and the second involving taste perception. In the first ostensible study, participants wrote an essay on a social issue that they found important and they argued in support of the side of the issue

they favored (e.g., legal drinking age). Then, the other ostensible participant supposedly read and evaluated their essay. Finally, participants read the feedback provided by the other participant. The feedback was designed to be insulting or not. Immediately after the feedback manipulation, EEG was recorded.

Then, participants completed the "second perception study" that involved taste perception. This "study" allowed us to obtain a behavioral measure of aggression. In this "study," participants were told that it was very important for experimenters to remain blind to the type of tastes to which participants are exposed in taste perception studies. The experimenter explained that one way to keep experimenters blind to the tastes is to have one participant assign the tastes to the other participant. He also explained that the other participant would have to drink all that he is given. He then showed that participant six types of beverages, which consisted of 11 oz of water with 1, 2, or 3 teaspoons of sugar, apple juice, lemon juice, salt, vinegar, or hot sauce mixed into the water. Thus, each of the six types of beverages had three concentration levels. It was explained that most persons find the sugar water most pleasant and the hot sauce most unpleasant, and that the other beverages were rated in between these two extremes, with those closer to sugar being more pleasant and those closer to hot sauce being more unpleasant (presented in the following order: sugar, apple juice, lemon juice, salt, vinegar, hot sauce).

Participants were told to select one of the six types of beverages for the other participant, to pour some of each of the three concentrations into cups, and to cover the cups with lids when done. The participants were also told to label the concentration level on the bottom of each cup. The experimenter indicated that the participants may choose which type of beverage to administer and how much to administer to the other participant. The participants were also given a black sheet to cover the unused beverages when they were finished administering the beverages, to keep the experimenter blind to the type of beverage they chose. Aggression was calculated by assigning each beverage a value that corresponded to its unpleasantness. This measure of aggression is similar to a technique developed by other researchers (Lieberman et al., 1999; McGregor et al., 1998).

Results indicated that participants in the insult condition reported feeling more angry and were more aggressive than participants in the no insult condition. More importantly, participants in the insult condition evidenced greater relative left frontal activity than participants in the no insult condition. Finally, within the insult condition, participants who evidenced greater relative left frontal activity in response to the insult reported feeling more angry and behaved more aggressively.

This research supports the prediction that manipulated anger causes increased relative left frontal brain activity. In conjunction with trait-based research (Harmon-Jones, 2004; Harmon-Jones and Allen, 1998), the research demonstrates that asymmetrical frontal brain activity reflects motivational direction rather than emotional valence. In addition, results suggested that relative left frontal activity during an anger-evoking situation related to behavioral aggression.

In addition to the reviewed evidence, other research is consistent with the hypothesis that anger is associated with left frontal activity.[2] For example, D'Alfonso et al. (2000) recently used slow repetitive transcranial magnetic stimulation (rTMS) to inhibit the left or right prefrontal cortex. They found that rTMS of the right prefrontal cortex caused selective attention towards angry faces whereas rTMS of the left prefrontal cortex caused selective

attention away from angry faces. Because slow rTMS produces inhibition of cortical excitability, these results suggests that the rTMS of the right prefrontal cortex decreases its activation and caused the left prefrontal cortex to become more active. The same holds true for rTMS of the right prefrontal cortex and activation of the left prefrontal cortex. The increase in activation left prefrontal led participants to attentionally approach angry faces, as in an aggressive confrontation. In contrast, the increase in activation right prefrontal led participants to attentionally avoid angry faces, as in a frightening confrontation. The interpretation of these results, which d'Alfonso et al. advanced, concurs with other research that has demonstrated that attention toward angry faces is associated with high levels of self-reported anger and that attention away from angry faces is associated with high levels of cortisol (van Honk et al., 1998, 1999, 2001), which is associated with fear.

8.3. Manipulating the intensity of approach motivation in an anger-evoking situation

According to the motivational direction model of asymmetrical frontal activity, approach motivation is related to left frontal activity and withdrawal motivation is related to right frontal activity. Thus, increased left frontal activation occurs in response to anger-inducing situations because the increase in relative left frontal activity increases approach motivational tendencies that would assist in behavior that may rectify the anger-inducing situation. From this perspective, it follows that if no approach behavior could be taken to deal with the anger-provoking situation, then this increase in relative left frontal activation should be less. In other words, if approach and withdrawal motivational tendencies do underlie asymmetrical frontal activity, then alterations in motivational intensity should affect the degree of activation in the frontal brain regions.

Several motivational theories posit that the expectancy of success or perceived task difficulty should affect motivational intensity (for reviews, see Brehm and Self, 1989; Wright and Kirby, 2001). For the emotion of anger, if a situation creates anger and the individual believes that she can successfully act to alter the situation, then motivational intensity should be relatively high. If, on the other hand, the individual believes that no action can be taken, then motivational intensity should be relatively low. A similar prediction follows from the idea of secondary coping (Lazarus, 1991). Negative emotions including anger, sadness, guilt and fear occur when persons find themselves in aversive situations. According to Lazarus (1991), the type of negative emotion evoked by a situation may be determined by coping potential—how persons appraise their ability to deal with the aversive situation. If something can be done to resolve the situation, then anger, an active and negative emotion, should be aroused. In contrast, if nothing can be done to resolve the situation, then a passive and negative emotion, sadness, may be aroused. Theorists make similar predictions for appraisals of power (Roseman, 1991), power and control (Scherer, 1993), and likelihood of reinstatement of the goal state (Levine, 1995).

Unfortunately, little research has addressed whether appraisals of higher coping potential lead to more anger. However, research by Levine (1995) found that, when 5-year-old children were presented with scenarios in which a child experienced a negative outcome, they expected the protagonist to experience more anger and less sadness when they judged the possibility of goal reinstatement more likely and less anger and more sadness when they judged goal reinstatement less likely.

Based on the integration of ideas from the motivational model of asymmetrical frontal activity with theories of motivational intensity and how coping potential relates to anger, we predicted that greater left frontal activation would occur in response to an anger-producing event when persons believe that action can be taken to resolve the situation as compared to when persons believe that no action can be taken to resolve the situation.

To test these predictions, university students who paid a sizable portion of their tuition and who were opposed to a tuition increase were invited to an experiment ostensibly concerned with reactions to pilot radio broadcasts. They then heard an editorial in which the speaker argued forcefully for a tuition increase. Immediately prior to hearing the editorial, participants were informed that the tuition increase may occur in the future and that petitions were being circulated to attempt to prevent the increase (action-possible condition), or they were informed that the tuition increase would definitely occur (action-impossible condition). Immediately after listening to the editorial, EEG was recorded, and then participants completed a self-report emotion questionnaire. Finally, participants in the action-possible condition were given the opportunity to sign a petition and take as many petitions as they wanted to have others sign.

Results revealed that participants in the action-possible condition evidenced greater relative left frontal activity than did participants in the action-impossible condition. Moreover, within the action-possible condition, this increase in relative left frontal activity directly related to self-reported anger and behaviors aimed at rectifying the anger-producing event (i.e., whether or not they signed the petition and number of petitions taken). Interestingly, self-reported anger did not differ between the action-possible and action-impossible conditions. Both conditions reported feeling much more angry after hearing the editorial as compared to before hearing the editorial. These results suggest that the appraisal of coping potential influenced relative left frontal activity but not angry feelings (Harmon-Jones et al., 2003b).

8.4. Individual differences that predict increased relative left frontal activity during anger

The research reviewed thus far suggests that trait and state anger are related to relative left frontal activity when anger is associated with approach motivational tendencies. As mentioned earlier, past research has revealed that individual differences in behavioral approach sensitivity are related to relatively greater left frontal activity (Harmon-Jones and Allen, 1997; Sutton and Davidson, 1997). Thus, greater BAS should predispose individuals to respond with greater left frontal activity when angered. Indeed, the BAS has been posited to be involved in predatory aggression (Depue and Iacono, 1989; Gray, 1982). In addition, the BAS has been proposed to underlie types of psychopathology, with depression involving a hypoactive BAS (Fowles, 1988, 1993) and mania/hypomania involving a hyperactive BAS (Depue and Iacono, 1989; Depue et al., 1987; Meyer et al., 1999).

Based on these ideas, research examined the relationship between proneness to hypomania/mania and anger-related left frontal activity (Harmon-Jones et al., 2002). In the study, individuals with proneness toward hypomania/mania or depression symptoms were exposed to the anger-evoking radio broadcast used in the previously mentioned study (Harmon-Jones et al., 2003b). Results indicated that individuals with proneness toward hypomania/mania

evidenced greater left frontal activation when confronted with the anger-evoking situation, whereas individuals with proneness toward depression symptoms evidenced less left frontal activation when confronted with the same anger-evoking situation. These results support predictions derived from models relating mania/hypomania to BAS activity (Depue and Iacono, 1989; Fowles, 1988, 1993), models of the motivational functions of asymmetrical frontal activity (Harmon-Jones and Allen, 1997; Sutton and Davidson, 1997), and models that consider anger as part of the BAS (Depue and Iacono, 1989; Harmon-Jones and Allen, 1998, 2001; Harmon-Jones and Sigelman, 2001; Harmon-Jones et al., 2003b).

This research extends the past research on anger and frontal brain activity by revealing individual difference characteristics that predict who is more likely, as well as less likely, to respond with increased left frontal activity in anger-inducing situations. That is, individuals with proneness toward hypomania/mania symptoms evidence greater relative left frontal activity, whereas individuals with proneness toward depressive symptoms evidence lesser relative left frontal activity when confronted with an anger-evoking event. From these results, it seems plausible to predict that proneness toward hypomania/mania symptoms may predispose persons toward responding with increased approach (and decreased withdrawal) motivational tendencies given challenging or frustrating situations, whereas proneness toward depressive symptoms may predispose persons toward responding with decreased approach (and increased withdrawal) motivational tendencies given these same situations. In other words, proneness toward hypomania/mania symptoms may lead to reactance-like responses and proneness toward depressive symptoms may lead to helpless responses in the face of challenges (e.g., Abramson et al., 1989; Mikulincer, 1988; Wortman and Brehm, 1975).

8.5. On the reduction of anger-related left frontal activity

Whereas the reviewed evidence cogently links approach anger to relative left frontal activity, it would be important to establish that manipulations that reduce angry approach behaviors also reduce relative left frontal activity. To address this issue, we tested whether sympathy would reduce the relative left frontal activity typically observed during anger. Past research has suggested that experiencing sympathy for another individual can reduce aggression toward that individual (e.g., see review by Miller and Eisenberg, 1988). We hypothesized that sympathy may reduce aggression by reducing the relative left frontal activity associated with anger. To test this hypothesis, participants were told that the study concerned personality, perception, and brain activity, and that they and another student would be writing essays and evaluating each other based on the essays. Participants then wrote a persuasive essay arguing either for or against a 10% tuition increase. Then, the experimenter returned to the participants' room and handed them a folder containing a reading perspective, an essay, and a questionnaire.

The reading perspective instructions asked participants to remain completely objective (low sympathy) or to try to imagine how the other person must feel (high sympathy), as in much past sympathy research (Batson, 1991; Harmon-Jones et al., 2003a). The participant then read the essay ostensibly written by the other participant. In the essay, the other participant described his/her difficulties with having multiple sclerosis. Following the reading of the essay, the participant received an evaluation of his/her essay ostensibly written by the

other participant. The evaluation contained either neutral ratings and comments (no insult) or insulting ratings and comments (insult). Immediately after feedback manipulation, EEG was collected. Then, the participant completed a questionnaire assessing impressions of the other participant and a questionnaire assessing emotions.

Results indicated that the insult condition evoked greater self-reported anger than the no-insult condition. Also, the high sympathy condition evoked greater self-reported sympathy than the low-sympathy condition. No significant insult X sympathy condition interactions emerged for either anger or sympathy. Moreover, no significant condition differences emerged for self-reported sadness, happiness, fear, or distress.

More importantly, the insult condition evoked greater left frontal activity but only when high levels of sympathy were not first evoked for the insulting person. That is, the low sympathy/insult condition produced greater relative left frontal activity than every other condition. In addition, the low sympathy/insult condition evoked greater left frontal activity and lesser right frontal activity than every other condition, when separate estimates of left and right frontal activity were examined using methods suggested by Wheeler et al. (1993). Thus, when participants first experienced sympathy for the target person, they did not evidence increased left frontal activity when insulted. Moreover, they expressed less hostile attitudes toward the insulting person than did participants who did not first experience sympathy for the insulter. That is, the low sympathy/insult condition differed from each of the other conditions. The experiment thus suggested that the alteration of relative left frontal activity via sympathy can reduce angry aggression.

9. Dissonance and left frontal activity

The anger research has strongly supported the motivational direction model over the emotional valence model of the frontal asymmetry. In addition to this anger research, some recent evidence suggests that cognitive dissonance is associated with left frontal activity. Because cognitive dissonance is associated with negative affect (e.g., Elliot and Devine, 1994; Harmon-Jones, 2000a; Zanna and Cooper, 1974; for a review, see Harmon-Jones, 2000b), this research further supports the motivational direction model over the valence model.

The idea that dissonance caused by commitment to a course of action might be associated with left frontal activity was derived from the action-based model of cognitive dissonance (Harmon-Jones, 1999; Harmon-Jones and Harmon-Jones, 2002). The action-based model proposes that inconsistency between cognitions makes persons uncomfortable because inconsistency has the potential to interfere with effective action. From the viewpoint of the action-based model, cognitions are important because they guide the actions of an organism. When an individual holds two relatively important cognitions that are inconsistent, the potential to act in accord with them is undermined. To reduce the inconsistency and resulting negative affect, individuals engage in a variety of cognitive strategies. For example, dissonance results when one “freely chooses” to engage in behavior that is inconsistent with an attitude or belief. The “free choice” is subtly induced by the experimenter in experimental research. Numerous experiments have found that when individuals engage in such behavior, they often change their attitudes to be consistent with their recent behavior.

In other research, it has been found that after making difficult decisions (which have been found to cause dissonance), individuals value the chosen alternative and devalue the rejected alternative more than they did prior to the decision (for reviews, see Beauvois and Joule, 1996; Brehm and Cohen, 1962; Harmon-Jones, 1999). In both of these dissonance-evoking situations, dissonance occurs because there are cognitions that are inconsistent with a chosen course of action. That is, in the former situation, the past attitude is inconsistent with the current behavior. In the latter situation, the positive aspects of the rejected alternative and the negative aspects of the chosen alternative are inconsistent with the decision. The dissonance thus has the potential of interfering with the translation of the decision into effective action. According to the action-based model, attitude change produced by dissonance is the result of following through with the commitment to the behavior. The attitude change is posited to be one of a number of processes that would assist with the translation of the commitment into effective and unconflicted action. Thus, according to the action-based model, dissonance evokes a negative affective state that signals the organism that something is wrong and motivates the organism to engage in behavior to correct the problem. The correction of the problem often involves following through with the commitment to the behavior or decision. This view of dissonance is consistent with past as well as present theorizing on the function of dissonance and dissonance reduction (e.g., Beckmann and Kuhl, 1984; Harmon-Jones, 1999, 2000a; Jones and Gerard, 1967; McGregor et al., 1999; Newby-Clark et al., 2002).

To assist in translating the intention into effective action, approach motivational processes should be activated, as the individual works to successfully implement the new commitment. Thus, the increase in approach motivation should activate the left frontal cortex. Interestingly, past research findings are consistent with the idea that the left frontal cortical region may be involved in approach motivational processes aimed at resolving inconsistency. For example, event-related functional magnetic resonance imaging research has found that the left dorsolateral prefrontal cortex is more active during preparation for color naming than during preparation for word naming in a Stroop task (MacDonald et al., 2000). Moreover, more activity in this brain region was associated with less conflict (i.e., smaller reaction time interference effects). MacDonald et al. suggested that these findings support the hypothesis that the left dorsolateral prefrontal cortex is involved "in the implementation of control, by representing and actively maintaining the attentional demands of the task (p. 1837)." They also suggested that greater activity in the left dorsolateral prefrontal cortex, which implements control, should cause less conflict. Other research has suggested that activity in the anterior cingulate cortex is involved in monitoring the occurrence of errors or the presence of response conflict (e.g., Carter et al., 1998; Gerhing et al., 1993). Importantly, recent research has found increased anterior cingulate cortex activity, as measured by the event-related potential known as the error-related negativity, when behavior conflicts with the self-concept (Amodio et al., 2004). This finding suggests that even higher level conflicts, the type with which dissonance theory has been most concerned, also activate the anterior cingulate cortex.

Based on this past research, it seems plausible that dissonance (or potential response conflict, in action-based model terms) activates the anterior cingulate cortex, and then activates left dorsolateral prefrontal cortex, which assists in resolving the conflict. To test the prediction that dissonance was associated with increased left frontal cortical activity, uni-

versity students who were opposed to a tuition increase participated in a study ostensibly concerned with attitudes and personality (Harmon-Jones et al., 2000c). They were *randomly assigned* to one of two choice conditions. In the low-choice condition, participants were told they were to write an essay supporting a 10% tuition increase at their university. In the high-choice condition, participants were told that writing the essay in favor of the tuition increase was their choice and completely voluntary. However, the instructions subtly encouraged them to write such an essay. EEG was assessed for 1 min following the beginning of the writing of the counterattitudinal essay, as past research has revealed that dissonance is greatest at this point in time (Beauvois and Joule, 1996). Moreover, the commitment alone (and not the complete essay writing) is sufficient to evoke dissonance (e.g., Beauvois and Joule, 1996; Rabbie et al., 1959). Then, participants completed an attitude measure. Replicating much past research, results revealed that high-choice participants changed their attitudes more than low-choice participants. Supporting the primary prediction, results also revealed that high-choice participants evidenced greater relative left frontal activity than low-choice participants (main effect of choice manipulation in an ANOVA with lateral frontal and mid-frontal asymmetry as repeated measures). It is important to note that high- and low-choice conditions did not differ in compliance rates; that is, an equal number of high- and low-choice individuals engaged in the counterattitudinal behavior (the illusion of choice is the critical variable in this paradigm). Moreover, they did not differ in baseline resting frontal asymmetry. These results suggest that a selection bias did not produce the above asymmetry results. In addition, the two conditions did not differ in how convincing the essays were or in essay length, suggesting that the differences observed on attitude and relative left frontal activity were not due to differences in the strength or length of the counterattitudinal statements. We have replicated this finding using a different attitudinal issue and in this experiment, we measured EEG immediately after commitment and before essay writing began (Harmon-Jones et al., 2000c, Experiment 2).

The results of this recent research suggest that dissonance, a negative emotive state, is associated with greater relative left frontal activity. While dissonance and left frontal activity co-occur, it is not yet empirically clear how they relate to each other. Based on other research, I would suggest that the initial experience of dissonance may activate the anterior cingulate cortex, which then activates the left frontal cortex to engage the approach motivational system, which ultimately may assist with the reduction of dissonance. Indeed, anger may relate to left frontal cortical activity in much the same way; that is, the left frontal cortex may become active during anger to engage the approach motivational system to ultimately assist with the reduction of anger. The findings of Harmon-Jones et al. (2003b) are consistent with such a view. Only when individuals expected to be able to rectify the anger-evoking situation did increased left frontal activity result. And the left frontal activity related directly to self-reported anger and actions taken to resolve the anger-evoking event. However, when individuals did not expect to be able to rectify the anger-evoking situation, increased left frontal activity did not occur. Interestingly, both experimental conditions caused an increase in self-reported anger. Thus, while left frontal activity may relate to the negative emotions of dissonance and anger, its relation is not due to the valence of the emotions but is instead due to the approach motivational tendencies activated with these emotions.

10. Discussion of some issues

The reviewed research provides strong support for the motivational direction model of asymmetrical frontal activity and directly contradicts the other two models that have been offered to explain the relationship between emotions and the frontal asymmetry. If asymmetrical frontal activity reflected emotional valence, then anger and dissonance would have directly related to relative right frontal activity. That the results of the reviewed studies were significantly opposite to the prediction derived from emotional valence models provides particularly strong support for the motivational direction model. Before concluding, it is important to discuss a few issues concerning the interpretations of asymmetrical frontal brain activity and its relation to emotion and motivation, and to discuss a few broad implications these findings have for research on and theories of emotions.

10.1. On the relationship of angry feelings and relative left frontal activity

The research examining the relationship between asymmetrical frontal brain activity and anger began with the assumption that anger is often associated with approach motivation. Indeed, as indicated earlier, much past research has revealed that anger is associated with approach motivation and behavior. However, it is important to note that angry feelings are not inevitably associated with approach motivation and left frontal activity. For instance, in the study in which we examined the relationship between coping potential and left frontal activity (Harmon-Jones et al., 2003b), we found that regardless of whether individuals expected to be able to potentially resolve the anger-producing event, equally intense feelings of anger were produced by the aversive event. However, relative left frontal activity was only increased when individuals expected to be able to potentially rectify the anger-producing event. In addition, feelings of anger were associated with left frontal activity only in this latter experimental condition. Thus, feelings of anger are often, but not inevitably, associated with approach motivation and left frontal activity.

Results from another study are consistent with this interpretation. In this study, results revealed a dissociation between angry feelings and left frontal activity when high levels of sympathy were first aroused for the insulting person (Harmon-Jones et al., 2004). In this case, angry feelings were equally high whether or not sympathy was aroused for the insulting person. In contrast, left frontal activity differed between these two conditions, such that left frontal activity was increased following an insult by a person for whom sympathy had not previously been aroused, whereas left frontal activity was not increased when participants first empathized with the insulting person. In fact, in this latter condition, feelings of anger were directly associated with right frontal activity, suggesting that that the anger experienced while sympathizing with the other person was associated with withdrawal motivation. It is possible that individuals in this condition were motivated to withdraw so that their anger would not lead them to harm the person with whom they had earlier sympathized.

In sum, research has revealed that whereas angry feelings are often associated with approach motivation and relative left frontal activity, they are not inevitably associated with these constructs, as has been revealed in recent research (Harmon-Jones et al., 2003b; Harmon-Jones et al., 2004). Future research is needed to assess whether a type of anger that evokes withdrawal and right frontal activity exists.

10.2. Defining emotional valence

Consistent with current theories of emotion, the perspective advanced in this paper assumes that anger is a negative emotion. However, it is possible that anger could be a positive emotion and thus the valence model of the frontal asymmetry could explain the evidence linking anger to increased left frontal activity. Most perspectives on emotion rarely discuss what is meant by the valence of emotion. Most scientists, like most laypersons, *know* that joy and enthusiasm are positive emotions, and that anger and fear are negative emotions. On the rare occasions when valence is discussed, emotions are defined as positive or negative (1) because of the cause of the emotion; (2) because of the emotion's adaptive consequences; (3) or because of the emotion's subjective feel (Lazarus, 1991). Indeed, Lazarus (1991) noted that definition 1—whether the person–environment relationship is beneficial or harmful—is "the most common, implicit, use of the terms" for positive and negative emotion (p. 6). By this definition, anger is indeed negative. Thus, the reviewed research demonstrates that a negative emotion with approach tendencies is associated with increased left frontal activity.

However, it is still possible that the frontal asymmetry is a function of emotional valence when emotional valence is defined in an alternative manner. In our research, we sought to test whether the valence model of asymmetrical frontal brain activity could explain the relationship of anger and left frontal activity when emotional valence was defined using the subjective feel definition. In the research, we first created a trait questionnaire that demonstrated that there were reliable individual differences in persons' subjective feelings about anger. Then, we examined the relationship between the subjective feel of anger and resting baseline left frontal activity. We found that while trait anger related to both left frontal activity and a more positive subjective feeling about anger, the subjective feel of anger did not relate to left frontal activity (Harmon-Jones, 2004). Thus, even when using a more arcane definition of emotion, we were unable to find a relationship between positivity of anger and left frontal activity.

Given the difficulties inherent in defining adaptational consequences, we have yet to examine relationships between the adaptational consequences of anger and asymmetrical frontal brain activity. However, in some definitions of adaptation, it does appear that anger is associated with increased left frontal activity regardless of the adaptive consequences. That is, regardless of whether anger is associated with constructive action (e.g., working to prevent an injustice; Harmon-Jones et al., 2003b) or destructive action (e.g., behavioral aggression; Harmon-Jones and Sigelman, 2001), anger has been found to relate to increased left frontal activity. In sum, the evidence strongly suggests that anger is a negatively valenced emotion that is related to relative left frontal activity because of its association with approach motivation.

10.3. Evoking emotions

Of the emotions examined in the research on brain mechanisms involved in emotions, anger has received less attention than emotions such as fear, sadness, and disgust, which can be induced using established stimuli (e.g., pictures, films). Part of this relative neglect of anger may be that fear, sadness, and disgust are relatively easier to evoke in the laboratory because active, involving situations are not necessarily required to elicit the emotions.

Because the evocation of anger often requires the use of more active and involving situations, the study of anger may require the assistance of social psychologists who are familiar with creating such high-impact settings (see e.g., Harmon-Jones et al., in press).

On a related note, examinations of emotions other than anger should consider implementing more active and involving situations, as the more active and involving situations may elicit vastly different brain responses than the ones obtained in more passive situations. Indeed, our research has revealed that the manipulation of coping potential (i.e., the belief that one can take action to resolve the anger-producing situation) affects the activation of asymmetrical frontal brain activity but not the experience of anger (Harmon-Jones et al., 2003b). That is, the belief that one can take action to resolve the anger-producing situation produced an increase in left frontal activity and self-reported anger, whereas the belief that one could not act to resolve the anger-producing situation produced an increase in self-reported anger but not an increase in left frontal activity. Given that one of the primary functions of emotions is the motivation of behavior (Brehm, 1999; Frijda, 1986), it is all the more important for emotion researchers to consider the behavioral context in which emotions are evoked.

10.4. The health consequences of increased left frontal cortical activity

Of course, the frontal cortex is a complex structure, and is involved in several psychological processes. The presently reviewed research, in conjunction with past research, suggests that the frontal cortex is also asymmetrically involved in approach and withdrawal motivation. Although many have viewed left frontal cortical activity as only associated with positive valence and positive outcomes, the reviewed research indicates that left frontal activity is also associated with anger, at both trait and state levels of analysis. Thus, it is most likely that left frontal cortical activity is associated with both positive and negative outcomes. Whether left frontal activity (and approach motivation) is associated with positive or negative outcomes likely depends on a variety of factors (e.g., environment) and perspectives (e.g., type of measure; individual versus society). That is, while left frontal activity may be associated with heightened immune system functioning, it may also be associated with other negative consequences for the individual and society. Individuals high in approach motivation, who have greater left frontal activity (Harmon-Jones and Allen, 1997; Sutton and Davidson, 1997), may also be grandiose, manic (Harmon-Jones et al., 2002; Meyer et al., 2001), angry (Harmon-Jones, 2003, in press; Harmon-Jones and Allen, 1998), defensive (Kline et al., 1998; Tomarken and Davidson, 1994), and at greater risk for cardiovascular problems (e.g., James et al., 1983). Moreover, some of the characteristics associated with left frontal activity may provide both benefits and harms. For example, angry approach-oriented behaviors may constitute highly effective short-term strategies for achieving specific goals, asserting positions of social influence, and even causing positive subjective feelings of satisfaction and accomplishment. On the other hand, those very same strategies could contribute to a variety of problems, from domestic abuse to international terrorism. Similarly, such putatively “left frontal” approach-oriented strategies could, over time, harm the body, such as occurs in the relationship between trait anger and cardiovascular disease or John Henryism (a pattern of active coping with adversity by trying harder and harder against obstacles that may be insurmountable).

Most of the evidence cited by Davidson (this issue) in raising the possibility that relative left frontal activity produces positive consequences and "may be associated with aspects of resilience" is correlational and subject to the limitations of correlational evidence (in particular, third variables). Given such correlational designs, it is prudent to assess the potential moderating or mediating role of frontal brain asymmetry (Coan and Allen, this issue). Davidson (this issue) argues in this regard that left frontal activity may not mediate emotional responses but only moderate them. In support, he reviews research that has found inverse relationships between left frontal activity and amygdala activity (as measured by startle eyeblink response and hemodynamic imaging) during fear and disgust, withdrawal-related emotions. In contrast, we have recently found that anger increases left frontal activity *and* amydala activity (as measured by the startle eyeblink response; Harmon-Jones et al., 2004). This evidence suggests that during an approach-related emotion, left frontal activity is not suppressing amygdala activity but is positively covarying with it. When emotions that naturally confound valence and motivational direction (e.g., fear) are used to test hypotheses, explanations can be muddled.

The point of this review is *not* to suggest that anger is inevitably associated with increased left frontal activity, or that left frontal activity is inevitably associated with negative outcomes. Our research has indicated that anger is not inevitably associated with left frontal activity. It does, however, suggest that approach motivation, which *can* involve anger and other negative affective states, is associated with left frontal activity. Moreover, it suggests that a valence model explanation of asymmetrical frontal cortical activity is no longer viable.

11. Conclusion

For the last few decades, several models of emotion have considered pleasant to unpleasant dimension of emotion an important organizing principle—one that assists in understanding trait mood and situational reactions to significant stimuli at both subjective and physiological levels of analysis. However, recent developments have suggested that this focus on the valence dimension may not adequately capture emotional space. Consideration of motivational direction in the analysis of emotion, particularly as it relates to asymmetrical frontal brain activity, seems especially important. In addition, as psychological science focuses more attention on the empirically neglected positive aspects to psychological life, it is important to keep in mind that approach motivations are not inevitably associated with positive subjective feelings or positive outcomes.

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