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# Implicit Measurement of Attitudes

## *A Physiological Approach*

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## Introduction

Psychology has a long history of developing methods to study mental states that avoid reliance on introspective self-report. Psychoanalysts, for instance, used word choice errors (Freud, 1933) or narratives generated after viewing ambiguous images (e.g., the TAT; Morgan & Murray, 1935) to infer unconscious motivations and preferences. Similarly, recognizing that verbal reports of attitudes only provide information regarding a subset of evaluative processes, social cognition researchers have developed a large arsenal of implicit attitude measures, such as the Implicit Association Test (Greenwald, McGhee, & Schwartz, 1998), bona fide pipeline (see Chapter 2, this volume), and Affect Misattribution Procedure (see Chapter 15, this volume). These measures have the potential to uncover aspects of evaluative processing that occur automatically (Fazio, Sanbonmatsu, Powell, & Kardes, 1986) and outside of conscious awareness (Draine & Greenwald, 1998). Thus, in addition to having the advantage that they circumvent obvious social desirability concerns (especially in sensitive domains such as prejudice), these types of indirect measures may also provide information regarding aspects of evaluative processing that people do not have accurate or complete introspective access to (e.g., processes that occur within hundreds of milliseconds). For this chapter, we define an implicit measure of attitude as one that does not require a self-report or conscious introspection.

From their earliest definitions, attitudes were thought to invoke a readiness for behavioral action and, as such, were expected to have physiological consequences supported by specific emotional states (Allport, 1935). Most simply stated, Thurstone (1931) defined an attitude as "the affect for or against a psychological object." Because the activation of an attitude often leads to an emotional reaction, it was assumed that one could understand the evaluative state of a person by monitoring various bodily responses, an assumption predicated on the following sequence of events:

Stimulus → Attitude → Emotional Response → Measurement

Thus, if a person with a negative attitude toward spiders should come across one, a negative emotional response is assumed to follow the activation and processing of the spider attitude. Following this logic, psychologists have measured physiological states to make inferences about attitudes for nearly a century. For example, electrodermal activity (i.e., the skin's ability to conduct electricity) has been shown to vary as a function of the emotionality (Smith, 1922) and attitude extremity (Dysinger, 1931) of presented stimuli, and agreement with attitude statements (Dickson & McGinnies, 1966).

## The Evaluative System and Physiology

At root, attitude research is concerned with the prediction of behavior, a task that has proven to be much more complicated than initially imagined by psychologists. Accordingly, the history of attitude research has shifted from a focus on the general relationship between attitudes and behavior to a more precise investigation and delineation of different attitudinal components, and their relation to the prediction of different aspects of behavior. Research in this vein has found, for instance, that more specific attitudes predict more specific behaviors (Ajzen & Fishbein, 1977) and that more automatic attitudes tend to influence more spontaneous behaviors (Dovidio, Kawakami, & Gaertner, 2002). These findings reveal the utility of studying the complexity of the evaluative system and suggest that multiple components of the evaluative system play relatively unique roles in driving behavior.

Understanding the evaluative system may allow us to dissect the complex relationship between specific stimuli and particular behavioral outcomes. As noted by Cacioppo and Berntson (1992), the relades were thought to invoke a such, were expected to have specific emotional states (All- ie (1931) defined an attitude as object." Because the activation reaction, it was assumed that te of a person by monitoring predicated on the following

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tionships among psychological events and their causes can take many forms, and the physiological measurement of attitudes necessitates a careful understanding of the relationships between any particular measurement and inferences about process and representation (i.e., inferences about how the evaluative system works). Thus, in order to make appropriate and productive use of physiological measures, it is necessary to ground their use and interpretation in an understanding of the evaluative system. Naturally, our understanding of the evaluative system will be continually revisited and revised based on the findings generated from physiological and other measures.

Evaluation is not the result of a single process that occurs within a fixed interval of time. Some judgments may be quick and remain stable after just a moment or two, whereas others can take a lifetime to develop. For example, an attitude toward a dishonest car salesman may consist of a fleeting impression that is constructed with minimal processing, whereas attitudes toward complex issues like immigration policy or environmental conservation may be slowly and continuously updated. Upon encountering a stimulus (whether a person, object, abstract concept, or situation), a sequence of evaluative processes is involved in the decoding and interpretation of a particular stimulus and the retrieval of appropriate and contextually meaningful memories that can be used to construct an evaluative state (see Figure 16.1).

We take an imperialist view of the concept of attitude—including all forms of associative or propositional representations that may guide or aid evaluative processing. That is, we use the term attitude to refer to all pre-existing evaluative information a person has about a stimulus, due to prior learning (directly experienced or socially communicated; conditioned stimuli) and maybe even innate preferences (unconditioned stimuli). These attitude representations may take the form of semantic information (cognitive aspects), emotional associations (affective

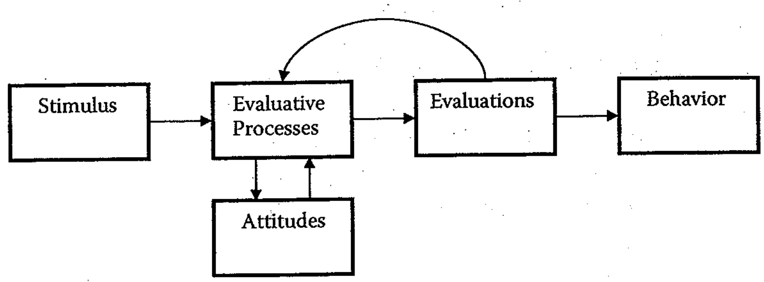


**FIGURE 16.1** Process depiction demonstrating the conceptual differences and relationships among attitudes, evaluations, and evaluative processes.

aspects), or scripts for action (behavioral aspects; Eagly & Chaiken, 1993). The fact that evaluations are constructed from multiple representations, contexts, and states does not imply that attitude representations are themselves constructed; relatively stable representations are needed to have consistency from situation to situation (and especially for novel contexts).

This conceptualization allows us to disentangle concepts that tend to be interchangeable in attitude research. Whereas the terms attitude and evaluation are often used synonymously, we have recently proposed a framework in which these constructs are assumed to be conceptually distinct aspects of the evaluative system (Cunningham, Zelazo, Packer, & Van Bavel, 2007). Whereas an attitude refers to a relatively stable set of representations (only some of which may be active at any time), an evaluation reflects the current processing state of the evaluative system (which is determined by the aspects of the attitude that are currently active).

Evaluative processes help determine the motivational significance of a stimulus as well as its expected reward or punishment value. These processes draw upon pre-existing attitudes, as well as novel information about the stimulus, contextual information, and current goal states. Evaluative states arise out of highly dynamic interactions between these elements. In our framework, we propose that this sequence is iterative and this information is weighted and reweighted multiple times with the goal of arriving at an optimal match between a stimulus and its evaluation. In other words, current evaluative states can serve as information to guide the next iteration of evaluative processing. In contrast to traditional dual-process models, we propose a continuum of implicit and explicit attitudes, in which implicit evaluations involve few iterations and a reduced set of cognitive operations and explicit evaluations involve many iterations and relatively more cognitive operations (see Cunningham & Johnson, 2007; Cunningham & Zelazo, 2007; Cunningham et al., in press). Thus, implicit, like explicit, evaluations may be rapidly constructed from a relatively stable set of attitudes in line with context and in accordance with motivational states (see Wilson & Hodges, 1992).

An advantage of physiological measures is that they are able to examine evaluative processes at multiple stages of information processing. Using different measures, with various spatial and temporal resolutions, the multiple components of this complex system can be disentangled. By turning to physiology, we can examine the antecedents (e.g., stimulus decoding, attention, and memory retrieval) and consequences (e.g., emotional and behavioral) of evaluative processing.

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An important challenge for attitude researchers has been to identity the various functional properties of these processes and to understand how they integrate to form coherent evaluations.

## Valence versus Arousal

In this review, we focus primarily on the concepts of valence and arousal/intensity. We acknowledge that this is a simplification of a highly complex system and do not wish to imply that these are the only important aspects of attitudes—multiple characteristics of attitudes, such as accessibility, certainty, elaboration, knowledge, personal relevance, and structural consistency, are all likely to be important (Petty & Krosnick, 1995). Yet, the concepts of valence (good vs. bad) and arousal (the amount of energy associated with the state of readiness induced by a stimulus) are currently among the best understood biological aspects of evaluation. A reliable distinction between emotional valence and arousal has been found in self-reports (Russell, 1979), behavior (Schacter & Singer, 1962), and more recently, neural signatures (Anderson et al., 2003; Cunningham, Raye, & Johnson, 2004; Small, Gregory, Mak, Gitelman, Mesulam, & Parrish, 2003).

In their classic work on meaning, Osgood, Suci, and Tannenbaum (1957) found that the concepts of valence and potency were almost always the two most dominant sources of variance in any set of stimuli. The constant presence of a valence factor is easily understood: Knowing what is good or bad has implications for immediate survival, as well as goal development and attainment. On the other hand, increased states of arousal (which are associated though not necessarily synonymous with potency) direct attention toward motivationally relevant stimuli in complex environments and prepare an organism for behavior. Because different stimuli may be deemed important at different times, a general arousal or vigilance system that is independent of valence might function efficiently; in this type of dual system, a stimulus can maintain a consistent valence across situations although its relevance changes.

## The Peripheral Nervous System and Attitudes

At one level, the output of evaluative processing is highly complex. The potential behavioral outcomes of evaluative processing approach the infinite; evaluative processing impacts the products people buy, the politicians they vote for, the proximity with which they sit to others, their body language, the newspapers they read, the places they travel to, the numbers they select on attitude scales, and so on. That said, at a more general level of analysis, behavioral responses can be divided into either approach or avoidance responses (see, for example, Gray, 1982). Loosely speaking, approach responses serve to increase the presence of a particular stimulus in an individual's environment, whereas avoidance responses serve to decrease its presence.

Although there is great variety in the specifics of different behaviors, these behaviors reflect more general orientations or directions of action. As behavioral responses are made (as products are put into shopping carts, ballots are cast, etc.), the peripheral nervous system coordinates the complex movement of muscles throughout the body. However, before behavior is even initiated, the peripheral nervous system is already preparing for action; indeed, this preparation for action occurs even if the action itself never takes place. Importantly for our purposes, the pattern of peripheral nervous system preparation appears to differ depending on the intended direction of action. For example, because the physiological requirements of approaching versus avoiding presumably differ, preparatory responses in the peripheral nervous system are likewise assumed to be different.

Attitude researchers are able to capitalize on this behavioral readiness by measuring indices of peripheral nervous system activity; different patterns of activity can be taken to indicate the organism's current orientation toward a stimulus. Because the peripheral nervous system prepares the body for action before behavior takes place, these measures can provide an assessment of a person's current evaluative state even in relatively impoverished laboratory environments. In general, we suggest that peripheral nervous system measures are most likely to tap current evaluative states, the outcome of evaluative processing, as opposed to the more cognitive aspects of processing itself.

## Sympathetic and Parasympathetic Activity

The state of readiness for action that results from evaluative processing of a stimulus depends largely on the activity of the sympathetic (SNS) and parasympathetic (PNS) nervous systems. Historically, these systems were thought to be associated with opposite patterns of behavioral readiness, such that an increase in one system is associated with a decrease in the other. Whereas the SNS generally serves to mobilize

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bodily resources, the PNS generally serves to conserve resources or restore the body to equilibrium/homeostasis. More recently, although the SNS and PNS can be reciprocally activated, they may operate more independently than previously thought (see Berntson, Cacioppo, & Quigley, 1993; Berntson, Cacioppo, Quigley, & Fabro, 1994).

One index of sympathetic activation is sweat gland activity, which can be measured using a small electrical current passed through electrodes attached to the hand; as the sweat glands fill with sweat, the skin is better able to conduct electricity (Cacioppo, Petty, Losch, & Crites, 1994). More sweat flowing to the glands (and the corresponding increase in electrical conductivity) is thought to indicate greater SNS activation. Stimuli in the environment that induce evaluative processing, and a subsequent state of behavioral readiness, differ in the extent to which they arouse the SNS. A great deal of research has demonstrated the association between arousal and the skin conductance response (SCR). For example, Codispoti, Bradley, and Lang (2001) found that skin conductance responses were positively associated with the arousal ratings of briefly presented pleasant and unpleasant pictures.

Although the state of preparedness induced by the peripheral nervous system is influenced by both the valence and arousal associated with the stimulus, skin conductance is typically used only as a measure of arousal. The skin conductance response does not vary as a function of whether an arousing stimulus is positive or negative, and is therefore a poor indicator of valence. That is, although skin conductance responses can serve as a measure of the intensity of the state of behavioral readiness, it is difficult to determine from skin conductance responses alone whether an individual is primed to approach or avoid the stimulus (see Cacioppo, Bernston, Klein, & Poehlmann, 1997). Despite these limitations, skin conductance has often been used as an indirect measure of attitudes. In an early example, Cooper and Singer (1956) observed greater skin conductance in response to hearing complimentary statements about their least liked group and derogatory statements about their most liked group, relative to complimentary and derogatory statements about an intermediately rated group.

Skin conductance responses have the potential to provide information about relatively implicit evaluations. For example, in the Iowa Gambling Task (see Bechara, 2004, for a review), participants select cards from a number of decks, each of which is associated with different reward contingencies and levels of risk. Typical participants show anticipatory skin conductance responses when making risky decisions and begin to switch toward advantageous strategies, even before they are able to articulate a specific strategy. The implicit nature of the skin conductance response is evidenced by the fact that these physiological changes occur before participants are able to give an introspective, verbal report of their strategy.

Whereas SCR only indexes SNS activity, measures of cardiac activity have been shown to be sensitive to both SNS and PNS activity. As such, these measures may be able to better differentiate the valence of different responses (Blascovich & Kelsey, 1990; Boiten, 1996). Although attitudes that evoke approach and avoidance response tendencies may both be associated with increased arousal (and correspondent SNS activity), they may be distinguished from one another by unique patterns of peripheral blood flow. For example, preparations to fight versus flee a foe may both increase heart rate (HR), and yet be distinguishable by the patterns of blood flow to different muscle groups.

Similarly, researchers have used aspects of cardiovascular activity to distinguish between challenge and threat responses. Depending on one's current evaluations or existing attitudes, an object or situation may be perceived as a threat or challenge. This perception may be activated relatively automatically or occur following reflective processing. In either event, both threat and challenge are likely to enhance arousal (indexed by constriction and dilation at the arterioles), but can be distinguished by the easy (challenge) or restricted (threat) passage of blood through the vessels (e.g., Blascovich, Mendes, Hunter, Lickel, & Kowai-Bell, 2001). In this context, different forms of arousal have different physiological consequences: Whereas a threatening stimulus may evoke an intense affective response, a challenging stimulus may evoke greater potential energy to act.

Within the emotion literature, there is a great deal of research examining the potential for indices of cardiovascular activity, such as heart rate, to discriminate between types of emotions and aspects of evaluation (for reviews of cardiovascular variability measurement and analysis, see Berntson et al., 1997; Blascovich & Kelsey, 1990). Arguing that discrete emotions may possess relatively unique physiological signatures, Levenson (1992) found greater HR acceleration to fear, anger, and sadness than disgust; to anger and fear than happiness; and to negative than positive emotions. In contrast, Lang, Greenwald, Bradley, and Hamm (1993) found that HR acceleration was related to positive valence. Providing some resolution to these contradictory findings, a meta-analysis found that although current measures of cardiovascular activity do not appear to reliably distinguish between discrete emotions, certain indices do discriminate between positive and negative valence

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(Cacioppo, Berntson, Larsen, Poehlmann, & Ito, 2000). For example, HR and other cardiovascular indices were more strongly associated with negative than positive emotional states.

Interestingly, the activation of an attitude may result in less automatic activity when making preference judgments. Blascovich, Ernst, Tomaka, Kelsey, Salomon, and Fazio (1993) had participants make quick preference judgments about two abstract paintings. In one condition, participants first "rehearsed" their attitudes prior to the judgment task. In the other condition, participants rehearsed their attitudes toward one set of paintings, but were presented with novel paintings during the test phase. In the rehearsal condition, autonomic activity when making the preference decisions was similar to baseline. In contrast, when participants were responding to novel paintings, they exhibited autonomic reactivity that was consistent with threat motivation: increased contractility and vasoconstriction. Presumably, the accessible attitudes facilitated decision making and, thus, reduced threat by making responses less ambiguous.

## Facial Electromyography

Facial expressions of emotion (e.g., smiles and frowns) have long been used to communicate personal evaluations and infer the emotional states of others. Indeed, several emotional states (e.g., fear, anger, disgust) are believed to remain relatively consistent in visual representation across cultures (Ekman, 1989). Given the strong relationship between emotional displays and evaluations, facial expressions have long been assumed to reflect (e.g., Darwin, 1872) or communicate (Kraut & Johnston, 1979) personal attitudes. Facial electromyography (EMG) measures the electrical impulses that result from the activation of selected facial muscles. Muscle activity is generally measured by placing electrodes (in pairs) over the muscles in the brow (*corrugator supercilii*), cheek (*zygomaticus major*), and forehead (*medial frontalis*); near the lips (*orbicular oris*); and near the eye (*orbicularis oculi*); for a review of surface electromyography, see Tassinary and Cacioppo (2000).

Facial EMG has been used to measure emotional expressions, including those too subtle or fleeting to observe. For example, participants exposed to mild and moderate positive and negative images revealed EMG activity near the brow, eye, and cheek that could not be detected by independent judges (Cacioppo, Petty, Losch, & Kim, 1986). Subtle EMG activity near the brow (frowning) was higher for moderately than mildly negative images and lower for moderately than mildly positive images. In contrast, EMG activity near the eye (smiling) was higher for moderately than mildly positive images. Together, these interactions between valence and intensity provide evidence that facial EMG can differentiate the valence and intensity of emotional reactions and may allow relatively independent assessments of the intensity of positivity and negativity (Cacioppo et al., 1986).

Facial EMG has also been shown to index automatically and unconsciously evoked emotional responses. In one study, people were presented with happy, neutral, and angry faces for 30 ms, followed by a 500-ms neutral face mask (Dimberg, Thunberg, & Elmehed, 2000). Despite the fact that participants could not consciously recognize the rapidly presented emotional faces, they showed greater cheek (smiling) activity to happy than neutral faces, and greater activity to neutral than angry faces approximately 500 ms after stimulus presentation. Conversely, there was greater brow (frowning) activity to angry than neutral faces, and greater activity to neutral than happy faces. In a related study, brow activity increased for negative stimuli and cheek activity increased to positive stimuli even when participants were instructed not to respond to these stimuli (Dimberg, Thunberg & Grunedal, 2002). This research provides additional evidence that EMG may provide an index of relatively automatic and unconscious responses to valenced stimuli (distinguishing between positive, neutral, and negative stimuli).

There is also some evidence that facial EMG may provide a valid indirect measure of individual attitudes. For example, when White participants rated the friendliness of White and Black faces, they reported a preference for Blacks in spite of facial EMG activity suggesting a preference for Whites (Vanmen, Paul, Ito, & Miller, 1997). Similarly, participants were most likely to choose a partner from a politically sensitive outgroup (African-American or homosexual) despite greater facial EMG negativity (cheek less brow activity) compared to less sensitive outgroup targets (business major or graduate student). However, after being insulted, self-reported partner preference converged with facial EMG negativity, such that participants were least positive toward politically sensitive outgroup members (Ensari et al., 2004). More recently, cheek EMG activity was found to be a stronger predictor of selecting a White over a Black applicant for a teaching fellowship ($r = .40$) than the IAT ($r = .09$; Vanman, Saltz, Nathan, & Warren, 2004). Taken together, these studies provide evidence of the utility and predictive validity of facial EMG as an indirect attitude measure.

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A related measure is the startle response. The startle response represents a quick launch into a state of behavioral readiness in response to a negative stimulus. Although the startle response involves a full body response, the eyeblink is a quick, reliable, and easily measured aspect of the startle response (Lang, Bradley, & Cuthbert, 1990). The startle response is typically evoked by a loud, aversive noise; the subsequent eyeblink is recorded by an electrode placed on the forehead. Although a startle response is always evoked, this response is potentiated or enhanced when it occurs in conjunction with negative or threatening stimuli. Conversely, the startle response is likely to be attenuated when presented in a positive context (Lang et al., 1990).

In the section that follows we turn to discussion of the central nervous system, including the role that the amygdala appears to play in evaluative processing. The startle response is highly associated with amygdala activity. Patients with lesions to the amygdala often show attenuated or absent startle responses (Angrilli et al., 1996; Funayama, Grillon, Davis, & Phelps, 2001). To the extent that the amygdala is involved in the processing of fear or threat, the startle response can be used to assess evaluations of this type. Phelps and colleagues (2000) found that a greater startle response when viewing Black faces was correlated with amygdala activation to Black faces (measured using functional magnetic resonance imaging, or fMRI) and IAT-assessed racial bias scores.

## The Central Nervous System and Attitudes

In recent years, technological advances such as electroencephalography (EEG) and functional magnetic resonance imaging have allowed us to examine more directly the ways that specific brain regions are involved in evaluative processes. These methods have the potential to allow us to dissect the evaluative system into its various processing subcomponents, which will increase understanding of the various ways that people make evaluative judgments. If, as mentioned earlier, evaluations are the outcome of multiple affective and cognitive processes, we now have the opportunity to examine directly the evaluative processes that are recruited to meet situational and motivational constraints. In combination with other methods, brain imaging should help illuminate how prior attitudes are dynamically transformed into evaluative states.

In this part of our review, we will examine methods and findings regarding how the central nervous system is involved in evaluative processing. Specifically, we will review research (a) from functional brain imaging that allows us to make inferences about the brain correlates of evaluative processing, (b) using event-related potentials (ERPs) derived from EEG to make inferences regarding the time course of evaluative processing, and (c) examining frontal EEG asymmetries to map evaluative responding to approach and avoidance motivational tendencies.

## Brain Correlates of Evaluative Processing

In the last 10 years, there has been a rapid expansion in cognitive neuroscience research using fMRI to study the brain correlates of complex thought and feeling. Researchers use fMRI under the assumption that following neural activity in a brain region, the ratio of oxygenated to deoxygenated hemoglobin changes, resulting in a measurable change in magnetic signal. Although fMRI has very poor temporal resolution (the magnetic signal resulting from mere milliseconds of neural activity can lag for up to 12 to 16 s), it provides a relatively fine-grained (within 10 mm or so) index of where neural activity occurs. By carefully designing tasks for participants to perform while being scanned, we can observe evidence that may support dissociations between processes (i.e., two processes have distinct neural generators), associations among processes (i.e., two processes have the same neural generator), and interactions among processes (i.e., interdependencies between processes). In addition, research such as this may reveal that different psychological phenomenon share common underlying processes and causes.

Of most relevance to our understanding of evaluation is research on emotional processing, in particular, the processing of emotional facial expressions, as well as the neural circuits involved in reward and punishment. Although little work has been conducted on attitudes per se, research on emotion can guide the development of hypotheses regarding evaluative processes. More directly, to the extent that implicit attitudes are learned through principles of evaluative conditioning (Olson & Fazio, 2001), animal models that have mapped the neural circuits of fear and reward conditioning should be relevant for our understanding of implicit evaluation. Below, we focus our discussion on several brain regions that are thought to be important for evaluation. As in the previous section, we highlight the distinction between the processing of valence and arousal as it is reflected in central nervous system activity.

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amygdala: a small almond-shaped structure in the medial temporal lobe at the tip of the hippocampus. The amygdala is one of the key components of the limbic system, which is involved in various aspects of emotional learning and memory (LeDoux, 1996). Damage to the amygdala has been shown to have dramatic effects on one's ability to automatically learn affective associations and on the ability to generate automatic physiological responses to stimuli (Davis, 1997). In addition, the amygdala appears to be critical for the decoding of emotional facial expressions. Damage to the amygdala is associated with impairments in the ability to correctly identify emotional facial expressions, especially the negatively valenced expressions of fear, anger, and disgust (Adolphs et al., 1999). Extending this, research using fMRI has consistently found greater amygdala activity to negative than positive stimuli. Interestingly, these effects have been shown in multiple stimulus and sensory modalities, including faces (Morris et al., 1996), scenes (Paradiso et al., 1999), words (Isenberg et al., 1999), odors (Small et al., 2003), and tastes (Anderson et al., 2003). Research using subliminal stimuli has shown that these processes are (at least somewhat) automatic. In a conceptual replication of previous research on supraliminal emotional face processing (Morris et al., 1996), Whalen, Rauch, Etcoff, McInerney, Lee, and Jenike (1998) demonstrated that subliminal presentations of emotionally fearful faces led to significant amygdala activation. In addition, Morris, Öhman, and Dolan (1998) found, using both subliminal and supraliminal presentations, that after participants were classically conditioned to associate particular angry faces with an aversive stimulus, the amygdala showed greater activity to these conditioned faces than control faces. In the domain of race, subliminal presentations of Black faces (compared to White faces) are associated with amygdala activation (Cunningham, Raye et al., 2004). Moreover, the degree of this amygdala activation to Black faces was significantly correlated with responses to the IAT.

Although it is tempting to think of the amygdala as the *valence region*—simply activating as a direct function of stimulus negativity—recent imaging research suggests otherwise. In addition to activating to negative stimuli, the amygdala also appears to activate to positive stimuli when compared with neutral stimuli (Liberzon, Phan, Decker, & Taylor, 2003; Hamann, Ely, Hoffman, & Kilts, 2002; Hamann & Mao, 2002; Garavan, Pendergrass, Ross, Stein, & Risinger, 2001; see Zald, 2003, for a review). In three fMRI studies that manipulated or parametrically analyzed both valence and arousal such that the two could be examined orthogonally, different brain areas were associated with valence and arousal (Anderson et al., 2003; Cunningham, Raye et al., 2004; Small et al., 2003). In each of these studies, arousal was associated with amygdala activation and negative valence was associated with right prefrontal activation.

Although these findings suggest that amygdala activity may be more a function of arousal or emotional intensity than valence, caution needs to be taken regarding fMRI studies of amygdala activation in general. The amygdala is a highly complex structure and has 12 separate nuclei, each with different inputs and outputs. Unfortunately, the spatial resolution of fMRI is not yet fine enough to separate out these individual nuclei. It is quite possible that each nucleus has a different information processing function and pattern (see Whalen, 1998). As such, attributing a global role to the whole amygdala may not be accurate. It is possible that some amygdalic regions are involved in arousal, whereas others are specific to fear, reward, or punishment. Future research using higher field strength MRIs may be able to sort out these potentially unique functional areas.

Several other brain regions have been more directly associated with the processing of valence. For example, the ventral striatum—part of the basal ganglia located just above the amygdala—has been proposed to be part of a fear conditioning circuit (Davis & Whalen, 2001). In addition, several cortical areas appear to be involved in the processing of negatively valenced information. Sutton, Davidson, Donzella, Irwin, and Dottl (1997) found, using positron emission tomography (PET), that viewing negatively valenced pictures was associated with activation in the right orbital frontal cortex (OFC) and the right inferior frontal cortex, whereas viewing positively valenced pictures was associated with activation in the left pre- and postcentral gyri. More recently, evidence for right lateralized processing of negative information has been found using fMRI (Anderson et al., 2003; Cunningham, Johnson, Gatenby, Gore, & Banaji, 2003; Cunningham, Raye et al., 2004). Specifically, areas of the right inferior frontal cortex and anterior insula consistently appear to be involved more in processing negative than positive valenced stimuli.

The brain regions associated with reward may be distinct from those involved in the processing of threat or negativity. Animal models suggest a limbic reward circuit made up of the amygdala, hippocampus, nucleus accumbens, ventral pallidum, and ventral tegmental area. Neuroimaging research in humans has replicated this work, finding greater activation in these regions when receiving or learning about rewards (Delgado, Nystrom, Fissell, Noll, & Fiez, 2000). In addition, regions of

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posterior orbital frontal cortex appear to be involved in the processing of reward or positive valence more generally (Anderson et al., 2003; Nitschke, Nelson, Rusch, Fox, Oakes, & Davidson, 2003; Kringelbach, O'Doherty, Rolls, & Andrews, 2003). Although such findings do not necessarily imply that the processing of positive and negative information is fully dissociated, this suggests that they may involve at least partially separable circuits.

## The Time Course of Evaluative Processing

Whereas fMRI provides detailed information regarding the location of neural processing, it provides little to no information regarding the time course of such processing. In contrast, EEG methods provide the opposite type of information—millisecond-by-millisecond timing information with poor spatial resolution.* Given that claims that a particular process is implicit often depend on the speed of processing (i.e., the process appears to occur before conscious awareness), EEG methods can help determine the automaticity of a neural process.

In one of the first studies to examine evaluation using EEG, Cacioppo and colleagues (Cacioppo, Crites, & Gardner, 1996) identified an event-related potential wave associated with the processing of valenced stimuli presented in an emotionally incongruous context. A series of valenced stimuli were presented before a critical stimulus that was of the same or different valence. Of interest were EEG signals that differentiated the stimuli presented in congruous versus incongruous contexts. Cacioppo and colleagues identified a particular type of wave form termed a late positive potential (LPP) when participants saw a stimulus that was incongruous with a context; in these studies, a negative stimulus in the context of positive stimuli, or a positive stimulus in the context of negative stimuli. The amplitude of the LPP wave in these studies was shown to vary as a function of the degree of difference between the valence of the stimulus and the valence of the context in which it occurs. For example, when presented in the context of positive stimuli, a strongly negative stimulus will result in a larger LPP than a mildly negative stimulus (Cacioppo et al., 1996; Cacioppo, Crites, Gardner, & Berntson, 1994). The LPP associated with evaluative

* New source localization techniques are now allowing us to estimate likely neural generators of EEG signals, but these estimates are still controversial and at their best still cannot provide the resolution of fMRI.

incongruity is widely distributed across scalp electrodes but is more pronounced over posterior (parietal) scalp regions than over frontal sites. There is also evidence that the amplitude of this posterior LPP is greater over the right hemisphere than over the left—for both positive and negative stimuli presented in an incongruous evaluative context (Cacioppo et al., 1996).

Although the timing of the posterior LPP varies as a function of context, it typically begins around 500 to 600 ms after stimulus presentation. Researchers using this paradigm have shown that the posterior LPP is evident when participants are making both evaluative and non-evaluative judgments, suggesting that evaluative incongruity may be detected automatically (Cacioppo et al., 1996; Ito & Cacioppo, 2000; see also Crites & Cacioppo, 1996). Providing further evidence for the LPP to be involved in evaluative extremity, Schupp, Cuthbert, Bradley, Cacioppo, Ito, and Lang (2000) found that the amplitude of the LPP was largest for stimuli that were the most arousing—presumably the stimuli with the greatest motivational relevance.

ERP data also has provided evidence for hypotheses suggesting that negative stimuli have more motivational force than positive stimuli. Showing evidence for this negativity bias, LPPs are typically larger for negative stimuli in a positive context than positive stimuli in a negative context (Ito, Larsen, Smith, & Cacioppo, 1998), and the degree of hemispheric asymmetry (right greater than left) is greater for these stimuli as well (Cacioppo et al., 1996). In addition, several studies have found that the processing of negative information may occur more rapidly than the processing of positive information. Some have suggested that negative information is privileged such that it is processed more quickly than positive information—a temporal negativity bias (Cacioppo & Gartner, 1999). For example, Kawasaki et al. (2001) found that the processing of negative, but not neutral or positive, stimuli occurred 120 to 160 ms after stimulus presentation in single cell recordings of the human orbital frontal cortex. Negative stimuli appear to be differentiated from positive stimuli in posterior perception areas as indexed by an early ERP component in visual areas occurring in the first 100 ms after stimulus presentation (Smith, Cacioppo, Larsen, & Chartrand, 2003). In one study using magnetoencephalography (MEG), researchers found that negative stimuli were processed 200 ms more quickly than positive stimuli in the OFC (Carretie, Martin-Loeches, Hinojosa, & Mercado, 2001). Similarly, some ERP components such as the P200 appear to occur more rapidly to negative than positive stimuli (Carretie, Mercado, Tapia, & Hinojosa, 2001).

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Given the importance of arousal in directing attention, it is not surprising that these effects occur at a very early stage of information processing. In a study of face perception, Asley, Vuilleumier, and Swick (2004) found that ERP signals differed between emotional and nonemotional faces as early as 120 to 160 ms after stimulus presentation (see also Pizzagalli, Lehmann, Hendrick, Regard, Pascual-Marqui, & Davidson, 2002; Eimer & Holmes, 2002). In fact, ERP differences to emotional stimuli compared to neutral stimuli have been observed as early as 94 ms after stimulus presentation in occipital regions (Batty & Taylor, 2003). What is particularly interesting about this rapid emotional processing is that identification of facial structure and features is thought to not occur until 170 ms after stimulus presentation (Sagiv & Bentin, 2001), suggesting that the processing of emotional expression, a signal that can denote safety or danger, may occur in parallel with the encoding of facial structure. In other words, emotional significance may be processed before a stimulus has been fully identified (see Niedenthal & Kitayama, 1994). In addition to occurring rapidly, these early emotional processes may also occur in the absence of conscious awareness. Several studies have now demonstrated emotional processing of stimuli that participants do not report even having seen. For example, skin conductance and ERP signals index the subliminal presentation of emotional faces as rapidly as 100 ms after stimulus presentation (Öhman & Soares, 1994; Williams et al., 2004).

## EEG Asymmetry and Evaluative Processing

Following this research, Cunningham, Espinet, DeYoung, and Zelazo (2005) found an LPP occurring approximately 450 ms after stimulus presentation that was greater in frontal electrodes on the right for concepts later rated on an explicit attitude scale as bad, and greater on the left for concepts later rated as good. The amplitude of the LPP effects did not differ between tasks for the first few hundreds of milliseconds of the LPP whether participants were making evaluative (good-bad) or control (abstract-concrete) judgments. Only later (approximately 750 ms after stimulus presentation) did the effects become amplified for the good-bad task. This suggests that early differences in right versus left frontal sites may differentiate implicit positive versus negative evaluations, whereas later differences differentiate explicit positive versus negative evaluations (see Davidson & Irwin, 1999).

Although initial theories linked frontal EEG alpha (8 to 12 Hz) asymmetries to valence, more recent research strongly suggests that frontal asymmetries index motivational tendency, rather than valence. Early research confounded valence with motivational tendency, finding that greater right hemisphere activation is associated with a tendency toward withdrawal behavior (and negative stimuli) and that greater left hemisphere activation is associated with a tendency for approach behavior (and positive stimuli; Sobotka, Davidson, & Senulis, 1992; Sutton & Davidson, 1997, 2000; see Davidson, 2004, for a review). Moreover, frontal EEG alpha asymmetries have been shown to predict depression (Davidson, 1988), emotion regulation ability (Jackson et al., 2003), and general well-being (Urry et al., 2004). Recent research has unconfounded valence with motivational tendency, showing that anger, an approach motivation with a negative valence, is associated with greater left frontal EEG activity (Harmon-Jones & Allen, 1998). The relationship between anger and left frontal asymmetries has been replicated extensively, suggesting that left hemispheric activity is primarily involved in approach motivation, regardless of valence (e.g., Harmon-Jones, Lueck, Fearn, & Harmon-Jones, 2006). Although these alpha power estimates have not yet been examined in the context of attitudes, it seems plausible that attitude valence should predict the direction of asymmetry and attitude strength variables should predict the intensity of the asymmetry. It may also prove fruitful to explore whether motivational tendencies mediate attitudes and behavior.

## Conclusion

In this chapter, we review a number of physiological measures that can be used to investigate attitudes and evaluations and the processes that underlie them. Specifically, these measures allow us to examine the neural architecture and processes (central nervous system) that support attitude activation and evaluative processing, and how the outcomes of evaluative processing are reflected in the body's readiness to act (peripheral nervous system). One of the central themes of this chapter has to do with the complexity of the evaluative system and the necessity of matching physiological measures with the specific aspect(s) of evaluation under investigation. The recent distinction between relatively implicit and explicit evaluations (Fazio, 1990; Greenwald & Banaji, 1995) captures some of this complexity, but a more comfrontal EEG alpha (8 to 12 Hz) t research strongly suggests that ıal tendency, rather than valence. th motivational tendency, finding ion is associated with a tendency ative stimuli) and that greater left th a tendency for approach behav- avidson, & Senulis, 1992; Sutton n, 2004, for a review). Moreover, ɔeen shown to predict depression ability (Jackson et al., 2003), and .ecent research has unconfounded showing that anger, an approach ıssociated with greater left frontal , 1998). The relationship between ; been replicated extensively, sug- s primarily involved in approach . Harmon-Jones, Lueck, Fearn, & : alpha power estimates have not attitudes, it seems plausible that ection of asymmetry and attitude ıtensity of the asymmetry. It may motivational tendencies mediate

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plete understanding of the evaluative system is an ongoing goal. We believe that physiological measures and methods, appropriately used, have enormous promise to help us achieve this objective by allowing researchers to more precisely explore specific processes of evaluation. These measures will represent useful tools as social psychologists investigate evaluation with increasing specificity.

In the introduction, we discuss the utility of distinguishing between attitudes as representations, evaluations as states, and evaluative processes as the computations that connect attitudes and evaluations (see Figure 16.1). In this framework, peripheral nervous system measures are more likely to be associated with evaluations and central nervous system measures with attitudes and evaluative processes. Within the peripheral nervous system, SNS and PNS activity are associated with patterns of readiness for action (e.g., approach or avoidance responses). EMG activity reflects the current emotional state of the perceiver, which includes aspects of valence (i.e., positive vs. negative affect) and arousal. fMRI and EEG, on the other hand, directly examine the neural processes that give rise to these bodily responses and, as such, likely reflect the evaluative processing component of our model. It is important to note that, at present, no physiological method directly measures the attitude representation itself. Evaluations arise out of evaluative processes that draw not only upon pre-existing attitudes, but also upon novel information about the stimulus, contextual information, current goals, and so on (see Schwarz & Bohner, 2001). The presence and strength of a pre-existing representation has to be inferred by its impact on evaluative processing and ultimately the current evaluation.

Admittedly, a one-to-one mapping of evaluation onto the peripheral nervous system and evaluative processing onto the central nervous system is somewhat overstated, especially considering the iterative nature of the evaluative system. According to our model, the evaluation of a particular stimulus is continually updated, with the current evaluation providing a source of information that feeds forward into future evaluative processing. This means that the links between the peripheral and central nervous systems are not unidirectional; rather, the individual's current state of behavioral readiness can feed into subsequent evaluative processing. For example, in the SCR section we describe research using the Iowa Gambling Task, which finds that participants show anticipatory skin conductance responses immediately before choosing from a risky deck of cards. Importantly, these anticipatory physiological responses occur before participants have begun to construct a conscious strategy for selecting appropriate cards and appear to feed into the on-line evaluative processes that occur as individuals attempt to develop a strategy. The importance of this peripheral nervous system feedback is revealed by research on orbital frontal patients, who show normal skin conductance responses when receiving rewards and punishments, but do not show the normal anticipatory physiological responses prior to their decisions. Patients with these types of lesions, unlike normal adults, typically continue to make disadvantageous decisions by choosing from risky decks of cards (see Bechara, 2004), perhaps because their ongoing evaluations do not include peripheral nervous system feedback from previous trials.

For social psychologists to make the best possible use of physiological measures, it will be necessary to validate them in the same manner as traditional attitude measures. Specifically, although there are direct associations between biology and each measurement technique, each measure also has its own sources of error. For example, although the amygdala and orbital frontal cortex are likely to play an important role in evaluative processing, fMRI signals from these regions are distorted due to signal interference from the surrounding sinus cavities. In addition, these regions are too distant from the scalp to provide reliable EEG signals (note that both of these problems are more severe for OFC than amygdala). Just as an answer on a questionnaire or a reaction time on a response latency measure can be influenced by various factors, only part of a physiological response is "caused" by the evaluation or process it is presumed to measure. Therefore, as for any other attitude measure, a careful analysis of the reliability of each method is necessary to ensure that our conclusions are justified, particularly if we want to make claims about individual, as opposed to group-level, differences.

The potential for measurement error highlights the need to use these measures in conjunction with traditional explicit and recently developed implicit attitude measures. In addition, because each physiological measure taps different aspects of the evaluative system, these measures should also be used in complement with one another to explore the entire evaluative system. Physiological measures should not replace or supersede other methods; rather, their greatest promise lies in helping to elucidate the processes that support and underlie behavior. In doing so, biologically informed research will enhance current models of attitudes. Although a relatively new approach, social neuroscience has already made insights into the complexity of the biological systems underlying evaluation (see Cunningham & Zelazo, 2007; Ito & Cacioppo, 2001). As social neuroscience further integrates the theories

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