

Studies of Emotion

A Theoretical and Empirical Review of Psychophysiological Studies of Emotion

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A discussion of current trends in psychophysiology studies about cerebral laterality and emotion regulation.

For over a century, human emotion has been an important theoretical and empirical idea in psychology. Dating back to the time of William James¹, psychology has accepted the idea that the human experience of emotion is the result of the interplay between an individual's cognitive appraisal of an event and his or her physiological response to it. Since James, psychologists have theorized about the temporal aspect of one's physiological and cognitive responses to a stimulus in the production of emotion,^{1,2,3} cognitive strategies for determining physiological emotional valence (*i.e.*, attraction or aversion to a specific object or even),^{4,5} and cerebral laterality for its predictive validity for physiological responses to emotion-provoking stimuli.^{6,7,8,9,10} This article gives a brief historical overview of the theoretical aspects of emotion; describes the use of electroencephalography (EEG) to study the psychophysiology of emotion and recent developments in this field, including research on cerebral laterality and emotion regulation; and suggests future directions for research in the psychophysiology of emotion.

THEORETICAL ASPECTS OF EMOTION

Among the first psychologists to formally discuss human emotion, William James¹ believed that after perceiving a stimulating event, an individual instantly and automatically experiences physiological changes (*e.g.*, increased or decreased heart rate, changes in respiration rate, sweating). It is in thinking about and assessing these physiological changes that the individual assigns an emo-

tion to them. Take the example of a man being burglarized. Upon witnessing the burglar entering his home, his heart races, he breathes more rapidly, and his hands tremble and sweat. In James's view, it is after cognitively assessing his physiological reactions to the situation that the man is able to assign the emotion of "frightened" to his experience. James believed emotional responses existed on a continuum, and the assignment of a specific emotion to one's experience depended solely on the specific physiological reactions that one experienced as a result of the stimulus. James also believed that emotional reactions were, to some degree, ordered; he listed categories of "coarse" affects (*e.g.*, anger, fear, love, hate, joy), which are coupled with strong bodily reactions.^{1,11} In this way, certain sets of physiological reactions could be grouped together in a predictable manner.

Wilhelm Wundt¹² offered a dimensional view of emotion, purporting that human emotional responses could be plotted along a two-dimensional plane, consisting of pleasure and arousal. Wundt's dimensional view did not focus on physiological reactions to stimuli as the origin of emotional responses; rather, he was concerned about grouping and categorizing human emotions. Through his dimensional view, however, he laid the groundwork for the eventual development of the most prominent theory used in contemporary research on the psychophysiology of emotion. Schneirla,¹³ following Wundt's dimensional classification of emotions, categorized all motivated behavior into two basic responses: approach and withdrawal. According to this classification, approach-

motivated behaviors are those elicited for acquisition, and are generally perceived as positive behaviors stemming from positive stimuli. Conversely, withdrawal-motivated behaviors are elicited in response to external threats and are meant to provide safety for the individual.¹¹

Bridging Wundt's¹² two-dimensional view of emotion and Schneirla's¹³ classification of motivated behaviors, Davidson^{14,15} and Lang¹⁶ have classified emotional responses as being either approach-oriented or withdrawal-oriented. In this classification, the primary view of any emotional response is on direction, either toward or away from an emotion-evoking stimulus.¹¹ This dimension along which emotion has been separated has been studied extensively in laboratory settings, with results suggesting a neurological basis for this classification of emotions. In addition, there is substantial empirical evidence suggesting that positive and negative affect experienced in response to emotional stimuli is also related to approach- and withdrawal-motivation.¹⁷

ELECTROENCEPHALOGRAPHY AND HUMAN EMOTION

Human electroencephalography (EEG) measures both the frequency and amplitude of electrical activity generated from the brain. The brain site under study is compared to a 'reference site,' a relatively non-active site used as a means of comparison to judge electrical activity. Common reference sites in emotion studies include the ear lobes and the mastoids, because physiologists believe that these specific sites are electrically non-active relative to sites on the brain.

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When measuring emotional response, researchers often focus on the reduction in alpha band (8-13 Hz) activity. Much research suggests an inverse relationship between alpha activity and brain activation in adults.¹⁸ Thus, the level of brain activation increases when emotion is experienced, which is observed as a reduction in alpha band activity as measured by EEG.

With the use of high-density electrode arrays, there exist many possible sources of 'noise' that can disrupt EEG recordings, including muscle activity near the active sites, gross motor movements, and eye movements and blinks.¹⁹ Eye movement artifact can have profound effects on frontal brain sites, specifically mid-frontal sites (F3 & F4), which are used in studying emotional reactivity. Davidson²⁰ and Tomarken, Davidson, Wheeler, & Doss²¹ report that individual epochs of 'clean' data could be as little as 1 second in length, but for each individual emotion under study a minimum of 10-15 seconds of activity must be collected. Although EEG has poor spatial resolution and requires many electrodes placed at various sites on the head, it provides excellent time resolution, allowing researchers to study phase changes in response to emotional stimuli. The use of EEG is noninvasive, fast, and inexpensive, and it is neither painful nor uncomfortable. For these reasons, EEG has become a preferred method in studying the brain's responses to emotional stimuli.

The use of EEG to study electrical activity in the human brain was demonstrated for the first time approximately 70 years ago.^{22,19} This development has had far-reaching implications for the study of human brain activity in general and specifically for the study of the human brain's changes in response to changes in emotion. The use of EEG has made possible the discovery of electrical differences in brain activity between resting state and stimulus conditions, the differences that exist between the two hemispheres of the brain (*e.g.*, cerebral laterality), and other physiological activity in response to stimuli (*i.e.*, heart rate, muscle activity, and skin conductance). The use of EEG has also enabled researchers to study

regional brain activity and brain function, in particular various human cognitive and emotional processes, individual differences in brain function, and brain activity in psychopathology.¹⁹

CEREBRAL LATERALITY AND EMOTIONAL RESPONSE

The use of EEG has been pivotal in studies concerned with brain asymmetry and emotion.¹⁹ Using EEG to study brain asymmetry in humans, researchers have recently made many discoveries suggesting that physiological reactions play a large role in the experience of emotion and that individual differences in electrical activity between the two brain hemispheres can be used to predict emotional responses to various stimuli. These findings have helped answer the questions concerned with how emotions that shape individuals' everyday life are generated and why individual differences in emotional experiences exist.

To address the question of why individual differences exist with respect to emotional experience, many studies have centered on frontal activation asymmetries. Davidson and his colleagues^{23,34} have viewed cerebral asymmetries in the frontal regions as having a basis in approach- and withdrawal-motivation, and thus being of prime importance to the mediation of behavior and emotional response. They hypothesized that the anterior, or frontal, region of the left hemisphere of the brain is specialized for approach behaviors, while the anterior region of the right hemisphere is specialized for withdrawal behaviors.^{14,20,23,24,25} This view suggests that individuals who have more activation in the left hemisphere will tend to approach situations more freely and experience positive emotions while doing so, compared to individuals with greater right-hemisphere activation. Conversely, individuals who have predominately right-hemisphere activation tend to withdraw from situations, and in doing so experience more negative emotions, compared to individuals who have greater left-hemisphere activation. These hypotheses are supported by empirical evidence.⁸ Researchers have also demonstrated that these individual differences appear at an

early age²⁶, are relatively stable over time,²⁷ and may be heritable.²⁸

These findings suggest that individual differences in cerebral laterality can be used to accurately predict emotional response and valence to various stimuli. Tomarken and his colleagues⁶ demonstrated that individuals' measure of resting alpha level could predict both negative affect in response to negative stimuli and affective valence (*e.g.*, the difference between one's positive and negative affect). They found that individuals with greater right-hemisphere activation experience more negative affect in response to negative stimuli, compared to individuals with greater left-hemisphere activation. The same study, however, did fail to demonstrate that greater left-hemisphere activation could predict greater positive affect. Wheeler and his colleagues⁸ not only validated Tomarken *et al.*'s findings,⁶ but also found that greater left-hemisphere activation predicts greater positive affect in response to positive stimuli. Wheeler *et al.*⁸ thus concluded that individual differences in tonic levels of asymmetry have predictive value with regards to individual temperament, affect reactivity, and dispositional mood. The findings thus far concerning cerebral asymmetry and its prediction of affective reactivity have focused solely on anterior cerebral sites (*e.g.*, mid-frontal and anterior temporal). One possible explanation for the difference in predictive validity between anterior and other cerebral sites has been that the frontal and anterior temporal sites have extensive anatomical connections with the limbic structures believed to be responsible for the control of emotion.^{29,30}

Relative to research regarding electrical activation in the brain, there has been little research on the muscle and eye movement activity that accompany emotional responses to stimuli. Ekman³¹ has suggested that all emotions have a specific physiological pattern that accompanies the electrical activity and subjective experience of that emotion. In studying this hypothesis, Davidson *et al.*⁷ found that when averaged across the entire length of the emotional stimulus, the EEG pattern in both the alpha and beta bands could not be used to differentiate between

the emotions of disgust and happiness. Rather, facial (*e.g.*, electromyography) activity have to accompany the EEG pattern to allow for reliable prediction of emotional experience.

Sutton *et al.*³² studied eye blink reflex and corrugator activity of subjects in response to negative pictures, compared to responses to positive pictures. They found that, compared to positive pictures, subjects demonstrated greater eye blink reflex and corrugator activity when viewing negative pictures. Although females tended to show more aversive emotional reaction to negative pictures compared to males, there were no overall effects for sex on either eye blink reflex or corrugator activity. These findings suggest that physiological activity in the brain, as a response to emotional stimuli, is accompanied by both muscle and eye activity. Furthermore, this eye activity, in addition to EEG patterns, can be used to help predict subjective emotional experience.

The Behavioral Approach System (BAS) and the Behavioral Inhibition System (BIS) are Gray's³³ systems hypothesized to underlie learning and affect.¹⁰ The BAS is utilized when behavior is motivated toward incentives, rewards, or both while the BIS motivates behaviors away from threats that exist in an individual's external world. Furthermore, Gray³⁴ has suggested that the levels of BAS and BIS activation within an individual can accurately predict predominant personality traits, individual temperament, and the possibility of depressive symptomology. Individuals who have a more active BAS system tend to be more extraverted and impulsive, compared to individuals who have more BIS system activity, who tend to be more neurotic and anxious.¹⁰ Researchers have shown that individuals who have a more active BAS system also tend to have greater left-hemisphere activation. Conversely, individuals who have greater activation of the BIS system tend to have greater right-hemisphere activation (Sutton and Davidson, 1997). These findings suggest that hemispheric activation can predict BAS/BIS activation and could in turn have predictive validity for personality. If future research supports this link, then the accuracy of EEG as a test for personality could be supported as well.

It is important that individual differences in frontal activation is viewed as a diathesis, requiring specific stimuli in order to elicit the emotions to which an individual may be predisposed.⁸ Cerebral asymmetries simply give rise to a vulnerability to respond emotionally to a stimulus in a certain way. This view does not suggest that, for example, individuals with greater right-hemisphere activation are destined to become depressed and inhibited. Finally, the discovery of a pattern for frontal activation and its predictive validity for affective response has been shown to generalize to other populations, including people with depression^{35,36} and infants.^{37,38} This generalizability offers promise that cerebral asymmetry truly can predict affective response and valence as well as individual personality and temperament.

EMOTION REGULATION

A relatively recent development in the psychophysiological study of emotion has been centered on emotion regulation, focusing on the strategies individuals utilize in order to deal with the negative emotions that they experience. This line of research also investigates the effects of emotion regulation on psychological and physical health, with interest lying in determining the healthiest ways to regulate negative emotions.

Gross³⁹ has postulated that emotions can be regulated either before an individual response to a stimulus through antecedent-focused emotion regulation (*e.g.*, reappraisal) or after response to a stimulus has been made through response-focused emotion regulation (*e.g.*, suppression). The term 'reappraisal' refers to the reinterpretation of an emotional stimulus, while 'suppression' refers to responding to an emotional stimulus in a way to mask its external display. Both types of regulation strategies were empirically shown to be effective in decreasing emotion-expressive behavior; while reappraisal decreases one's experience of the emotion disgust, suppression increases one's sympathetic activation in response to the stimulus.³⁹ The results of Gross' study³⁹ suggests that reappraisal as a regulation strategy decreases the amount of stress an individual experiences, thereby improving psychological health. Suppression

tends to increase one's level of sympathetic activation, thus having deleterious effects on physical wellbeing.

In a related study on emotion regulation, Jackson and his colleagues⁵ found that emotion regulation has effects on muscle and eye blink activity related to that emotion. Specifically, they found that suppression of a negative emotion tends to decrease eye blink and corrugator activity, while enhancement of negative emotion tends to increase eye blink and corrugator activity. These results suggest that the ways in which individuals cognitively respond to emotion-provoking stimuli have effects on physiological reactions to and experience of a given emotion. The psychophysiological study of emotion regulation could thus have important applications to the enhancement of psychological and physical well-being.

FUTURE RESEARCH

Much of the present research on cerebral asymmetry has focused only on female and non-depressed individuals, and thus its generalizability is limited. Future research should attempt to use mixed-sex samples, include both clinical and normal populations, and include a broader age-range. Furthermore, future research in cerebral asymmetry must extend the range of emotions experimentally manipulated; most studies manipulate only happiness and disgust. The limitations of this are obvious. First, the human range of emotions extends far beyond these two basic emotions. If psychologists are to understand the human emotional response, they must study a wider range of emotions. Second, more people do not regularly experience disgust. It serves a useful purpose to be highly withdrawal-motivated, but the inclusion of anger, fear, and sadness as negative emotions to be experimentally manipulated would substantially advance the study of cerebral laterality and human emotion. Finally, the temporal aspects of emotion could be investigated, in which researchers would look into expressive, physiological, and subjective experiences of emotion and their relation to each other through time.

Similar to the study of cerebral laterality, future research on emotion regulation could utilize the experimental manipulation of a

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wider range of emotions. Also, other forms of emotion regulation, in addition to reappraisal and suppression, could be studied and their effectiveness assessed. Finally, emotion regulation is a commonplace activity for everyone. As such, there exists a need for future research to investigate emotion regulation strategies and their effectiveness as they occur outside of the laboratory.

CONCLUSION

The study of the psychophysiology of emotion has been a recent development in psychology, and consequently has few empirical studies from which psychologists can draw conclusions. In spite of this, the results generated so far regarding cerebral laterality and affective response are promising. With additional research, psychologists can learn much about why individuals respond to emotion-provoking situations in different

ways. Furthermore, coping strategies, which occur frequently in individuals' lives, could be more fully understood. Investigation of these issues could have important implications for individual health and well-being.

Christopher Niemic is a senior completing his honors degree in psychology this year. The author's future plans include graduate work in social psychology studying intrinsic motivation and its effects on self-regulation and well-being. Also, Niemic would like to work in academia as a researcher and professor specializing in self-determination theory.