Brain Lateralization of Emotional Processing: Historical Roots and a Future Incorporating "Dominance"

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This article provides a review of research on the hemispheric specialization in emotional processing during the past 40 years and the theoretical models derived from the conceptual analysis of these results. The publications reviewed here were collected to better appreciate the cortical lateralization of emotional perception (visual and auditory), expression (facial and prosodic), and experience. Four major models of emotional processing are discussed—the Right Hemisphere, Valence, Approach-Withdrawal, and Behavioral Inhibition System–Behavioral Activation System models. Observing the relative merits and limitations of these models, a new direction for exploration is offered. Specifically, to better appreciate the strength and direction (i.e., approach versus withdrawal) of experienced emotions, it is recommended that state "dominance" be evaluated in the context of asymmetrical activation of left-frontal (dominance) versus right-frontal (submission) brain regions.

Key Words: emotion, affect, brain, lateralization, asymmetry, valence, approach, withdrawal, dominance, neuropsychology

In the order that they were introduced to the scientific community, this article reviews four main theories concerning the cortical lateralization of emotional processing. First, research supporting the "Right-Hemisphere Model," which suggests that emotional perception and expression are largely subserved by the right cerebrum, is reviewed. Second, the theory that left- and right-frontal brain regions underlie positive and negative emotional processing (the "Valence Model") is presented. Third, data supporting the "Approach-Withdrawal" model, which posits that emotional states driving approach- and withdrawal-related behavior are primarily processed with left- and right-anterior regions, are presented. Last, the lateralization of emotional traits is explored via an appreciation of the "Behavioral Inhibition System–Behavioral Activation System (BIS/BAS)" processing model. It should be noted that each of the theories presented have significant strengths. For example, the right-hemisphere model incorporates more perceptual data than the other models (which primarily utilize emotional expression and experiential data). Conversely, the rather discrete focus on the lateralization of emotional *states* may be considered an asset of the valence and approach-withdrawal models. The BIS/BAS theory provides for the conceptual lateralization of emotional traits, rather than states.

At the end of this review article, a direction for future research is provided. To better appreciate the strength and direction of discrete emotional states, it is suggested that the lateralization of emotional "dominance" be explored with the hypothesis that relative left- and right-frontal activation would be associated with feelings of dominance and submission, respectively.

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THE RIGHT-HEMISPHERE MODEL

Observations of a direct link between emotion processing and the right hemisphere were made nearly 100 years ago. For instance, Mills (1912a, 1912b) observed that the presence of a unilateral right-sided lesion was associated with a decrease in emotional expression. Likewise, Babinski (1914) and others (see, for example, Denny-Brown, Meyer, & Horenstein, 1952) noted that patients with right-hemisphere lesions were often inappropriately indifferent or manic. In explaining these frequent observations, 30 years of cumulative research led to the development of the right-hemisphere model (or hypothesis). The right-hemisphere hypothesis posits that the right hemisphere is specialized for the perception, expression, and experience of emotion, regardless of valence (Borod, Koff, & Caron, 1983; Heilman & Bowers, 1990; Ross, 1985; Tucker, 1981).

There is now a substantial literature base pertaining to hemispheric specialization and the *perception* of emotion. Previous studies have traditionally focused on two channels of emotion communication (facial affect and affective prosody), whereas more recent studies have also examined lexical emotion (Borod et al., 1998; Borod, Tabert, Santschi, & Strauss, 2000). Regarding facial affect perception, tachistoscopic studies have demonstrated left visual field (right hemisphere) superiority for discriminating emotional faces (Landis, Assal, & Perret, 1979; Ley & Bryden, 1979; McKeever & Dixon, 1981; Suberi & McKeever, 1977) among individuals without brain damage. Relatedly, there is evidence that a larger left visual field advantage occurs for faces with *extreme* emotional expressions (Ley & Bryden, 1979). Consistent with these findings, studies incorporating brain-damaged patients have found that individuals with right-hemisphere lesions performed worse than patients with left-hemisphere lesions on tasks requiring the recognition or the discrimination of facial affect (Adolphs, Damasio, Tranel, & Damasio, 1996; Borod et al., 1998; Cicone, Wapner, & Gardner, 1980; Etcoff, 1986). Similar findings have also been documented for patients with split-brain syndrome. For instance, Benowitz and colleagues (1983) found that a split-brain patient had no difficulty identifying facial expressions when presented to the right hemisphere. However, this patient failed to identify the same facial expressions when presented to the left hemisphere. Consistent findings have been documented among patients who are undergoing intracarotid sodium amytal procedures, as Ahern and colleagues (1991) found that patients rated affective faces as less emotionally intense (in comparison to baseline ratings) when they were shown to the anesthetized right hemisphere. This effect was not observed when faces were shown to the anesthetized left hemisphere. The accumulation of findings described above led some researchers to argue that the right hemisphere may contain a "store of facial emotion icons" or representations (Bowers & Heilman, 1984).

The findings from electrophysiological recording and neuroimaging studies in general lend support to the notion that the right hemisphere is specialized for the processing of facial emotion. Specifically, scalp-recorded evoked response potential (ERP) studies have yielded greater right- versus left-hemisphere activity during the processing of facial affect (Kestenbaum & Nelson, 1992; Laurian, Bader, Lanares, & Oros, 1991; Munte et al., 1998; Vanderploeg, Brown, & Marsh, 1987). Recent functional magnetic resonance imaging (fMRI) studies have also found evidence of specialization of some right-hemisphere structures for the perception of emotion. For instance, Narumoto, Okada, Sadato, Fukui, and Yonekura (2001) found that selective attention to facial emotion specifically enhanced activity within the right superior temporal sulcus compared with attention to the face without regard to emotion. These results were essentially replicated and extended by Sato, Kochiyama, Yoshikawa, Naito, and Matsumura (2004) who found that broad regions of the occipital and temporal cortices, particularly within the right hemisphere, evidenced increased activity during the viewing of dynamical facial expressions.

In comparison to facial affect perception, less is known about the role of the right hemisphere with regard to the perception of affective prosody. However, earlier studies supported the notion that the right hemisphere was relatively specialized for the perception of affective prosody. As presented by Ross (1981), a group of communication disorders referred to as the "aprosodias" largely reflects disturbance of the ability to perceive (sensory aprosodias) or to express (motor aprosodias) the emotional components of speech. Aprosodias are typically observed following right-hemisphere lesions (Ross, Thompson, & Yenkosky, 1997). Supportively, early dichotic listening studies demonstrated a left ear advantage in the recognition of emotional aspects of speech (Carmon & Nachshon, 1973; Haggard & Parkinson, 1971; King & Kimura, 1972), as did studies that utilized monaural presentations (Safer & Leventhal, 1977). As with facial affect perception, the findings from electrophysiological recording studies (Bostanov & Kotchoubey, 2004; Everhart, Carpenter, Carmona, Ethridge, & Demaree, 2003; Jordan, Everhart, & Demaree, 2004; Pihan, Altenmuller, & Ackermann, 1997) and neuroimaging studies (Buchanan et al., 2000; George et al., 1996; Imaizumi et al., 1997) implicate the role of the right hemisphere in the perception of affective prosody.

As reviewed by Borod, Haywood, and Koff (1997), systematic study of facial asymmetry began to proliferate in the 1970s. In essence, early observations revealed that one hemiface, relative to the other, was more expressive. Borod and colleagues (1997) initially put forth two predictions regarding facial asymmetry, which were as follows:

> The first hypothesis was derived from the lateral dominance literature and proposed that facial expression represented another lateralized motoric function like handedness and footedness, which might be controlled by the dominant cerebral hemisphere. Thus, facial expression would be right-sided for right-handers and left-sided for left-handers. The second hypothesis emanated from the emotional processing literature available in the early 1970s (Gainotti, 1972; Gardner, 1975; Heilman, Scholes, & Watson, 1975) and proposed that the facial expression of emotion might be mediated by the right hemisphere. Thus, facial expression would be left-sided in right-handers, but not necessarily predictable in left-handers.

Over time, Borod and colleagues, as well as other groups of investigators (e.g., Moscovitch & Olds, 1982; Sackeim & Gur, 1978), noted that the left side of the face (rather than the right) was more active than the right side of the face during emotional expression. As the lower portion of the face is predominantly innervated by the contralateral hemisphere, this frequently replicated finding suggested relative right-hemisphere control of facial expression (Borod, 1993).

Within the literature, a distinction has been made between studies that examine posed expression versus spontaneous emotional expression. As reviewed by Borod et al. (1997), studies of posed emotional expression were based on the assumption that the face is contralaterally controlled by neocortical structures. However, whereas the lower face receives predominantly contralateral projections, the upper portion of the face receives bilateral projections (Borod et al., 1997; DeJong, 1979). In contrast to posed expression, which appears to be mediated predominantly by cortical structures, spontaneous expression is thought to be controlled by various subcortical structures (DeJong, 1979). However, Borod and Koff (1984, 1991) suggested that there is no agreement about whether the pathways are crossed or uncrossed. Moreover, some researchers have implicated cortical involvement in spontaneous expression (Damasio & Maurer, 1978). Despite the presence of these unknowns, a comprehensive review of 49 experiments of emotion expression and facial asymmetry in the adult literature found that the left hemiface is more involved than the right hemiface in the expression of facial emotions. Thus, the relative specialization of the right hemisphere is implicated in these findings. Of note, no significant differences were found for facial asymmetry distributions for posed versus spontaneous conditions (Borod et al., 1997).

As with facial affect expression, right-hemisphere damage is often associated with poor ability to express emotional prosody. For instance, patients with right-hemisphere damage may speak in a monotone voice (Ross & Mesulam, 1979; Tucker, Watson, & Heilman, 1977; Williamson, Shenal, Harrison, & Demaree, 2003). In a review of seven studies involving brain-damaged patients, Borod (1993) indicated that patients with right brain damage more frequently experience problems with the expression of emotional prosody. Some studies have also examined spontaneous conditions, in which patients are audio-taped while describing feelings about emotionally provocative material. Likewise, studies have also examined posed conditions where participants are requested to say a neutral-content sentence in an emotional tone of voice (e.g., Borod et al., 1990).

With regard to the right-hemisphere hypothesis, the experience of emotion (i.e., mood and affect) is thought to be predominantly regulated by the right hemisphere. Gainotti (1972) defended this notion when he witnessed "indifferent" and "catastrophic" reactions following right- and left-intracarotid sodium amytal administration. Other early evidence for this hypothesis was provided by Davidson and colleagues (see Davidson & Schwartz, 1976). Lateralized electrophysiological parameters measured during emotionally charged states found relative activation (as measured by decreased alpha power using electroencephalography [EEG]) during the recollection of past events associated with anger or relaxation. Similar findings were obtained during self-reported emotional reactions to visual material (Davidson, Schwartz, Saron, Bennett, & Goleman, 1979). Other laboratories found evidence of relative right-hemisphere activation when participants were asked to generate emotional imagery (Karlin, Weinapple, Rochford, & Goldstein, 1979), and during hypnotically induced depression (Tucker, Stenslie, Roth, & Shearer, 1981). More recent quantitative EEG research has demonstrated reliable relationships between the magnitude of cerebral activation and the intensity of emotional arousal (Foster & Harrison, 2002). In related research, the ages of emotional memories correlated with the magnitude of activation using quantitative EEG (Foster & Harrison, 2004).

A plethora of behavioral and psychophysiological studies have now been completed investigating individuals experiencing elevated levels of negative affect (e.g., depressed, anxious, or hostile individuals). Specifically regarding anxiety, early studies found evidence of increased right visual field errors on verbal and spatial tasks during periods of increased anxiety (Tucker, Antes,

Stenslie, & Barnhardt, 1978) and right ear bias in the perception of tones in subjects with high-trait anxiety (Tucker et al., 1978) and during periods of depressed mood (Tucker et al., 1981). While the authors of these studies argued that the results were indicative of increased left-hemisphere activity during depression and anxiety, others argued that these data may suggest that the poorer "left-hemisphere" performance may stem from relative increased right-hemisphere activity (Everhart & Harrison, 2000; Silberman & Weingartner, 1986). Moreover, the same group of researchers found increased left initial lateral eye movements (LEMs) in anxious versus nonanxious participants (Tucker et al., 1977); increased left initial LEMs have also been observed among participants who are asked to perform emotion-laden versus neutral tasks (Schwartz, Davidson, & Maier, 1975). Within our own laboratories, high-trait anxiety has been associated with increased accuracy for negative affective faces presented to the left visual field (right hemisphere) in comparison to low-trait anxious individuals (Everhart & Harrison, 2000). We concluded that this finding was supportive of the right-hemisphere hypothesis. Other researchers have also presented evidence that anxiety is associated with relative right-hemisphere activity (Heller, 1993), although this is qualified depending on the type of anxiety experienced (i.e., anxious apprehension versus anxious arousal) by the participant (see Nitschke, Heller, & Miller, 2000).

The relationship between hostility and the right cerebrum has also been studied using similar behavioral and electrophysiological procedures. For example, Herridge, Harrison, and Demaree (1997) found heightened and prolonged left hemibody GSR after high-hostile participants were asked to pose angry faces. Relatedly, in a forced-choice tachistoscopic paradigm, Harrison and Gorelczenko (1990) found that high-hostile individuals identified neutral faces presented within the left visual field as negative significantly more than did low-hostile counterparts. High-hostiles showed diminished accuracy in affective facial recognition at the left visual field (Herridge, Harrison, Mollet, & Shenal, 2004). In a dichotic listening study, Demaree and Harrison (1997) found enhanced left ear detections in high-hostile participants and an enhanced right ear advantage in low-hostile participants as a function of exposure to pain (a cold pressor stimulus) indicating dynamic activation of either the left or the right hemisphere as a function of trait hostility. Finally, in a study of anterior function, high-hostiles evidenced significantly less hand grip strength at the right hand and significantly more hand grip strength at the left hand in comparison to low-hostile counterparts (Demaree, Higgins, Williamson, & Harrison, 2002). In essence, these findings are interpreted as evidence of relative right-hemisphere activity among high-hostile individuals.

Other emotional states and disorders have also been linked to increased (or decreased) activity of the right hemisphere. For instance, Heller (1993) suggested that depressive states were associated with relatively increased right versus left anterior activity and decreased right posterior activity. In addition, secondary mania has historically been associated with right anterior lesions (Gainotti, 1972).

THE VALENCE MODEL

Although evidence for the right-hemisphere hypothesis continues to accumulate today (e.g., Sato et al., 2004), many of the studies described above (particularly those concerned with the *perception* of emotion) found hemispheric differences as a function of positive versus negative emotions. For instance, it is now well known that patients are more likely to have difficulty perceiving negative versus positive emotion following injury to the right hemisphere (see Adolphs et al., 1996; Borod et al., 1998). Likewise, happy affective faces are more easily identified by normal participants than are other affective faces (Everhart et al., 2003; Everhart & Harrison, 2000), and the perception of happy affective faces is typically preserved following right-hemisphere injury (Adolphs et al., 1996). A myriad of early amytal injection studies found that injection at the left carotid artery produced a "catastrophic reaction," which was characterized by crying, pessimistic statements, guilt, complaints, and worries about the future (Rossi & Rosadini, 1967; Silberman & Weingartner, 1986). In contrast, injection at the right carotid artery produced a euphoric reaction that consisted of lack of apprehension, smiling, laughing, mimicry, and a sense of well-being. The mood changes associated with the injection of one hemisphere are thought to represent the release of one hemisphere from contralateral inhibitory influences (Silberman & Weingartner, 1986). These findings, in combination with observations of patients with left- or right-hemisphere brain damage, have led to the valence hypothesis.

The valence hypothesis postulates that the right hemisphere is specialized for negative emotion and that the left hemisphere is specialized for positive emotion (Ehrlichman, 1987; Silberman & Weingartner, 1986). Of note, a variant of the valence hypothesis contends that differential specialization exists for the expression and the experience of emotion as a function of valence, whereas *percepual* processing of both positive and negative affective stimuli is a right cerebral function (Bryden, 1982; Davidson, 1984). Relatedly, this variant of the valence hypothesis indicates that the left and right ante-

rior regions are specialized for the expression and experience of positive and negative valence, respectively, whereas the right posterior parietal, temporal, and occipital regions are dominant for the perception of emotion (Borod, 1993).

Early tachistoscopic studies provided support for the valence hypothesis. For example, Reuter-Lorenz, Givis, and Moscovitch (1983) presented happy or sad facial expressions in one visual field while simultaneously presenting a neutral expression in the opposing visual field. Participants were required to identify the side that contained the emotional face. Reaction times were shorter for happy faces shown within the right visual field (left hemisphere) and sad faces shown within the left visual field (right hemisphere). Natale, Gur, and Gur (1983) presented happy, sad, and chimeric faces and found that the chimeric faces were more likely to be judged as positive when presented within the right visual field. Subsequent studies also found that in some cases, negative affective faces are identified more rapidly or more accurately when presented within the left visual field (see Everhart & Harrison, 2000; Harrison & Gorelczenko, 1990).

More recent studies involving brain-damaged patients have provided mixed support for the notion that left and right hemispheres are specialized for the perception of positive and negative valences, respectively. For instance, Adolphs et al. (1996) reported on brain-damaged participants who performed a task that required recognition of facial expressions. No impairment in the processing of facial expressions was noted among any of the patients with left-hemisphere lesions. In contrast, impairment among patients with right-hemisphere lesions was associated with damage to two discrete regions in the right neocortex, the right inferior parietal cortex, and the anterior infracalcarine cortex. Within the same study, happy expressions were recognized normally by all participants, whereas impaired recognition of negatively valenced expressions was most salient for fear. Thus, the hemispheric differences may be most apparent for the negative emotional expressions. Borod et al. (1998) also reported on a group of patients with left brain damage or right brain damage in comparison to normal controls. Dependent measures in this study included three communication channels: facial, prosodic, and lexical. Patients with right brain damage were significantly more impaired relative to patients with left brain damage and normal controls across channels and valence. Thus, there was no evidence of a valence effect regardless of emotional channel. Interestingly, Borod et al. (1998) did not report a significant valence effect for the perception of prosody, a finding that has also been documented for normal participants (see Everhart et al., 2003).

Regarding emotion expression, early studies of facial expression asymmetry noted that the tendency for expressions to be stronger on the left side of the face was more pronounced for negative than positive emotions (Sackeim & Gur, 1978; Silberman & Weingartner, 1986). Relatedly, using electromyography, Schwartz, Ahern, and Brown (1979) found that right-sided contractions were stronger during periods of happiness and excitement, whereas left-sided contractions were stronger during sadness and fear. Of note, however, posed expressions (versus spontaneous) showed stronger left-sided contractions regardless of the type of affect. As discussed previously (see above), it is thought that separate neuronal systems are involved for posed versus spontaneous emotions.

These issues were carefully considered in two comprehensive review articles (Borod, 1993; Borod et al., 1997). The first review (Borod, 1993) of emotional expression studies (including facial, prosodic, and lexical data) examined brain-damaged patients with unilateral lesions as well as normal controls. Borod (1993) concluded that for facial emotional valence, there were no overall deficits for patients with right brain damage or left brain damage. However, a number of studies demonstrated that patients with right brain damage showed selective deficits for positive or negative emotions. The findings were equally divided between the two valences. In accounting for these findings, Borod identified a number of inconsistencies across studies including lesion etiology, age, gender, handedness, and various procedural differences. Regarding the expression of prosody, Borod concluded that patients with right brain damage are generally more impaired in terms of emotional processing than are patients with left brain damage or normal controls, and that the results do not appear to be particularly associated with valence.

In the second comprehensive review, Borod and colleagues (1997) focused on the review of 35 sources yielding 49 experiments. Approximately half of the experiments utilized spontaneous facial expression, whereas the other half used posed facial expression. Overall, the review of these studies suggested that the left hemiface is more involved than the right during facial expression of emotion. In addition, the left-sided facial asymmetries were more frequent for negative than positive emotions. In review of these experiments, no instances of right-sided asymmetries for negative emotions were documented, whereas a 15% incidence of right-sided asymmetry for positive emotion was documented. Given these findings, it is possible that the expression of positive emotion is associated with left hemisphere (Borod et al., 1997) or bilateral involvement (Ehrlichman, 1987).

As reviewed above, observations of changes in emotion during the amytal procedure suggest a difference

between the two hemispheres with regard to the experience of emotion. These findings have been supported by observations of brain-damaged patients in which individuals with left-hemisphere lesions were more likely to exhibit "catastrophic" behavior, whereas right-hemisphere patients were more likely to exhibit "indifference reactions" (Heilman et al., 1975). Similar findings have also been observed among poststroke patients, in that left-hemisphere lesions (particularly close to the left frontal pole) have been more commonly associated with depression (Robinson, Starr, & Price, 1984; Starkstein, Boston, & Robinson, 1988). Interestingly, lesions within the right posterior region are also associated with an increased incidence of depression (Robinson et al., 1984), a finding that is consistent with Heller's (1993) quadrant model of emotion that separates arousal and valence.

Perhaps the strongest evidence in support of the valence hypothesis was derived from a plethora of EEG studies that have associated relative increased left-hemisphere activity with positive emotional states and relative increased right-hemisphere activity with negative emotional states (Davidson & Fox, 1982; Davidson & Henriques, 2000; Davidson et al., 1979; Ekman & Davidson, 1993; Ekman, Davidson, & Friesen, 1990; Fox & Davidson, 1987, 1988; Lee et al., 2004; Mandal et al., 1999; Reuter-Lorenz & Davidson, 1981; Schaffer, Davidson, & Saron, 1983; Sutton & Davidson, 2000; Tomarken, Davidson, Wheeler, & Doss, 1992; Tucker, 1981; Waldstein et al., 2000; Wheeler, Davidson, & Tomarken, 1993). For example, Davidson et al. (1979) required participants to indicate their emotional responses while watching a television program with varying emotional content. Frontal EEG leads displayed relative left-hemisphere activity during a positive emotional response, whereas the opposite pattern was displayed during a negative emotional response. Similar findings were obtained among infants by Davidson and Fox (1982), in which greater relative activity was observed within the left frontal region in response to an actress portraying happy faces; greater right than left activity was observed during the portrayal of sad facial expressions. In general, findings from neuroimaging studies have been commensurate with the findings reported above (Bench et al., 1992; Passero, Nardini, & Battistini, 1995; Wager, Phan, Liberzon, & Taylor, 2003). It should be noted, however, that other EEG researchers investigating the valence hypothesis have either accepted the null or even found the opposite pattern of activation (e.g., Cole & Ray, 1985; Schellberg, Besthern, Klos, & Gasser, 1990; Schellberg, Besthern, Pfleger, & Gasser, 1993; Tucker & Dawson, 1984).

By now, the finding of relative decrements in left anterior activity among patients with depression is well documented (Henriques & Davidson, 1991). It is also interesting to note that these findings may be representative of traitlike characteristics and possibly indicative of vulnerability to depression (Davidson, 1995), as remitted depressives also demonstrate the expected left < right anterior asymmetry. However, Shenal, Harrison, and Demaree (2003) offered a model providing for functional subtypes of depression based on the relative activation of cerebral quadrants where differences may include the relative depletion or activation of positive or negative emotional valences as a function of expressive or sensory receptive deficits.

Anterior asymmetries have also been explored among patients with other diagnoses. For instance, some researchers have found greater right versus left cerebral blood flow among patients with high-trait anxiety (Naveteur, Roy, Ovelac, & Steinling, 1992). However, inconsistency has been noted within the literature (see for review Everhart & Harrison, 2000; Nitschke et al., 2000). These inconsistencies are in part attributable to the high prevalence of comorbid depression, as well as subtypes of anxiety that involve anxious apprehension or anxious arousal (Clark & Watson, 1991; Nitschke et al., 2000).

THE APPROACH-WITHDRAWAL MODEL

The valence hypothesis was largely subsumed by the approach-withdrawal model of emotion processing, which posits that emotions associated with approach behaviors and withdrawal behaviors are processed within the left- and right-anterior brain regions, respectively. The overlap between the valence and approach-withdrawal models is extensive, with most negative emotions (e.g., fear, disgust) eliciting withdrawal behavior and most positive emotions (e.g., happiness, amusement) eliciting approach behavior. Although data collected during motivational drive—the desire to approach a reward or escape a punishment—support the approach-withdrawal hypothesis, the early distinction between the two models appears to have been largely theoretical in nature (Davidson, 1995). Specifically, it has been argued that the fundamental distinction between animal/human behaviors is whether the organism approaches or flees a social context (Schneirla, 1959; Stellar & Stellar, 1985) and, thus, the classification of emotions and/or their brain systems should be similarly directional in nature. Phylogenetically, the approach-withdrawal distinction is critical in that an error in direction may cause procreation-limiting injury or death.

Early in the model's development, Davidson and colleagues offered several reasons why left- and right-frontal regions may be specialized for approach- and

withdrawal processing, respectively (Davidson, 1987, 1988, 1995; Davidson, Ekman, Saron, Senulis, & Friesen, 1990; Davidson & Tomarken, 1989). First, Luria's (1973) account of the left-frontal region as central to intention, regulation, and planning—important theoretical constructs underlying approach behavior—was offered (e.g., Davidson, 1995). Second, infants and toddlers have been found to be significantly more likely to reach for interesting objects using their right relative to left hands (e.g., Young, Segalowitz, Misek, Alp, & Boulet, 1983). Last, persons experiencing depression symptomatology (characterized by a lack of positive affect [depressed mood, anhedonia, feelings of worthlessness or guilt] and approach behavior [psychomotor retardation, fatigue, and impaired social and/or occupational functioning]) have been found to exhibit a relative dearth of approach behavior and decreased left-frontal arousal as measured by EEG (e.g., Allen, Urry, Hitt, & Coan, 2004; American Psychiatric Association, 1994; Debener et al., 2000; Heller & Nitschke, 1997; Henriques & Davidson, 1990, 1991; Robinson & Downhill, 1995; Robinson et al., 1984; Schaffer et al., 1983). For example, in their study of left brain–damaged patients, Robinson and colleagues (1984) found that the severity of depression symptomatology was positively related to the proximity of the injury to the frontal pole. Of note, later evidence emerged that symptoms of mania appear to be associated with decreased right frontal arousal, potentially producing a patient with a preponderance of approach behavior (e.g., increased loquaciousness, goal-directed activities, and excessive involvement in pleasurable activities that have the potential for painful consequences; American Psychiatric Association, 1994; Bearden, Hoffman, & Cannon, 2001; Garcia-Toro, Montes, & Talavera, 2001). These more recent data seem to bolster the basic underlying tenet of the approach-withdrawal model of emotional processing.

We now turn to other empirical evidence supportive of the approach-withdrawal model, but strictly focus on research investigating emotional experience/behavior rather than perception. Indeed, a basic tenet of the approach-withdrawal model is that emotional experience—an elicitor of behavior—is lateralized within frontal brain regions, whereas other previous models (e.g., the right-hemisphere model) is largely supported by studies involving emotion perception predominantly processed within right-posterior brain regions (Davidson, 1995, p. 364). Because of the motivational quality of the emotional stimuli used in their research, we continue to believe that some of the most compelling data associated with the approach-withdrawal hypothesis were derived from a study by Sobotka, Davidson, and Senulis (1992). In this study, undergraduate students were given $5 and asked to play a computer game in which they could win or lose money (the net result of which they could keep). In each of their 400 trials, subjects were first informed by an up- or down-arrow on a computer screen whether they could win or lose money during that particular trial. If they saw an up (win) arrow, they were required to press a button as fast as possible when they saw a subsequently presented stimulus (a square) and were rewarded 25 cents if their response was faster than the mean of their prior responses (their earnings were not affected if they failed to meet the time criteria). Conversely, during "lose conditions," they were required to withdraw their finger from a button as fast as possible and lost 25 cents if they did so slower than their previous mean reaction time (again, no money changed hands if they were faster than their previous average). EEG recordings were collected from multiple scalp sites after they learned whether they were participating in a win or lose condition but before their response to the square stimulus (presented 4 seconds after the arrow). Analyses revealed a significant shift in frontal brain arousal (F3 versus F4 and F7 versus F8) between win ("reward") and lose ("punishment") trials, such that participants exhibited heightened left-frontal arousal (i.e., alpha power suppression) during win relative to lose trials. These data, taken together with the heightened self-reported positive affect and approach behavior displayed during win trials, provide strong evidence linking frontal asymmetry to approach and withdrawal affect.

Although Sobotka and colleagues' (1992) study was remarkable for its incorporation of truly motivating stimuli, most EEG researchers have studied brain asymmetry during the presentation of affective films eliciting an emotional response. For example, Davidson and colleagues (1990) showed participants video recordings designed to elicit an approach (happiness) or withdrawal (disgust) emotion, and collected behavioral, self-reported affect, and EEG data corresponding to the stimuli. As expected, participants self-reported more positive affect and facially exhibited a greater positive emotional response to the positive film. In terms of brain asymmetry, relative to the happiness-inducing film, the disgusting film was associated with a significant shift toward greater right relative to left frontal (F4 versus F3) and anterior temporal (T4 versus T3) arousal. Other studies have also assessed for cerebral asymmetry during *voluntary* facial expression (e.g., Coan, Allen, & Harmon-Jones, 2001; Ekman & Davidson, 1993; Ekman et al., 1990). For example, Coan and colleagues (2001) monitored brain activity while participants produced facial configurations of joy, fear, anger, disgust, and sadness. These researchers found that the production of withdrawal-related faces (e.g., fear, disgust) were associated with relatively less left-frontal activation in

the lateral-frontal, midfrontal, and frontal-temporal-central regions as recorded via EEG. Similarly, researchers have found increased left-frontotemporal arousal when participants were instructed to produce a "Duchenne" ("real") smile ("Raise your cheeks, part your lips, and let your lip corners come up") relative to a social smile ("Part your lips and let your lip corners come up"). Consistent with the facial feedback hypothesis (e.g., Buck, 1980; Duclos & Laird, 2001; Duclos et al., 1989; Flack, Laird, & Cavallaro, 1999; Hess, Kappas, McHugo, Lanzetta, & Kleck, 1992; Larsen, Kasimatis, & Frey, 1992; Levenson, Ekman, & Friesen, 1990; Soussignan, 2002; Strack, Martin, & Stepper, 1988; Zuckerman, Klorman, Larrance, & Spiegel, 1981), these data suggest that brain regions responsible for approach/withdrawal emotional experience become activated in response to one's own production of emotional facial expressions.

An effective case has been made for baseline frontal asymmetry providing a good marker for approach-withdrawal tendencies (or temperament), beginning at an early age. Fox and colleagues (1995), for example, correlated baseline frontal EEG asymmetry with social and interactive behaviors among 48 four-year-old children during free play, while making speeches, and during a ticket-sorting task. They found that children who exhibited greater left- and right-frontal arousal also evidenced greater social competence (e.g., social initiation and positive affect) and social withdrawal (e.g., isolated, onlooking behavior), respectively. This relationship between resting frontal asymmetry and affective style has likewise been supported in the adult population, and the reader is referred to extensive reviews of this literature elsewhere (e.g., Davidson, 1992a, 1992b, 1993, 1995; Davidson, Abercrombie, Nitschke, & Putnam, 1999; Fox et al., 1995).

With the possible exceptions of the studies by Fox et al. (1995) and Sobotka et al. (1992), the data discussed thus far essentially lend themselves no more to the approach-withdrawal model than they do to the valence model of emotional processing. Conversely, the study of frontal asymmetry associated with feelings of anger—a negative emotion that elicits approach behavior—has provided enormously important data in support of the approach-withdrawal model. Several studies in the Harmon-Jones lab have assessed cerebral asymmetry associated with anger. The first study incorporated 19 children from middle school and 7 children from an adolescent inpatient psychiatric unit (admitted for affective and impulse control problems). Harmon-Jones and Allen (1998) compared 6 min of EEG data collected under eyes-open and eyes-closed conditions with self-report data assessing dispositional anger using the Buss and Perry Aggression Questionnaire (Buss & Perry, 1992). They found that anger significantly correlated positively with right alpha power (decreased left-anterior cortical activity) and negatively with left alpha power (increased right-cortical activity). More fully supporting a transition from the valence model, significant correlations were not found between frontal asymmetry and positive and negative affect (as measured by the Positive and Negative Affect Schedule or PANAS; Watson, Clark, & Tellegen, 1988). In a follow-up study, Harmon-Jones and Sigelman (2001) manipulated state anger among undergraduate participants by having a nonexistent fellow student provide either relatively neutral or negative feedback on a 1-page essay written by the subject. The anger manipulation was found to be effective (as determined from self-report data), and a comparison of baseline to postfeedback EEG data revealed significant shifts to increased left-prefrontal activity following the induction of anger. Creatively, the researchers told participants that the study was also about taste perception, which, in fact, was a measure of aggression. Specifically, following the neutral or negative feedback, participants were asked to select one of six sauces for the other undergraduate student (who provided feedback on the essay) to ostensibly drink. These sauces ranged from very pleasant (sugar water) to very unpleasant (hot sauce) with four intermediate liquids (from positive to negative: apple juice, lemon juice, salt, and vinegar). EEG asymmetry was also found to predict aggression level: Among those who received negative feedback on their essays, increased postfeedback left-prefrontal arousal was associated with increased aggression. Similar research has found that being insulted increases left- and decreases right-frontal activity but that these physiological effects may be inhibited by having the participants sympathize for the person committing the insult (Harmon-Jones, Vaughn-Scott, Mohr, Sigelman, & Harmon-Jones, 2004). For additional discussion of this line of investigation, please see Harmon-Jones (2003b).

To the current authors, perhaps the most compelling research on the laterality of anger processing involved the manipulation of perceived control over an anger-inducing situation (Harmon-Jones, Sigelman, Bohlig, & Harmon-Jones, 2003). In this study, 77 undergraduates who independently paid at least one third of their tuition and were opposed to a university tuition increase underwent baseline EEG testing. They were then informed that their university had just voted to increase tuition by 10%. Half of the participants were told that the increase was definitely going to take effect, whereas the other half were told that they could petition the decision. In essence, by manipulating perceived control, the researchers effectively altered the degree to which participant action (i.e., approach behavior) may alter the university's ultimate decision. As expected, greater rela-

tive left midfrontal activity occurred when the anger-inducing information was presented in a way in which the student could act against (approach) the university but not when this action was impossible.

Taken together, the above evidence strongly suggests that the approach-withdrawal model is not only theoretically important but also a better fit for the behavioral/experiential data. Again, it must be stated that earlier born theories (e.g., the right-hemisphere model) were partially constructed from perceptual data, which may be a very different physiological process from emotional experience or display.

THE BEHAVIORAL ACTIVATION AND BEHAVIORAL INHIBITION (BIS/BAS) MODEL

More recent data suggest that left- and right-frontal activity may reflect strength of the behavioral activation and behavioral inhibition systems (the BAS and BIS, respectively; Gray, 1981, 1982, 1987, 1990, 1994; Gray et al., 1997). In part, frontal EEG data were compared to self-reported BIS and BAS strength because (a) the propensity toward approach emotion (e.g., anger) is associated with high BAS activation and (b) affective disorders associated with frontal asymmetry (e.g., depression and mania) are likewise associated with vastly different BIS and BAS strengths. Although these data will be more fully reviewed later, it is first important to understand the history of BIS and BAS and what these systems represent.

Two anatomical pathways underlying emotional/motivational systems have been termed the behavioral activation (or facilitation; BAS) and behavioral inhibition systems (BIS). These systems (originally termed the BIS and "approach" systems) were first proposed by Jeffrey Gray in his review of relevant animal literature (Gray, 1982, 1987, 1990, 1994; Gray et al., 1997). The BAS appears to activate behavior in response to conditioned, rewarding stimuli and in relieving nonpunishment. Thus, this system is responsible for both approach and active avoidance behaviors and the emotions associated with these behaviors are generally positive in nature ("hope" for reward or "relief" from nonpunishment). Animal research suggests that it is mediated by mostly dopaminergic pathways emanating from the ventral tegmental area to the nucleus accumbens and ventral striatum (Depue & Iacono, 1989; Fowles, 1994; Gray, 1987; Nothen et al., 1992). The BIS, conversely, inhibits behavior in response to stimuli that are novel, innately feared, and conditioned to be aversive. In essence, the animal stops, looks, listens, and prepares for vigorous action (Gray, 1987). BIS activation is associated with behavior consistent with passive avoidance and extinction and its activation is generally associated with negative hedonic experience (e.g., anxiety, fear). The BIS appears to be largely controlled by serotonergic pathways from the raphe nucleus to septo-hippocampal systems (Fowles, 1994; Gray, 1982, 1990, 1994; Gray et al., 1997; Winters, Scott, & Beevers, 2000).

The publication of the BIS/BAS scales (Carver & White, 1994) allows for better appreciation of individual trait differences in human BIS and BAS strength. Focusing more on self-reported emotions (and less on behaviors) associated with BIS and BAS activation, the questionnaire asks respondents to answer seven BIS-related questions (e.g., "I worry about making mistakes), five BAS-reward responsiveness questions (e.g., "It would excite me to win a contest"), four BAS-drive questions (e.g., "I go out of my way to get the things I want"), and four BAS–fun seeking questions (e.g., "I crave excitement and new sensations"). Reflecting traits, these scores are thought to be stable over time (Carver & White, 1994). Although this questionnaire certainly made human BIS/BAS research easier, it is important to note that the BIS/BAS scales appear to do a better job at quantifying emotional traits than they do predicting the behaviors associated with Gray's original model. Specifically, recall that activation of Gray's BAS produced approach *or* withdrawal behavior (and positive affective experience, hope or relief) whereas activation of Gray's BIS produced freezing behavior (and negative affective experience, fear or anxiety). Carver and White's (1994) BIS/BAS scales, conversely, measure affective strength in response to potential punishing/threatening (the BIS scale) or fun/rewarding (the BAS scale) stimuli. There thus appears to be an important disjoint between the two literatures, and the extension of the neurophysiological findings associated with animal BIS/BAS research into the human population should be performed with great caution. That said, the BIS/BAS scales perform an important function in measuring self-reported human predispositions toward positive (approach) and negative (withdrawal) affect in response to generally rewarding or threatening situations.

Given the unmistakable relationship between BIS, BAS, and emotion, much has been theorized about the relationship between the strength of these systems and affective disorders (e.g., Corr, 2002; Depue & Iacono, 1989; Fowles, 1988, 1994; Gray, 1990, 1994; Matthews & Gilliland, 1999, 2001). For example, although the BIS and BAS are thought to be rather stable over time, variability around a strong BAS is thought to produce mania whereas variability around a weak BAS may yield depression (Depue & Iacono, 1989; Depue, Krauss, & Spoont, 1987; Depue & Zald, 1993; Fowles, 1994; Meyer, Johnson, & Carver, 1999). As evidence of this relationship, dopaminergic agonists and antagonists may produce and ameliorate manic symptoms, respectively (e.g., Depue & Iacono, 1989). The BIS, too, may be implicated

in the manifestation of affective disorders. Among individuals who were considered high risk for the disease, Meyer et al. (1999) found that a weak BAS and strong BIS predicted depression symptomatology (accounting for 44% of the total variance). In a follow-up study, this research group again found that a strong BIS significantly predicted depression symptoms among persons diagnosed with bipolar I disorder (Meyer, Johnson, & Winters, 2001).

Naturally, left- and right-frontal arousal has also been associated with BAS and BIS strength, respectively. Theoretically, this is highly logical if one considers the following:

1. BAS activation is associated with positive feelings such as hope, whereas BIS activation is associated with negative feelings such as fear and anxiety. As previously discussed, a large corpus of research has found that left- and right-rostral arousal is associated with positive-approach and negative-withdrawal emotion, respectively.
2. Depression and mania appear to be associated with BIS > BAS and BAS > BIS profiles, respectively. Similarly, depression and mania have been found to be associated with right > left and left > right anterior arousal, respectively (Allen et al., 2004; Bearden et al., 2001; Clark & Watson, 1991; Debener et al., 2000; Garcia-Toro et al., 2001; Gotlib, Ranganath, & Rosenfeld, 1998; Heller & Nitschke, 1997; Henriques & Davidson, 1991; Robinson & Downhill, 1995; Robinson et al., 1984; Schaffer et al., 1983).
3. Trait anger, associated with increased left-frontal arousal, also corresponds to increased BAS (Harmon-Jones, 2003a).

Among healthy individuals, EEG technologies have quantified BAS and BIS lateralization strength. Specifically, persons with higher BAS scores were found to have increased left-frontal activation (Coan & Allen, 2003; Harmon-Jones & Allen, 1997; Sutton & Davidson, 1997), whereas individuals with higher BIS scores had greater right-frontal activation (Sutton & Davidson, 1997). Of note, persons with high BAS and BIS scores experience more positive and negative affect during everyday experiences, respectively (e.g., Gable, Reis, & Elliot, 2000), a finding consistent with prior data suggesting that greater left- and right-frontal activity is associated with a more positive and negative evaluation of equivalent stimuli (Fox & Davidson, 1987; Sutton & Davidson, 2000). Taken together, the above research suggests that trait BAS and BIS strength may be associated with increased left- and right-frontal activation, respectively.

Although findings for the neuropsychological underpinnings of the BAS have been fairly robust, results pertaining to the BIS suggest that there are multiple pathways involved in fear and anxiety. This challenges the model of the BIS as a single, unitary system (Blair, in press). Interestingly, there has been a similar increase in the complexity of models of anxiety disorders. Findings suggest much more nuanced relationships between specific anxiety disorders and emotion systems, such as fear (implicated in panic) and general negative affect (most implicated in generalized anxiety disorder, and perhaps most directly analogous to BIS; Chorpita, Albano, & Barlow, 1998; Clark & Watson, 1991; Joinier, Catanzaro, & Laurent, 1996; Watson, Clark, et al., 1995; Watson, Weber, et al., 1995). Similarly, disgust appears to be the salient emotion in at least some simple phobias and obsessive/compulsive disorder (Davey, Forster, & Mayhew, 1993; Davey, 1994).

THE NEXT STEP IN BRAIN ASYMMETRY RESEARCH: THE INVESTIGATION OF DOMINANCE

The above lateralization models of emotional processing each appear to have strengths. The right-hemisphere model, for example, emphasizes emotional perception at least as much as expression/experience. Focusing largely on experience, the valence model largely gave way to the approach-withdrawal model, which appears to be a better fit for the majority of data (e.g., anger). Note, however, that the BIS/BAS model is essentially identical to the approach-withdrawal model but focuses on relatively stable emotional traits (BIS and BAS strength) instead of states (the primary focus of the approach-withdrawal model). The current authors believe that the approach-withdrawal model is compelling not only for its excellent fit to the available data but also for its theoretical importance (i.e., the motivational direction of an emotion is of utmost importance to species survival and procreation ability). At the same time, however, we believe that the designation of discrete emotions as "approach" or "withdrawal" is somewhat cumbersome and the strength of the motivational impulse can be quite difficult to quantify. In this last section, we make an argument for using "dominance" as an important state construct underlying frontal asymmetry.

Emotion researchers overwhelmingly agree that at least two dimensions are required to describe an affective experience. These two dimensions, commonly referred to as "valence" and "arousal" (together known as the "circumplex model"; Lang, Greenwald, Bradley, & Hamm, 1993), may be depicted along two continuums or axes. The valence continuum ranges from *negative* (e.g., fear, anger) to *positive* (e.g., happiness, contentment) whereas the arousal axis ranges from *low* to *high*. Many emotions may be distinguished from one another using the circumplex model: For instance, anger may be described as "negative valence" and "high arousal," whereas contentment may be characterized as "positive

valence" and "low arousal." Perhaps because of its ease of use, many emotion researchers use the circumplex model to describe affective experience.

There are two primary reasons, however, to suggest that a "three-factor" model is required to adequately describe an emotional experience. First, factor analytic results from data collected using emotion questionnaires indicate that a third factor, in addition to valence and arousal, is required to adequately depict an affective state (Mehrabian, 1978, 1996; Mehrabian & Russell, 1974; Morgan & Heise, 1988; Russell & Mehrabian, 1977; Shaver, Schwartz, Kirson, & O'Connor, 1987). This third factor has been rather consistently labeled, and we will use the term *dominance.* Dominance has been defined as "feelings of control and influence over everyday situations, events, and relationships versus feelings of being controlled and influenced by circumstances and others" (Mehrabian, 1994, p. 2).

Second, emotion researchers acknowledge that the circumplex model cannot differentiate between two primary affective states, anger and fear (Larsen & Diener, 1992; Watson, 2000). Specifically, both emotional states may be described as highly negative and arousing. Although the circumplex model notes the emotional similarities between the two emotions, the two affective states are actually very different. For instance, fear and anger run through distinct neuroanatomical pathways (LeDoux, 1993) and are associated with different patterns of frontal asymmetry (Coan et al., 2001; Harmon-Jones & Allen, 1997, 1998; Harmon-Jones & Sigelman, 2001; Lang, Davis, & Ohman, 2000). Only the third factor of emotion, dominance, is reliably able to disentangle these two very different emotions. Specifically, anger and fear are associated with feelings of dominance and submission, respectively.

It is important to note that dominance is also very useful in differentiating between other affective experiences. For instance, using only the State Pleasure and State Arousal scales of the Pleasure, Arousal, and Dominance Inventory (PAD; Mehrabian, 1978), Russell (1980) was able to account for a "satisfactory" amount of variance in self-reported emotion but suggested that dominance may account for a significant portion of the remaining variance. To compare the circumplex model to the three-factor model, Shaver et al. (1987) used all three PAD state inventories (pleasure, arousal, and dominance) to rate 135 different emotion terms. Comparing their results to those attained when only using the valence and arousal factors, Shaver et al. (1987 p. 1071) wrote, "The three-dimensional solution helps to differentiate between what the cluster analysis suggests are separate basic-emotion categories, and it is clearly more informative as a representation of emotion knowledge than the two-dimensional solution." Interestingly, factor analytic research suggests that dominance is not significantly associated with valence (Mehrabian, 1978, 1996; Mehrabian & Russell, 1974; Morgan & Heise, 1988; Russell & Mehrabian, 1977; Shaver et al., 1987). That is, feelings of dominance may be associated with positive (e.g., self-assurance, arrogance, and feeling bold or triumphant) or negative affective states (e.g., hostility, irritability, and anger) (Youngstrom, Frazier, & Butt, 2001).

The dominance dimension separates anger, hostility, and contempt (which all involve higher levels of perceived controllability) from other manifestations of negative affectivity, including sadness, shyness, and shame, which entail lower levels of dominance. The dominance dimension also separates positively valenced emotional experiences, such as self-confidence (moderate dominance) from arrogance or cockiness (high dominance) or awe (low dominance). Many questionnaires only ask about hostility-related items (i.e., anger, irritability, annoyance, disgust) and not other more positively valenced emotions that occupy different positions along the dominance dimension. If hostility (vs. fear) is the only marker for emotions high in dominance, then the dominance factor cannot be separated from hostility itself, and the factor structure of emotions (including the apparent correlation between emotion dimensions) could be distorted as a result (Youngstrom et al., 2001). For this reason, it is important to sample emotions that represent a range of dominance levels reflecting both positive and negative valence.

Although the dominance dimension has received less attention than the other two dimensions of emotion, there is evidence that dominance also has implications for psychopathology. Depression involves downward shifts on the dominance dimension (Mehrabian, 1995; Plutchik, 1993). Depressive symptoms appear associated with decrements in a sense of control, self-assurance, and increases in emotions of feeling beaten, overwhelmed, helpless, and hopeless. Social dominance in animals, measured as success in competitive encounters, increases with central 5-HT injections (Edwards & Kravitz, 1997) as well as administration of a serotonin selective reuptake inhibitor (SSRI) antidepressant (Raleigh, McGuire, Brammer, Pollack, & Yuwiler, 1991). Conversely, social dominance in animal models decreases with the administration of medication decreasing SSRI function (Raleigh et al., 1991). There are clinical data indicating that depressed patients taking SSRIs show measurable increases in personality attributes related to dominance, such as assertiveness and boldness (Brody et al., 2000). More generally, dominance plays an important role in distinguishing internalizing versus externalizing behavior problems. Internalizing problems are more characterized by low-dominance

affect such as anxiety, depression, and discrete emotions of sadness, shame, and guilt (Blumberg & Izard, 1986). Externalizing/disruptive behaviors are often, though not always, associated with higher dominance emotions such as anger and contempt (Bradley, 2000; Tsytsarev, 1995), as well as smugness, gloating, and teasing (Miller & Olson, 2000). Dominance-related emotions are likely to be important in reactive aggression, which often involves anger (Lemerise & Dodge, 2000). Dominance may be more subtly implicated in instrumental aggression, because high dominance emotions such as contempt and disdain will motivate behaviors that disregard the rights and feelings of others regardless of whether the situation involves anger or not (cf. Bushman & Anderson, 2001; Dodge, 1991).

In recent research linking BIS/BAS strength to feelings of dominance/submission, Demaree, Robinson, Everhart, & Youngstrom (in press) asked 67 male and female undergraduates to complete the BIS/BAS scales and then watch a series of four films depicting dyadic interactions in which one person "controlled" or "dominated" the other. Following each film, participants were asked to identify the character with whom they identified (i.e., the dominant or submissive character) while watching the film, as well as their self-reported affective response to the clip. As expected, high BIS predicted taking the submissive perspective and having a more negative response to the film. We believe that films depicting dyadic interactions may be very useful to future neurophysiological research designed to investigate individual differences with regard to dominance/submission.

For decades, scores of scientists have pursued a better understanding of how activation of anterior brain regions produces different emotional experiences. Such work, as previously noted, led to a paradigm shift from the valence to the "approach-withdrawal" model. However, the approach-withdrawal model appears to suffer from a relative inability to operationalize and to quantify "approach" and "withdrawal" emotion, the basic unit of the literature. What is "approach" and "withdrawal" emotion, anyway? To help answer this question, it is important to recognize that approach/withdrawal emotions are closely associated with dominance. Specifically, research suggests that all the approach emotions are rated as relatively high dominance, whereas all withdrawal emotions are rated as low dominance. For example, anger and happiness are associated with feelings of dominance, whereas fear and disgust are associated with feelings of submission (Mehrabian, 1978, 1996; Mehrabian & Russell, 1974; Russell & Mehrabian, 1977). Thus, it follows that the discovered patterns of frontal asymmetry may be attributable to feelings of dominance (left-frontal arousal) and submission (right-frontal arousal) rather than "approach/positive" and "withdrawal/negative" affect, respectively.

To date, no neuroimaging research has been performed to specifically assess the influence of dominance, a void that the current authors feel is important to address. How should such an investigation be designed? One possibility, as discussed previously, is to use dyadic films depicting dominant-submissive interactions. A second possibility is to use pictures from the International Affective Picture System (IAPS, Center for the Study of Emotion and Attention, 1999) because norms have been established for both men and women using valence, arousal, and dominance parameters. It appears possible to select a series of slides that elicit feelings of dominance or submission, *while controlling for valence and arousal.* In fact, we have identified pictures that may be appropriate for such stimulus sets. (It is suggested that readers check for the most recent norms. For women, the Dominant slide set might include IAPS picture numbers 2515, 4532, 4608, 4659, 4664, 5628, 7281, 7284, 7285, 7286, 8050, and 8220, whereas the Submissive slide set might include pictures 1640, 1650, 1660, 1720, 4490, 4598, 5300, 5970, 5990, 5991, 7620, and 8178. For men, the Dominant set might include picture numbers 1600, 2220, 2250, 4672, 6840, 6910, 7284, 7289, 7402, 8117, 8232, 8251, whereas the Submissive set could include pictures 1114, 1321, 1726, 1810, 1932, 5260, 5300, 5890, 5900, 5920, 5990, and 5991.) The collection of EEG or other neurophysiological data during slide set presentation (while quantifying the emotional response of participants) would provide a test for this proposed theory.

Improved understanding of the cerebral contributions to emotional processing may significantly improve our clinical understanding of mental health disorders. Perhaps the two emotional disorders that most closely fit with the approach-withdrawal zeitgeist are depression and anxiety. Depression symptomatology, for example, has been associated with decreased left-frontal arousal and consequent reductions in approach behavior (Garcia-Toro et al., 2001; Heller & Nitschke, 1997; Henriques & Davidson, 1990, 1991). Anxiety without depression, on the other hand, has been associated with increased right-anterior arousal and consequent withdrawal behavior (Davidson, Marshall, Tomarken, & Henriques, 2000; Petruzzello & Tate, 1997). It is important to remember, however, that the approach-withdrawal theory clearly fits with the third (but oft-forgotten) factor of emotion, dominance. Thus, by quantifying feelings of dominance/submission during physiological data collection, the understanding of the brain's role in emotional processing may be improved. The notion that right-anterior regions mediate submissive feelings rather than withdrawal behavior is a significant

distinction that may have implications for both psychotherapeutic and pharmacologic interventions.

LIMITATIONS OF THE PREVIOUS DISCUSSION

It is important to note that the data previously presented largely conceptualize *cortical* contributions to affective experience. Specifically, the research described generally fit within two domains—studies designed to quantify (a) emotional deficits following cortical brain injury or (b) regional cortex activation, as measured by such technologies as EEG, during emotional processing. Although subcortical activation asymmetry is beyond the scope of this article, it should be noted that the lateralization of such areas may differ from the previously presented cortical models. Gainotti, Caltagirone, and Zoccolotti (1993) and Liotti and Tucker (1995) were among the first to discuss asymmetric subcortical contributions to emotional processing. Given Liotti and Tucker's (1995) tenet that subcortical regions may be impaired by the ipsilateral cortex, one might expect emotional processing to induce opposite patterns of lateralization within cortical and subcortical regions. In partial support of this hypothesis, Hagemann, Waldstein, and Thayer (2003) suggested that autonomic arousal due to emotional processing—robustly demonstrated during the experience of anger or fear—is associated with right cortical and left subcortical activation. Similarly, Baas, Nugent, Lissek, Pine, and Grillon (2004) found greater left- than right-amygdala activation during emotional processing in their meta-analytic review of 54 emotion-related fMRI and PET studies.

CONCLUSIONS

Much progress has been made during the last 4 decades regarding our understanding of the lateralization of emotional processing. Generally speaking, a shift from perceptual/expressive data to experiential data has led to increased emphasis on left- and right-anterior involvement in positive/approach and negative/withdrawal processing, respectively. Although progress has been made, we believe that the lack of approach and withdrawal intensity measurement has been a significant casualty of this theoretical transformation (i.e., right-hemisphere and valence hypotheses were tested while adequately measuring emotional intensity and valence, respectively). The third (or "z") axis of emotion—dominance—is proposed as a measure of approach/withdrawal emotion intensity for future lateralization research. Moreover, this emphasis promises to broaden the inquiry of emotion to a social interactive approach where perceived locus of control (external versus internal) and sociopolitical factors lending themselves to submission or dominance are stressed.

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