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The current status of research on the structure of evaluative space

Catherine J. Norris,
Dartmouth College

Jackie Gollan,
Northwestern University

Gary G. Berntson, and
The Ohio State University

John T. Cacioppo
The University of Chicago

Abstract

The structure of evaluative space shapes emotional life. Although behavior may be constrained to a single bipolar dimension, for example as defined by the opposing movements of approach and withdrawal, the mechanisms underlying the affect system must be capable of an astonishing range of emotional experience and expression. The model of evaluative space (ESM; J. T. Cacioppo, W. L. Gardner, & G. G. Berntson, 1997, 1999) proposes that behavioral predispositions are the ultimate output of the affect system, which is defined by operating characteristics that differ both for positivity and negativity, as well as across levels of the nervous system. In this article, we outline the current status of theory and research on the structure of evaluative space. First, we summarize the basic tenets of the model, as well as recent research supporting these ideas and counterarguments that have been raised by other theorists. To address these counterarguments, we discuss the postulates of affective oscillation and calibration, two mechanistic features of the affect system proposed to underlie the durability and adaptability of affect. We summarize empirical support for the functional consequences of the principles of affective oscillation and calibration, with a focus on how oscillation and the “stickiness” of affect can lead to the emergence of ambivalence, whereas affective calibration and the flexibility of the affect system produce asymmetries in affective processing (e.g., the negativity bias). Finally, we consider the clinical implications of disorder in the structure of evaluative space for the comprehension and treatment of depression and anxiety.

Our emotional world is composed of an interconnected web of people, objects, and events that each carry potentially critical information for not only our ability to survive, but also thrive. The complex and dynamic nature of this emotional world, combined with the survival value inherent in many of the stimuli encountered in its reaches, demands the capability of responding both quickly and flexibly when determining whether a stimulus is hostile, hospitable, or has features of both. The affect system has evolved to efficiently and effectively promote adaptive responses to stimuli, and to produce an astonishing range of emotional experience and expression. Discriminating hostile from hospitable stimuli is so fundamental to and important for mammalian survival that this behavioral organization can

be found at multiple levels of the neuraxis, ranging from the spinal cord to the neocortex (Berntson, Boysen, & Cacioppo, 1993; Berntson & Cacioppo, 2008), and can happen quickly, efficiently, and without awareness (Wilson & Bar-Anan, 2008). However, although the primary function of the affect system is to discriminate bad from good, harmful from helpful, aversive from appetitive, it does not follow that the structure of the affect system is necessarily constrained to a bipolar configuration. Rather, the complexity and flexibility of observable emotional responses suggest that the underlying structure of the affect system is capable of nuanced and adaptive processing. The model of evaluative space (ESM; Cacioppo & Berntson, 1994; Cacioppo, Gardner, & Berntson, 1997, 1999) proposes that bipolar behavioral predispositions are influenced by the affect system, but the affect system is not constrained to a bipolar processing continuum.

In the current paper we review the basic principles of the ESM, as well as emerging evidence supporting them and counterarguments that have been raised against the ESM by other researchers. We then discuss the principles of affective calibration and affective oscillation, the support for each, and their functional utility for understanding emotional responses. Finally, we consider the utility of the ESM for understanding and studying clinical disorders, particularly major depression and generalized anxiety.

Historical Perspectives on the Structure of Evaluative Space

Historically, emotion was thought to vary along a bipolar continuum, with a reduction in negative affect being equivalent to an increase in positive affect. In other words, feeling “less bad” following a traumatic event such as the loss of a loved one was considered functionally equivalent to feeling “more good”. One of the first researchers to challenge this assumption was Norman Bradburn (1969), who in his analysis of survey data raised the possibility that positive and negative affect were separable. Counterarguments from other theorists, however, ranged from the fact that people were reporting on different periods of their life during which their emotions were bipolar (thus, positive and negative affect were never co-experienced or independent within a single individual) to the possibility that the apparent separability was simply a measurement artifact. Although the idea that positive and negative affect were separable clearly had many strong opponents, evidence for the separability of appetition and aversion continued to accrue and some version of separability was featured in many dominant theories of emotion – notably, this is especially true for neurally-mechanistic theories (i.e., those that explicitly propose specific neural mechanisms underlying emotional processes). Gray (1982) suggested that two separable neural systems subserved behavioral appetition and aversion, with the *behavioral activation system* primarily composed of mesolimbic dopaminergic projections from the ventral tegmentum to the ventral striatum (including the nucleus accumbens) and the *behavioral inhibition system* including the amygdala and septohippocampal system (SHS; see McNaughton & Gray, 2000 for an update of this model). Lang and his colleagues (Lang, 1995) have proposed that emotions are action dispositions that are driven by two opponent motivational systems, namely the appetitive and aversive systems, housed in subcortical regions of the brain. Lang and colleagues’ theory of motivational priming (1995) suggests that activation of each of these systems primes associations, representations, and actions that are consistent with the active system. Both Gray (1982; McNaughton & Gray, 2000) and Lang’s (1995) theories, however, are explicit in positing that appetition and aversion are reciprocally activated, which means that emotions continue to be conceptualized along a bipolar valence dimension (i.e., ranging from very negative to very positive). In other words, feeling “less bad” is equivalent to feeling “more good,” regardless of the underlying structure of evaluative space proposed by these different models.

The Evaluative Space Model

Affect refers to feelings beyond those of the traditional five senses, with an emphasis on the experience of emotions and variations in hedonic tone. Accordingly, the scientific study of human affect and emotion has tended to emphasize reportable feeling states. Studies of the conceptual organization of affect and emotion indicate that people represent feelings and emotions in terms of a circular order around the perimeter of the space defined by a bipolar valence dimension and an orthogonal dimension labeled activation (i.e., a circumplex; e.g., see Russell & Carroll, 1999) or, alternatively, by a space defined by two bipolar valence dimensions, one ranging from low positive affect to high negative affect (NA) and a second ranging from low negative affect to high positive affect (PA; Watson & Tellegen, 1985). Although there is an appeal to studying feelings to understand affect, this approach often fails to consider the mechanisms underlying our mental contents and ignores the fact that most cognitive processes occur outside of direct awareness (Nisbett & Wilson, 1977; Wilson & Bar-Anan, 2008). Over millions of years of evolution, efficient and manifold mechanisms have evolved for differentiating hostile from hospitable stimuli and for organizing adaptive responses to these stimuli. These are critically important functions for the evolution of mammals, and the integrated set of mechanisms that serve these functions can be thought of as an “affect system.” It is this affect system – its architecture and operating characteristics – that is the focus of the ESM (Cacioppo & Berntson, 1994; Cacioppo & Berntson, 1999; Cacioppo, Gardner, & Berntson, 1997; Cacioppo, Gardner, & Berntson, 1999).

Emotional life is incredibly varied. Current research in the field of emotion continues to debate the number of core or basic emotions that we experience (e.g., Ekman, Friesen, & Ellsworth, 1972), as well as their structure in affective space, and particularly along the emotion circumplex (e.g., Watson et al., 1999; Russell & Carroll, 1999). Both the basic emotions approach and the dimensional approach to the study of affect have their strengths and weaknesses, in that each focuses on one aspect of emotional processes often by ignoring or disregarding others. For example, the basic emotions approach explores the cultural and situational specificity and generalizability of emotional experience and expression to better understand the evolutionary history and, ultimately, the functional roles that emotions serve. The basic emotions approach, however, tends to overlook the global underlying mechanisms of emotional processes in favor of a focus on specific antecedents, consequents, and (often facial) correlates of a small set of emotions, such as happiness, sadness, anger, disgust, fear, and surprise. In other words, theories of basic emotions emphasize the trees over the forest. Similarly, dimensional approaches emphasize the fundamental underlying components of emotional experience, whether valence and arousal (e.g., Russell & Carroll, 1999), PA and NA (Watson et al., 1999), appetite and aversion (Lang et al., 1995), behavioral activation and behavioral inhibition (Gray, 1982), or some other conceptualization, without regard to the discrete states that form the building blocks of our emotional life. Theories of dimensional emotion processes often cannot see the trees for the forest.

Both of the discrete emotion and dimensional approaches clearly have merit. More importantly, both approaches provide complementary information and limiting conditions for the understanding of emotion and affect. As indicated above, we suggest that the relationship between discrete emotions and the structure of evaluative space is analogous to that between trees and forests. Although trees are the fundamental building blocks of forests, it can be difficult to delineate individual trees, to separate one from the next, or to determine the contributions of a single unit to the whole. Rather, individual trees are part of a vast ecosystem that contains internal organizations critical to their creation and continued existence. In the current paper, we focus on the forests of emotional experience, at times overlooking the trees. This is not to suggest that a discrete emotion conceptualization of the affect system is in any way unimportant or uninformative. Indeed, discrete emotions have

received much of the focus of emotion research since the time of Darwin (1872). Instead, we suggest that studying the forests of emotional experience will shed light on the underlying structure of the affect system, ultimately contributing to a better understanding of the guiding principles of affective processes and their consequences for both adaptive and dysregulated behavior.

Although behavior may be constrained to a single bipolar dimension defined by the opposing movements of approach and withdrawal, the mechanisms underlying the affect system must be capable of an astonishing range of emotional experience and expression. In addition, constraints on the output of any system do not necessarily require that the internal mechanisms conform to the same structure. In other words, the affect system may very well have an underlying structure that allows for great flexibility of responses. The ESM (Cacioppo, Gardner, & Berntson, 1997, 1999) proposes that behavioral predispositions are the ultimate output of the affect system, which is defined by separable systems for processing positivity and negativity, each characterized by unique operating characteristics. The ESM does not contest the circumplex as a stable endpoint of the conceptual organization of affect and emotion, nor does it question the existence of core emotions. The ESM does, however, dispute the assumption that the circumplex structure fully captures the functional dimensions of the affect system. The ESM is not a theory of what elicits affective states or emotions. Rather, it is a theory of the mechanisms that underlie affect, and how these mechanisms are engaged in theoretically predicted circumstances. We begin by describing the primary dimensions of evaluative space and summarizing evidence for the support of a multidimensional approach to the study of affect and emotion.

It is worth noting at the outset that the ESM assumes that positive affect is linked with appetitive motivation and negative affect with aversive motivation, such that high positivity will more often than not lead to motivation to approach and high negativity will lead to motivation to avoid. Certain emotions appear to violate this assumption – in particular, anger is an approach-oriented negative emotion (Carver & Harmon-Jones, 2009). We argue that although under specific circumstances anger may result in approach-oriented behavior, the underlying motivation remains defensive. One must approach the target to eliminate the threat. Such behavior is exhibited in more mundane circumstances as well – for example, writing a nasty review of a rival's manuscript may be an aggressive, approach-oriented behavior, but the underlying motivation is to prevent publication (i.e., is defensive). Thus, although the proximal behavior appears to be appetitive or approach-oriented, the distal motivation is defensive. Consistent with this perspective, the startle reflex is potentiated when individuals view angry faces (Springer, Rosas, McGetrick, & Bowers, 2007), suggesting that viewing angry faces induces a defensive motivation. Similarly, we may be required to perform avoidant or withdrawal-oriented behaviors in order to pursue a goal, as in the early days of courtship, when over-eagerness may be viewed as desperation. Waiting three days to call after a first date is clearly an avoidant behavior with, often, an appetitive motivation. The proximal behavior is avoidant, the distal motivation is appetitive. Therefore, the ESM equates positivity with appetitive motivation and negativity with aversive motivation.

The structure of evaluative space is bivariate: Positivity and negativity are separable

Positivity and negativity represent two systems that underlie emotion and affect. Although moods, subjective feelings, and discrete emotions vary widely across contexts, cultures, and individuals, when considered in terms of their behavioral profiles two clusters of emotional experiences emerge: positive (pleasant, appetitive) and negative (unpleasant, aversive) states (Cacioppo, Berntson, Larsen, Poehlman, & Ito, 2000). The *level of organization* postulate

suggests that although there are distinctions among both positive and negative emotions, positive emotions are more similar to each other than they are to negative emotions, and vice versa (see Table 1 for descriptions of all postulates discussed herein). This organization is suggestive of two underlying dimensions of the affect system: one focused on processing appetitive stimuli such as food and cooperative conspecifics, and a second on aversive stimuli such as predators. Thus, the ESM argues that the dimensions of positivity and negativity are at least partially functionally separable, in that they are not equivalent in their constitution, operations, or consequences (*functional separability* postulate). In this respect, we agree with researchers who suggest that appetite and aversion are two distinct dimensions (e.g., Lang, 1995; Gray, 1982). What separates the ESM from these theories is that we explicitly argue that these dimensions are not necessarily reciprocally or equally activated. The combined outputs of the appetitive and aversive systems produce a behavioral predisposition to either approach or avoid the stimulus (*evaluative activation* postulate), where the behavioral effects of positive affect (i.e., approach) are generally in opposition to those of negative affect (i.e., avoidance; *antagonistic effects* postulate). Although some of these calculations may be straightforward, such as avoiding a potentially harmful stimulus (e.g., snake, angry person), others require more complicated algorithms. For example, animals must come to water sources to drink even though this exposes them to predators. The ability to simultaneously hold two opposing motivations, to approach the water and avoid being eaten, is clearly adaptive and requires nuanced and flexible evaluative processes. The affect system performs such calculations to ultimately determine behavior toward or away from a stimulus.

Behavioral evidence for the separability of positivity and negativity

Much research over the past twenty years supports the separability of positivity and negativity in emotional responses, both in self-reports of mood and in responses to emotional events in the laboratory. Warr, Barter, and Brownbridge (1983) found that although positive affect was correlated with the number of self-reported positive life events over a six month period and negative affect was correlated with the number of negative events, positive and negative affect were not correlated, consistent with the notion that positivity and negativity may not be reciprocally activated. Diener and Iran-Nejad (1986) found that self-reported mood also showed some independence of positivity and negativity, such that when one type of affect is present at a relatively low level, the level of the opposing type can range anywhere from low to high without affecting the original affect. In other words, a strongly positive event (e.g., getting a manuscript accepted in a top journal) that occurs on a day characterized by a mild level of negative mood (e.g., getting up on the wrong side of bed) may selectively increase positive mood while a mild negative mood state persists. In the laboratory, Brehm and Miron (2006) provided evidence for this independence of emotional states, such that a negative event (e.g., losing a lottery) experienced after a positive event (e.g., receipt of a candy bar) did not eliminate the initial emotional response (i.e., happiness). Therefore, a change in one affect (positivity, negativity) does not necessarily influence pre-existing emotional states.

Neural evidence for the separability of positivity and negativity

The structure of neural systems itself provides some preliminary evidence for the potential for a separation of appetitive and aversive information processing. The literature generally supports the conclusion that reward and punishment circuitry remain at least partially independent, with reward involving the nucleus accumbens (and the ventral striatum more broadly) and punishment implicating aspects of the insula, amygdala, and bed nucleus stria terminalis. As mentioned previously, Gray's neurally-mechanistic theory of motivation (1982; McNaughton & Gray, 2000; see also Canli, 2006 for an excellent review of this model) proposes that two separable neural systems subserve behavioral appetite and

aversion: the behavioral activation system (BAS), which mediates responses to rewarding and non-punishing stimuli, and the behavioral inhibition system (BIS), which is activated only under conditions of conflict when goals are incompatible (e.g., when dangerous stimuli need to be approached). Gray (1982; McNaughton & Gray, 2000) clearly relates individual differences in BAS and BIS function to different emotional disorders, namely those of impulsivity (or addiction) and anxiety, respectively. Although many aspects of this theory remain up for debate, the central conceptualization of different neural systems underlying particular behavioral dispositions is well-supported.

O'Doherty and his colleagues have taken a complementary approach to understanding the neural correlates of emotional processes, focusing on reward and punishment as potentially separable systems. Using functional magnetic resonance imaging (fMRI) and a multitude of affective stimuli (e.g., faces, odors, gambles, tastes), O'Doherty and his colleagues (O'Doherty, Winston, Critchley, Perrett, Burt, & Dolan, 2003; Gottfried, O'Doherty, & Dolan, 2002; O'Doherty, Kringelbach, Rolls, Hornak, & Andrews, 2001; O'Doherty, Deichmann, Critchley, & Dolan, 2002) have reported that different subregions of the orbitofrontal cortex (OFC) are involved in reward and punishment processing, with monetary reward – as well as appetitive and pleasant odors, smells, and faces – activating medial OFC and monetary punishment – as well as aversive and unpleasant odors, smells, and faces – activating lateral OFC (although other studies have failed to find this dissociation; cf. Elliott, Newman, Longe, & Deakin, 2003; Breiter, Aharon, Kahneman, Dale, & Shizgal, 2001). Furthermore, even within a single neural structure (e.g., the striatum), losses and gains may be represented in spatially distinct regions. Seymour and his colleagues (2007) found that although prediction errors for losses and gains both activated the ventral striatum, the activation peaks for gains and losses were spatially distinct, with anterior regions of the striatum responding to gains and posterior regions to losses. Importantly, this spatial selectivity mirrors the relationship between the anterior-posterior dimension of the striatum and valence (i.e., reward-punishment) observed in rats (Reynolds & Berridge, 2001). An additional dimension of functional separability within the striatum/nucleus accumbens is the selective involvement of dopamine (DA) and acetylcholine (ACh) in positivity and negativity, respectively (Hoebel et al., 2007).

Other support for the separability of neural systems for negativity and positivity comes from a meta-analysis of neuroimaging studies of emotion conducted by Wager, Phan, Liberzon, and Taylor (2003), which showed clear differences in brain activation as a function of valence. Wager et al. (2003) found that more peaks of activation were reported in the cerebellum and insula for negative than positive stimuli, but that more peaks of activation were reported in the basal ganglia (including the ventral striatum) for positive than negative stimuli. These results are consistent with animal work on the separability of reward and punishment neural circuitry (cf., Reynolds & Berridge, 2001, 2002). Importantly, as activation increased for both negative and positive stimuli in all of these areas, activation patterns did not reflect a bipolar function of valence. In other words, a bipolar structure of emotion might indicate that positive and negative affect are opposite outputs of a single neural generator such that one neural system may account for the experience of both affects, with increased activation corresponding to, for example, increased positive and decreased negative affect, and decreased activation corresponding to decreased positive and increased negative affect (i.e., reciprocal activation). The extant neural data do not support this conclusion.

A final source of neural evidence for the separability of reward and punishment is that of the apparent specialization of neurotransmitters and their receptor densities. Hariri and his colleagues (Hariri et al., 2002) have repeatedly shown that polymorphisms of the serotonin reuptake gene (5HTT) are associated with differences in amygdala reactivity to emotional

(and particularly negative – both fearful and angry) faces, such that individuals with a short allele show increased amygdala reactivity. The same polymorphism is also associated with individual differences in neuroticism and anxiety disorders (Gonda et al., 2008; Gunthert, Conner, Armeli, Tennen, Covault, & Kranzler, 2007), and recent studies suggest that the short allele affects not only amygdala reactivity, but also functional connectivity between the amygdala and regions of the ventromedial prefrontal cortex (particularly the subgenual anterior cingulate cortex [ACC]). Serotonin itself has long been linked to depressive mood, and the projections of the serotonergic system extend from the raphe nucleus to neural regions associated with negativity (as well as Gray's behavioral inhibition system), including the amygdala and areas of prefrontal cortex, ultimately projecting broadly throughout the cortex. Dopamine, however, has long been linked to reward and even addiction. Animals will electrically self-stimulate dopaminergic pathways (Olds, 1958), and dopamine reuptake is decreased following the administration of cocaine, resulting in an accumulation of dopamine in the synaptic cleft (Ritz, Lamb, Goldberg, & Kuhar, 1987; Hoebel et al., 1999). Contrary to the serotonergic pathway leading from the amygdala to the prefrontal cortex (PFC), the dopaminergic pathway extends from regions of the midbrain including the ventral tegmentum to the nucleus accumbens. Furthermore, there are high concentrations of dopamine receptors (D1, D2) in the ventral striatum, a structure clearly implicated in reward-related behaviors such as wanting and liking (Berridge, 1996). Thus, the serotonin system appears to be relatively selective for responding (and controlling responses) to negative, aversive stimuli, whereas the dopaminergic system is selective for responding to positive, appetitive stimuli.

The separability of positivity and negativity allows for multiple modes of activation

Previous models of emotion have proposed multiple underlying dimensions (e.g., Lang et al., 1995; Gray, 1982; Watson & Tellegen, 1999). None of these models, however, have questioned the assumption that positivity and negativity are reciprocally-activated, meaning that increasing one necessarily decreases the other. The ESM suggests that, although reciprocal activation may be the most common mode of the affect system and may result in more stable behavior over time (*energetic efficiency* postulate), it is not the only mode of activation (see Figure 1). Because positivity and negativity are functionally separable and partially independent, increasing one is not assumed to have a direct effect on the other (*modes of evaluative activation* postulate). Consider a typical political campaign, in which the average voter may possess a few pieces of positive information about her favored candidate. The revelation that the candidate's views on a particular issue (e.g., abortion) are more moderate or even in opposition to the voter's own position will likely have an effect on the voter's feelings toward the candidate. Traditional models of affect would suggest that the voter's feelings will not only become *more negative*, but also *less positive* (i.e., reciprocal activation), perhaps resulting in a change in voting behavior. The ESM, however, suggests that an increase in negativity is not necessarily accompanied by a decrease in positivity. Thus, positivity may be maintained even as negativity increases, resulting in coactivation (i.e., objective ambivalence). Reciprocal activation and coactivation are two possible modes of activation proposed by the ESM. Independent activation by either the positivity or negativity system is also possible. Returning to our voter, the discovery that her original information about the candidate was unfounded may affect her positivity toward the candidate, but will likely not increase (or decrease) her negativity.

Coactivation

Thus, the ESM proposes that the separability of positivity and negativity at initial levels of processing allows for multiple relationships between the two, characterized as different

modes of activation. One hallmark of this proposed feature of the affect system is that it provides a theoretical base for the experience of objective ambivalence. If positivity and negativity can be co-activated rather than simply reciprocally related, under specific theoretically-derived circumstances an individual may feel both positive and negative, resulting in a conflict between approach and avoidant behaviors. Consider the case of a gazelle that must approach the water to drink even though its fiercest predator often hunts in that proximity. Coactivation of positivity and negativity may promote approach behavior while maintaining vigilance for a potentially harmful encounter. The conflict between approach and avoidance may result in a high energy state in which resources can be quickly utilized for escape, if necessary. And ultimately, the animal that can simultaneously experience positive and negative affect will have an evolutionary advantage over one that must process serially.

A more mundane example of the utility of coactivation concerns a voter who possesses both positive and negative information about a candidate, and thus faces a difficult decision – to cast her vote for the candidate or a rival. The ESM proposes that situations in which positivity and negativity are co-activated are generally rare and highly arousing, as they provide indeterminant guidance for behavior. The ability to weigh and simultaneously experience positivity and negativity, however, allows for a flexibility of responding that is critical for adapting to changing environments and need states. Even though objective ambivalence (i.e., the simultaneous experience of positivity and negativity) may be unpleasant, it is arguably critical for human survival.

These examples of coactivation all concern situations in which an individual is simultaneously attending to positive and negative features of a single stimulus or event, which is a form of achieving coactivation that results from *parallel evaluative processing*. A second form of achieving coactivation results from *oscillation*, or the ability to fluctuate between positive and negative stimuli with sufficient speed to produce a sustained activation of both. Russell and Carroll (1999) have long argued that happiness and sadness, which they conceptualize as being opposite ends on a bipolar continuum, cannot occur simultaneously; rather, that individuals may simply oscillate between these two states. In other words, ambivalence is just oscillation between positivity and negativity, happiness and sadness – the two affects do not actually co-occur. We argue that oscillation may simply be a second mechanism for achieving coactivation. Affect is “sticky”. A mood or emotional state, once obtained, can be difficult to reverse (Brehm & Miron, 2006; Diener & Iran-Nejad, 1986). When oscillating quickly enough between positivity and negativity, both affects may be activated for an extended period of time, resulting in the experience of a blurred but stable state of coactivation or subjective ambivalence. In other words, if an individual is oscillating between two emotional states at a rate fast enough that the subjective experience is that of ambivalence, the product of oscillation is conceptually identical to that of simultaneous experience. Fast oscillation between happiness and sadness may function much as a low-pass filter, such that high frequency activity (i.e., that of the individual states of positivity and negativity) is removed, leaving behind only the blurred product of the two.

Evidence for the coactivation of positivity and negativity

Behavioral evidence

Larsen, McGraw, and Cacioppo (2001) showed that individuals report experiencing subjective ambivalence (i.e., coactivation of positivity and negativity) in specific, theoretically-predicted, but atypical situations, such as on the day of their graduation from college. On a normal, average day on campus, however, emotional states conformed to a bipolar configuration, as participants reported some happiness or some sadness, but little to no coactivation of the two. This study is critical for illustrating our position on the structure

of evaluative space. The ESM proposes that a bipolar structure of affect provides a stable and efficient guide for how to deal with the world, and thus this is an organization that dominates our emotional experience under normal circumstances, and toward which we tend to gravitate.

The experience of ambivalence in ecologically-valid situations is strong evidence for the coactivation of positivity and negativity. Such field settings, however, often sacrifice experimental control for psychological impact. Larsen, McGraw, Mellers, and Cacioppo (2004) elicited ambivalence in the laboratory environment via a unique set of gamble outcomes in which winning (or losing) the lesser of two amounts (e.g., \$5 instead of \$10) reliably produced simultaneous happiness and sadness. Disappointing wins (and relieving losses) have proven to be a useful tool for studying the experience of ambivalence in the laboratory, and have been used to validate the *evaluative space grid* (ESG), a new measure of affect that directly follows from the theoretical predictions of the ESM (Larsen, Norris, Hawley, McGraw, & Cacioppo, 2009).

Finally, we have recently found evidence for the role of oscillation in the experience of objective ambivalence (Norris, Eichenold, & Cacioppo, 2009). Participants viewed pairs of emotional images taken from the International Affective Picture System (IAPS; Lang & Bradley, 2005) that oscillated at either 0.2 Hz or 2 Hz for a duration of 10 seconds. Participants reported feeling ambivalent following oscillating pairs that included one pleasant picture (e.g., happy couple) and one unpleasant picture (e.g., car accident). Importantly, no ambivalence was reported when participants viewed pairs of matched valence pictures (i.e., two pleasant, two neutral, two unpleasant pictures). In sum, oscillation between two stimuli of opposing valence elicits objective ambivalence much as single stimuli that elicit both positive and negative affect (e.g., a disappointing win) elicit objective ambivalence.

Neural evidence

Grabenhorst and his colleagues (2007) used fMRI to show that the brain represents not only the overall affective value of a stimulus but also the independent contributions of positivity and negativity to that overall evaluation. Specifically, a complex odor mixture composed of pleasant and unpleasant components elicited activation in both regions associated with representing odor pleasantness (medial OFC) and those representing odor unpleasantness (dorsal ACC, mid OFC). The brain is thus capable of simultaneously representing the positive and negative hedonic value of a complex stimulus, and this ability may contribute to affective decision making.

Grabenhorst et al. (2007) focused on the coactivation of separable neural circuits associated with positivity and negativity (i.e., pleasant and unpleasant odors) that contribute to the overall evaluation of a complex and objectively ambivalent affective stimulus (i.e., an odor mixture). In other words, Grabenhorst and colleagues examined patterns of neural activation in neural networks involved in processing positivity and negativity in response to stimuli that were both positive and negative, or objectively ambivalent. Taking a complementary approach, Cunningham and his colleagues (Cunningham, Johnson, Gatenby, Gore, & Banaji, 2003; Cunningham, Raye, & Johnson, 2004) examined the neural substrates of objective ambivalence by correlating patterns of brain activation with individuals' ambivalent responses to stimuli. Specifically, participants rated famous names as "good" and/or "bad" on separate scales, and objective ambivalence was calculated from these ratings (Priester & Petty, 1996) and used to predict brain activation. Cunningham et al. (2003) reported that greater ambivalence was associated with increased activation of the right ventrolateral prefrontal cortex (vlPFC; see Cunningham, Raye, & Johnson, 2004 for a replication). Cunningham and his colleagues (2003) also found this area of vlPFC to be

more active when participants made an evaluative (good/bad) versus nonevaluative (past/present) judgment, suggesting that the vIPFC may be critical for evaluative processes. Although these findings do not directly address the separable neural systems that underlie positivity and negativity and their coactivation during objective ambivalence, they do suggest that objective ambivalence recruits neural areas involved in evaluation, perhaps to reduce the behavioral indeterminacy associated with the coactivation of positivity and negativity.

In sum, the experience of objective ambivalence, or the coactivation of positivity and negativity, is supported by both behavioral and neural data. Behavioral results suggest that although affect may be constrained to a reciprocal organization under most normal circumstances (i.e., increased positivity is associated with decreased negativity), ambivalence does occur in highly evocative, complex emotional situations (e.g., on graduation day; Larsen et al., 2001) and in well-controlled laboratory paradigms (Larsen et al., 2004). Occam's razor, or the law of parsimony, states that "All other things being equal, the simplest solution is the best." Larsen and his colleagues have conclusively demonstrated that, although reciprocal activation may represent the simplest relationship between positivity and negativity, it is not the only possible pattern of activation, and that positivity and negativity can be co-activated under specific, theoretically-predicted circumstances. Thus, parsimony is not satisfied by any model of the affect system that posits that positivity and negativity are always reciprocally-activated. Furthermore, the relative independence of neural systems for positivity and negativity, their coactivation during the experience of objective ambivalence, and the specificity of function observed by neurotransmitters (e.g., serotonin, dopamine) are supportive of the separability of positivity and negativity, at least at initial underlying levels of processing. The ESM, therefore, provides a more comprehensive approach to understanding the structure of evaluative space.

Heterarchical organization across the neuraxis allows for multiple representations

The ESM suggests that affective processes are multiply-represented in the brain and spinal cord, but function differently across levels of the neuraxis (i.e., the central nervous system; *heterarchical organization* postulate). Having studied stroke patients who lost the functionality of large areas of cortex yet remained capable of performing fundamental activities (e.g., eating, talking, moving), John Hughlings Jackson (1897) was perhaps the first researcher to clearly articulate the view that functions critical for human survival may be represented in multiple neural structures. The ESM argues that, as differentiating good from bad, appetitive from aversive, helpful from harmful are critical functions, evaluative processes are instantiated at multiple levels of the neuraxis. The spinal cord produces perhaps the most primitive and gross reflexive response to a stimulus, which is constrained to an approach/withdrawal configuration and specific to inherently noxious stimuli – but is also fast and efficient. At this level of the neuraxis, flexor and extensor muscles are reciprocally-coupled, mechanically, so that a limb movement can only be an extension or a flexion (Berntson & Cacioppo, 2003). Even at this level, however, the basic spinal motoneuron circuits are separate and distinct, and hence can be subject to independent, reciprocal, or coactive control. Although there are interneuronal links which tend to promote reciprocal activity (e.g., crossed extension reflex), both flexor and extensor muscles can be simultaneously contracted. In this case, the mechanical bipolar constraints of limb movement belie the greater underlying complexity of neuromuscular systems. At higher levels of the neuraxis, responses become even more flexible, providing the organism with an increasingly sensitive and context-dependent behavioral repertoire (Berntson et al., 1993). Because of the greater information processing capacities and the broader range of output resources, rostral regions of the brain often produce slower, more serial-like response

dispositions, and may implement behavioral output by modulating lower-level reflexes or by direct control of lower motor neurons via descending influences.

The multiple levels of representation of approach and avoidance behaviors allow for different modes of activation to be dominant or prevail depending on the level of representation. At particularly low levels of organization, such as spinal reflexes, responses may be constrained to be reciprocally activated (e.g., flexion/extension responses to painful stimulation such as heat). These low level responses, however, can be overridden via involvement of top down mechanisms triggered by complex contextual and interpersonal cues (e.g., in the need to walk through fire to save a child). In other words, muscular reflexes may be constrained to a mode of reciprocal activation to provide immediate, automatic, behaviorally-rigid responses to stimuli of clear valence and import (e.g., fire, food); whereas higher levels of the neuraxis have the ability to override these dominant responses to produce adaptive, flexible responses that consider the current environment and context.

Asymmetries in positivity and negativity

We have argued that the independence of positivity and negativity allows for multiple modes of activation, such that increasing one does not necessarily affect the other, a feature of the affect system that also allows for the coactivation of both positivity and negativity (i.e., the experience of ambivalence). In addition, separable systems for the processing of positivity and negativity allows for differences in how appetitive and aversive stimuli are processed. The ESM suggests that positivity and negativity may be characterized by distinctive activation functions, where an activation function is the relationship between input to a system and output from that system (postulate of *distinct activation functions*). Imagine two audio speakers that are controlled by different volume controls. The speakers can be set so that a one-unit increase in input (i.e., one notch on the volume knob) results in the same change in output (i.e., the same increase in decibels), resulting in symmetry in the speakers' activation functions. The affect system, however, may not be well-served by symmetry in activation functions for positivity and negativity. Rather, as aversive stimuli have arguably stronger implications for survival than do equally appetitive stimuli (e.g., avoiding a predator is more critical than pursuing a mate), the affect system may have evolved to be vigilant for and to produce rapid and strong responses to aversive and potentially harmful stimuli. In other words, a one-unit increase in volume produces a different decibel output for our two hypothetical speakers, such that increasing negativity has a stronger impact than does increasing positivity. This asymmetry is termed the *negativity bias* (see Figure 3, Table 1).

Positivity, however, promotes exploration and curiosity, behaviors that contribute to knowledge about the world around us and, ultimately, to the resources we obtain. Thus, in the absence of stimulus input to the affect system, the default response may be approach-oriented. Turning again to our speaker metaphor, when the volume on our pair of speakers is turned off, one speaker may continue to produce a low-level output or "hum". The affect system may have evolved such that in the absence of stimulus input to the system, positivity is stronger than negativity, producing a *positivity offset* (Figure 3, Table 1) that results in a tendency to approach and explore novel (but neutral) environments.

In sum, the ESM proposes two asymmetries in the activation functions for positivity and negativity: a *negativity bias*, such that strongly aversive stimuli elicit stronger responses than do appetitive, all else being equal; and a *positivity offset*, such that when input to the affect system is absent or minimal, positivity outweighs negativity.

Evidence for the negativity bias and positivity offset

Negativity bias

Negativity bias is readily apparent at the lowest level of neuraxial organization. Flexor withdrawal reflexes are the first to emerge developmentally, the first to re-emerge after spinal cord injuries, and the most powerful of spinal reflexes (see Berntson & Cacioppo, 2008). In the past twenty years, multiple review articles have provided strong support for the existence of a negativity bias in emotional responses. Taylor (1991) argued that negative events evoke stronger physiological, cognitive, emotional, and social responses than do neutral or positive events, and that this mobilization of the organism is often followed by a minimization phase, in which the impact of the event is minimized or even erased. Cacioppo and his colleagues (2000) performed a meta-analysis of studies examining physiological responses during experienced emotion states and found that negative emotions did indeed elicit stronger and more reliable physiological responses than did positive emotions. Other reviews have focused on the contributions of the diagnosticity and salience (Baumeister, Bratslavsky, Finkenauer, & Vohs, 2001) and the contagion (Rozin & Royzman, 2001) of negative stimuli, such that the presence of a negative entity (e.g., a cockroach) can ruin an otherwise positive entity (e.g., a delicious dinner). Few of these reviews, however, delve into the level of underlying mechanism, and few theories regarding the structure of the affect system can account for a negativity bias.

Kahneman and Tversky (1984) explored the differential impact of positivity and negativity in their studies on framing, showing that losses and gains have different effects on risk-seeking behavior (i.e., individuals are risk averse in the domain of gains and risk seeking in the domain of losses), that a negative frame has a stronger effect on behavior than a positive frame (e.g., “200 of 600 infected people will die” versus “400 of 600 infected people may live”), and that losses loom larger than gains (e.g., a loss of \$100 has a stronger effect on behavior than does a gain of the same amount). Pratto and John (1991) found that negative words (e.g., murder, cancer) elicited stronger Stroop interference than did neutral or positive words, suggesting that the meaning of negative words is automatically processed. Hansen and Hansen (1988; see also Öhman, Lundqvist, & Esteves, 2001 and Öhman, Flykt, & Esteves, 2001) showed that angry faces “pop out” of a display of distracters, whereas happy faces take longer to be detected and require a more effortful search. Crawford and Cacioppo (2002) found that individuals are better able to implicitly learn a relationship between negative affect and spatial location than between positive affect and spatial location, suggesting that there is an advantage to learning where to look for danger. In sum, both basic processes, such as attentional capture and implicit learning, and more conscious, deliberate judgments involved in decision making are subject to a bias towards negativity.

Psychophysiological data support a negativity bias in emotional reactivity. James (1884) first proposed that peripheral psychophysiological responses precede rather than follow a change in emotional state, giving rise to the prediction that distinct emotions (e.g., anger, fear, sadness, happiness, disgust) ought to be differentiated by unique physiological signatures. In a recent meta-analysis, Cacioppo and colleagues (2000) found that, although strong support for the psychophysiological differentiation of distinct emotions is ultimately lacking, negative and positive emotional states are distinguished (with the exception of skin conductance and cutaneous blood flow). Furthermore, negative emotions were generally associated with stronger responses of the autonomic nervous system (ANS) than were positive emotions. Interestingly, we recently found that even though skin conductance does not typically distinguish between positive and negative affective states, as it is a measure of arousal and not of valence, individuals high in neuroticism exhibited marginally stronger skin conductance reactivity to unpleasant than pleasant pictures (Norris, Larsen, &

Cacioppo, 2007). This finding is consistent with a negativity bias in physiological responding for some individuals – we return to a discussion of individual differences below.

Researchers have begun to use other measures, such as event-related brain potentials (ERPs) and functional magnetic resonance imaging (fMRI) to further investigate the mechanisms underlying the negativity bias. Using ERPs, Ito and her colleagues (Ito, Larsen, Smith, & Cacioppo, 1998) found evidence for a negativity bias in the evaluative categorization stage of processing (i.e., deciding a stimulus is good or bad), as indexed by the late positive potential (LPP), a positive-going component maximal over central midline sites at approximately 500 ms post-stimulus onset that is sensitive to context violations. Ito et al. (1998) reported a larger LPP to context-inconsistent visual scenes (e.g., an emotionally-evocative target picture presented in the context of many neutral pictures), but also found that the LPP was larger to unpleasant than to equally frequent, arousing, and extreme pleasant target pictures. Furthermore, Ito and Cacioppo (2000) showed that the LPP is also sensitive to implicit categorization, such that even when participants categorized stimuli on a non-evaluative dimension (e.g., people/no people), a negativity bias emerged in the LPP. These findings indicate that even when processed indirectly, negativity has a stronger effect on neural responses than does positivity.

Additional ERP research has shown that the negativity bias emerges at earlier stages of processing than the relatively late LPP. Smith and his colleagues (Smith, Cacioppo, Larsen, & Chartrand, 2003; Smith et al., 2006) focused on early attentional components of the ERP, and found evidence for a negativity bias in the P1, a positive-going component maximal over occipital sites at about 120 ms post-stimulus onset. The P1 is larger to contextually-primed stimuli, as well as to negative visual stimuli, suggesting that aversive stimuli may be “chronically-primed”, a finding consistent with research on selective attention to aversive or threatening stimuli (e.g., Bradley et al., 2003). It is worth noting that the negativity bias in the P1 can be eliminated, but only by making positive stimuli more accessible (i.e., attention to positivity can be increased, but attention to negativity cannot be decreased; Smith et al., 2006). Carretié and his colleagues (Carretié, Mercado, Tapia, & Hinojosa, 2001) found that the P200, another attention-related ERP component, had higher amplitudes and shorter latencies for negative than positive stimuli. The P200 negativity bias was replicated and extended in a subsequent paper in which Carretié and his colleagues (Carretié, Martín-Loeches, Hinojosa, & Mercado, 2001) argue that an expectancy bias toward negative stimuli (i.e., pre-stimulus onset, a larger frontal N280 is observed for cues indicating a subsequent negative target) gives way to an initial, rapid and brief “early” attentional response to negative stimuli (i.e., post-stimulus P200), which is followed by a slower but longer “late” attentional response to positive stimuli (i.e., post-stimulus P340; see also Carretié, Hinojosa, Martín-Loeches, Mercado, & Tapia, 2004). Importantly, the purpose of these responses is thought to differ, with the earlier bias towards negativity focused on rapid motor action, and the later bias towards positivity aimed at deeper levels of processing. Furthermore, source localization analyses of the two ERP components exhibiting a negativity bias in attention revealed possible neural substrates, with the anterior cingulate cortex (ACC; BA 32) implicated in expectancy-related effects and the visual association cortex implicated in the early attentional bias toward negative stimuli.

Source localization analyses of electrocortical activity collected from the scalp, however, are an indirect index of neural correlates. Using fMRI as a more direct index of neural activity, we have recently conducted multiple studies examining the neural correlates of the negativity bias. Participants viewed pleasant and unpleasant pictures that were matched on both psychological (e.g., extremity, arousal) and physical (e.g., spatial frequency, color, complexity) dimensions while full brain volumes were acquired. In three studies individuals showed greater activation of the right visual association cortex (e.g., BA 19, extending to

BA 39) to unpleasant than to equally extreme and arousing pleasant pictures (Norris & Cacioppo, 2009). Importantly, when auditory stimuli were used in lieu of pictures, the negativity bias in neural activation moved from visual association cortex to auditory association cortex (e.g., BA 22), suggesting both that (a) the negativity bias generalizes to other modalities, and (b) emerges at the same level of processing regardless of stimulus type. In addition, one study also revealed a negativity bias in neural activity in the ACC, consistent with Carretié's source localization results. Other studies using PET (Fredrikson et al., 1993; Kosslyn et al., 1996) and fMRI (Mourão-Miranda et al., 2003) have produced similar results. In sum, evidence from both source-localized ERPs (Carretié et al., 2001, 2004) and from fMRI (Norris & Cacioppo, 2009) is consistent with a negativity bias in early stages of attention. It remains to be seen how this early attentional bias toward negativity produces the broad mobilization of behavior observed toward aversive and potentially harmful stimuli.

Finally, Cunningham, Van Bavel, and Johnson (2008) have shown a negativity bias in amygdala activation to stimuli that contain both positivity and negativity. Cunningham and his colleagues asked participants to either (a) indicate their attitude toward a famous person using a 4-point valence scale ranging from *very negative* to *very positive*, (b) focus on their positive responses to that individual and respond on a 4-point positivity scale ranging from *not at all positive* to *very positive*, or (c) focus on their negative responses to that individual and respond on a 4-point negativity scale ranging from *not at all negative* to *very negative*. Results indicated that although the amygdala was activated when participants made overall attitude judgments of both positive and negative stimuli, amygdala activation was also affected by motivational frame. When asked to focus on negativity or positivity, amygdala activation was strongest to negative and positive stimuli, respectively. A negativity bias was observed, however, in that the amygdala was still responsive to negative stimuli even when participants were focusing on their positive feelings. Given recent theories that the amygdala responds to motivationally relevant stimuli (Norris et al., 2004; Cunningham, Van Bavel, & Johnson, 2008) and ERP findings supporting the implicit processing of negativity (Ito & Cacioppo, 2000), this pattern of findings suggests that negative stimuli remain significant even when an individual is focused elsewhere.

Positivity offset

As with the negativity bias, a positivity offset can be seen at the level of spinal reflexes. Although flexor withdrawal reflexes predominate at higher stimulus intensities, lower level stimuli predominately trigger extensor, approach, and engagement responses (see Berntson & Cacioppo, 2008). As with the negativity bias, many findings in the field of social psychology provide some evidence for a similar positivity offset, or the tendency for positivity to outweigh negativity when little information (or input to the affect system) is available. Zajonc (1968) showed that under conditions of mere exposure – when a stimulus has simply been observed more frequently, all else remaining equal – exposure increases liking of a stimulus (e.g., Chinese ideographs, nonsense words). Zajonc (1968) also showed that positive words (e.g., good, happy, clean) are used more frequently than their negative counterparts (e.g., bad, sad, dirty; see also research on the *Pollyanna hypothesis*, Boucher & Osgood, 1969). The person perception literature has repeatedly shown that individuals express mild liking of unknown others. Originally termed the person-positivity bias (Sears, 1983), this robust finding has recently been extended to targets that are not human, including fish and insects (Cacioppo, Gardner & Berntson, 1997). Furthermore, research on egotistic optimism has shown that individuals predict that they will experience more positive than negative outcomes in the upcoming week (Pulford & Colman, 1996), attribute lower health risks to themselves than others (Hoorens & Buunk, 1993), and expect that joining an extracurricular group will have more rewards than costs for themselves than for others

(Brinthaup, Moreland, & Levine, 1991). Returning to studies on loss aversion (Kahneman & Tversky, 1984), Harinck, Van Dijk, Van Beest, and Mersmann (2007) recently showed that although losses do loom larger than gains for larger outcomes (e.g., losing €150 versus finding €150), gains loom larger than losses for smaller outcomes (e.g., finding €0.10 versus losing €0.10). These results are consistent with the operation of both a positivity offset at relatively low levels of affective input and a negativity bias at relatively high levels of affective input.¹

In sum, research on emotional responses from many different perspectives is consistent with the functioning of a positivity offset, such that under conditions in which little to no affective information is available (e.g., when encountering a novel stimulus or person, making predictions about our own uncertain futures, or responding to a mild and un consequential gain or loss), positivity outweighs negativity. Indeed, Diener and his colleagues have argued that the normative human experience involves a basal level of positive affect (Diener & Diener, 1996). Emerging research and theory suggests that a subjective well-being “set point” may (a) be set for most individuals such that the default emotional state is slightly positive (e.g., Diener & Diener, 1996), and (b) function such that following aversive events the set point is re-attained more quickly than expected (e.g., Gilbert, Pinel, Wilson, Blumberg, & Wheatley, 1998). This well-being “set point” may function much like a weight set point, such that although differences across individuals exist, it is relatively difficult to maintain a state beyond a range immediately surrounding one’s individual set point.

Calibration of the affect system

To maintain flexibility in multiple contexts and ecological niches, the affect system may have evolved to function in ways similar to the visual system, such that affective processes may adapt to differing emotional contexts much as the eye adapts to contexts differing in brightness. When entering a darkened room from a bright summer day the pupil must adjust (i.e., dilate) to the new environment in order to remain sensitive to small changes in light. This adjustment is performed automatically, and allows us to catch enough light to sustain vision; but also comes at a cost, as image quality is sacrificed. We argue that the affect system may perform the same kind of calibration as a function of different emotional contexts (see Kahneman, 1999 for a similar argument; *recalibration* postulate). Specifically, the negativity bias will ensure that an individual remains vigilant for aversive stimuli and the positivity offset will provide some basis for exploration and curiosity, regardless of the emotional context, whether the environment is safe and familiar or dangerous and unknown.

One possible mechanism by which the affect system may calibrate is that of contrast, or the effects of preceding or surrounding stimuli on our interpretation of a target stimulus. Returning to the visual analogy, Hong and Shevell (2008) have studied the neural correlates of chromatic contrast, by which a single color swatch appears to change its hue depending on its surroundings. Sandusky and Parducci (1965) found that neutral odors were rated as more pleasant when they followed unpleasant versus pleasant odors, suggesting that a neutral stimulus is rendered either pleasing or displeasing depending on the effects of a preceding stimulus. Parducci (1968) also found evidence for an affective contrast effect in the moral realm, as participants rated the act of poisoning a neighbor’s dog more objectionable when it was preceded by more despicable acts (e.g., the murder of a parent)

¹Note that the ESM is agnostic regarding the definitive levels of intensity (or input to the affect system) required to produce a positivity offset versus negativity bias. Given the flexibility of the affect system to adjust to different environments, these intensity thresholds may change to accommodate different ranges of input. Thus, a positivity offset is expected to emerge at relatively low intensity levels within a context, whereas the negativity bias is expected to emerge at relatively high intensity levels with the same context.

versus less despicable acts (e.g., stealing towels from a hotel). The fact that both our basic sensory processes like color vision and odor perception and our moral decisions can be affected by arguably irrelevant contextual stimuli is a strong argument for the importance of contrast in multiple domains.

Although many researchers have argued that affective contrast may be a result of a response bias, such that participants feel required to use the entire span of a rating scale, recent findings argue against this. Larsen and J. I. Norris (2009) found that moderately pleasant stimuli elicit stronger decreases in EMG activity over *corrugator supercilii* when included in a set with mildly pleasant stimuli than in a set with extremely pleasant stimuli. In other words, when presented alongside less positive images, moderately positive images become more rewarding and pleasant, but when presented in the context of extremely positive images, those same pictures become less rewarding and more neutral. Reynolds and Berridge (2008) found in rats that context (i.e., stressful versus preferred home environments) can affect the function of the nucleus accumbens, tuning the neural structure to generate more defensive or appetitive behaviors. Finally, Foti and Hajcak (2008) used contextual sentences to manipulate participants' perceptions of emotional images (e.g., a picture of a car accident accompanied by the statement "The set was dressed for the next scene of filming"). Foti and Hajcak (2008) found that contextual sentences manipulated emotional responses, reflected in both self-reports and ERPs. Emotional processes are clearly very sensitive to context; we simply argue that the affect system has evolved to take context into consideration.

Individual differences in the negativity bias and positivity offset

The Evaluative Space Model suggests that asymmetries in the activation functions for positivity and negativity have evolved over time to provide certain adaptive advantages, such that the positivity offset promotes exploration and discovery whereas the negativity bias provides vigilance for aversive and potentially harmful stimuli. As these asymmetries are thought to be adaptive, most individuals should exhibit evidence of both a negativity bias and positivity offset. However, as variance is the engine of evolution, individual differences in the magnitude of the negativity bias and positivity should exist, be stable over time, generalize across different types of stimuli, and predict behavior (*affective dispositions* postulate, Table 1). The summary of literature providing support for the functioning of a negativity bias and positivity offset reveals that these asymmetries do affect emotional judgments toward a broad variety of stimuli under diverse conditions. Yet, little research has directly examined individual differences in these proposed operating characteristics of the affect system.

Ito and Cacioppo (2005) measured individuals' responses to emotional pictures and found strong support for both a negativity bias and positivity offset at the normative level in their sample. Furthermore, the magnitude of both features differed across individuals, was normally distributed in the sample, and was stable over about two weeks. Importantly, both the negativity bias and positivity offset predicted judgments on an unrelated impression formation task, such that individuals with higher positivity offsets made more positive judgments about an unknown other when given only neutral information (e.g., "Sam was exposed to sunlight"), and individuals with higher negativity biases felt more negative about the target when provided with negative behavioral information (e.g., "Sam stole vegetables from his neighbor's garden"). In a recent replication and extension of this work, we have found that not only do individual differences in the negativity bias and positivity offset exist, but they generalize across different modalities (e.g., visual, auditory) and types of stimuli (e.g., pictures, words), are relatively stable over a one-year period, and predict implicit learning of relationships between affect and space (Norris, Larsen, Crawford, & Cacioppo,

2009). Specifically, when participants are exposed to a correlation between affect (e.g., pictures ranging from neutral to very unpleasant or from neutral to very pleasant) and spatial location, such that unpleasant images tend to appear toward the top of the computer screen ($r = .5$) or, in a separate version of the task, pleasant images tend to appear toward the right of the screen ($r = .5$), they are (a) better at learning the relationship between negativity and space than that between positivity and space, and (b) individual differences in both the negativity bias and the positivity offset predict implicit learning on this task (Norris et al., 2009). Finally, individual differences in the negativity bias predicted patterns of neural activation to affective stimuli, such that individuals with a higher negativity bias show even greater activation of association cortices (visual for pictures, auditory for sounds) to unpleasant than to pleasant pictures (Norris & Cacioppo, 2009). The observed relationship between neural activation and individual differences in the negativity bias provides strong evidence for the conclusion that the negativity bias is driven at least in part by greater attention to unpleasant stimuli than to pleasant stimuli, at least at early stages of processing. In sum, individual differences in the negativity bias and positivity offset may have far-reaching consequences for how we learn about and respond to stimuli in the environment.

Implications for understanding affective disorders

One consequence of variance in emotional processes across individuals is that studying individual differences may clarify the key processes that bring about the expression of symptoms of affective disorders (i.e., pervasive sadness, anhedonia). Individual differences in the features of affective processing that are postulated by the ESM, such as the positivity offset and negativity bias and the independent contributions of positivity and negativity to emotional states, may shed light on the mechanisms by which emotion processes become disordered. Although we argue that both the positivity offset and negativity bias are adaptive, research has made it clear that individuals differ in the magnitude of these asymmetries. Such individual differences in the positivity offset and negativity bias may predict whether an individual is prone to experience depression or anxiety. A similar argument has been made by Watson, Clark, and Tellegen (1988), who have suggested that although both depression and anxiety are characterized by increased negative affect, they can be distinguished by the addition of decreased positive affect in depression. The ESM differs from earlier perspectives in that it describes multiple features of affective processes that may affect mental health, including the calibration process, the independence of positivity and negativity, the “stickiness” of affect, and both the negativity bias and positivity offset. In addition, the ESM suggests that affective disorders may be characterized by dysregulation at specific levels of the neuraxis, and that the levels affected may differ across individuals. We now turn to detailed discussion of a select set of these hypotheses.

First, the ESM suggests that positivity and negativity are functionally separable at initial stages of processing. Unlike many models of emotion which assume that positivity/happiness and negativity/sadness are opposite ends of a single bipolar continuum, the ESM allows for independent contributions of positivity and negativity to emotional states and to approach/avoidance behavior. Research by Davidson and his colleagues has supported this conclusion, as they have long shown that positive and negative affect are associated with differential patterns of electrocortical activity over the prefrontal cortex, suggesting that positivity and negativity may rely on separable neural systems and may differentially contribute to the development of affective disorders. Individuals who exhibit greater relative left frontal electroencephalographic (EEG) activity tend to experience more positive affect in their lives (Tomarken, Davidson, Wheeler, & Doss, 1992), respond with more extreme positive affect following a positive mood induction (Wheeler, Davidson, & Tomarken, 1993), and have greater behavioral activation system (BAS) sensitivity (Sutton & Davidson, 1997). In comparison, individuals who exhibit greater relative right frontal EEG activity

experience more negative affect, respond to a negative mood induction with more negative affect, and report greater BIS sensitivity. In addition, patients diagnosed with major depressive disorder (MDD) show relatively less left than right prefrontal EEG activity. Finally, prefrontal EEG asymmetry is predictive of pharmacological treatment response (Bruder et al., 2001) and covaries with genetic risk for depression (Smit, Posthuma, Boomsma, & De Geus, 2007), suggesting that resting prefrontal asymmetry reflects a stable diathesis (i.e., endophenotype) for the development of depression (Allen, Urry, Hitt, & Coan, 2004).

In more recent work, Harmon-Jones and his colleagues have argued that the critical variable in research on frontal EEG activity is not positivity/negativity but rather approach/avoidance (Harmon-Jones & Allen, 1998). Supporting evidence for this conclusion comes from a series of methodical studies investigating the relationship between prefrontal cortical activity and anger, a negative affect with an approach motivation (Carver & Harmon-Jones, 2009). Individuals with higher trait anger show greater left relative resting EEG activity (Harmon-Jones & Allen, 1998), individuals who are insulted in the laboratory show greater left relative EEG activity (Harmon-Jones & Sigelmen, 2001), and a direct manipulation of approach motivation (i.e., ability to cope) within an anger manipulation showed that greater coping ability was related to greater left relative EEG activity (Harmon-Jones, Sigelman, Bohlig, & Harmon-Jones, 2003). Thus, frontal EEG asymmetry appears to more strongly reflect motivational orientation (i.e., approach/avoidance) than affect (positivity/negativity; see Harmon-Jones, Gable, & Peterson, 2009, for a thorough review). In sum, research has demonstrated the utility of studying the independence of positivity and negativity – as well as that of approach and avoidance – for understanding mental health disorders such as depression.

The separability of positivity and negativity contributes to the flexibility of the affect system, which allows for adaptive responses in highly variable and changing environments. The independence of positivity and negativity, however, also allows for multiple forms of dysregulation involving one or both of these systems. Heightened sensitivity to negativity may give rise to anxiety or depression, depending on positive functioning. If positivity is intact, anxiety may result; if positivity is diminished, depression may result (Watson & Tellegen, 1985). Manic states may occur when sensitivity to positivity is heightened, regardless of the function of negativity. The ESM therefore suggests that understanding the component processes that give rise to emotion is necessary for distinguishing between different forms of emotional disorders. One implication of this suggestion is that knowing how the component processes are dysregulated in depression, for example, will provide clinicians with a more focused approach to treatment. Consider two depressed individuals, one extremely dysphoric and anxious, the other characterized by decreased positivity (i.e., lack of enjoyment in activities that were previously pleasurable). If the component affective processes differ between these individuals, such that the former is characterized by heightened sensitivity to negativity and the latter by decreased sensitivity to positivity, the therapist can elect the most effective course of treatment for each. Thus, understanding the component processes of affect has implications for both diagnosis and treatment of emotional disorders.

Second, the negativity bias and positivity offset are the products of the component processes of positivity and negativity. Therefore, it is to be expected that individual differences in these asymmetries may also contribute to the development of emotional disorders. Although we argue that a negativity bias is adaptive, in that it fosters vigilance for potentially harmful events (even over the possibility of a beneficial experience, like finding food or a mate), heightened sensitivity to negativity and decreased responding to positivity might produce an overly large negativity bias that may result in behavioral paralysis. If one expects nothing

but the worst at all times, the world becomes a dangerous, hostile place. The ESM, however, distinguishes between responses to extremely evocative stimuli and mildly emotional stimuli, toward which positivity is thought to be greater than negativity. A second possibility in depression is that, if positivity is decreased across the board, individuals may fail to experience a positivity offset. Importantly, as depression is a disorder with a broad range of symptoms and causes, disorders of affective processes will differ greatly across individuals. Thus, the magnitudes of both the negativity bias and the positivity offset are critical for understanding the pathology of emotional disorders.

Much research supports the hypothesis that both anxiety and depression are characterized by strong biases toward negative (and particularly threatening) information. Anxious individuals in particular tend to show greater interference to negative stimuli on the Stroop color-naming task, whether stimuli are anxiety-related (Richards, French, Johnson, Naparstek, & Williams, 1992) or threat-related (Dalgleish, 1995; Amir et al., 1996). Depressed individuals have also exhibited increased Stroop interference for negative – and particularly sad – words (Williams & Nulty, 1986). Furthermore, a recent neuroimaging study has shown that the rostral anterior cingulate cortex (ACC), a region previously implicated in cognitive interference and the Stroop interference effect more specifically (Bush et al., 2000), was more active in depressed individuals on sad than neutral Stroop trials, and activation of the rostral ACC correlated with color-naming latencies of negative words in depressed patients (Mitterschiffthaler et al., 2008). In sum, research on depressed and anxious individuals using the emotional Stroop task supports the ESM's prediction that both depression and anxiety disorders may be characterized by a larger negativity bias.

Studies using the dot probe paradigm, in which participants first see two faces (one on the left, one on the right) and then indicate the position of a dot that follows (i.e., left or right), have also revealed a bias toward negative information in anxiety and depression. High trait anxious individuals show an attention bias toward angry (and sometimes fearful; Mogg, Garner, & Bradley, 2007) faces (Mogg & Bradley, 1999; Bradley, Mogg, White, Groom, & de Bono, 1999; Bradley, Mogg, & Millar, 2000; Pishyar, Harris, & Menzies, 2004), this bias can be observed in 7- to 12-year olds with generalized anxiety disorder (although they also show a bias for happy faces; Waters, Mogg, Bradley, & Pine, 2008) and in teenagers with high but subclinical trait anxiety levels (Telzer et al., 2008), and this bias may be more specific to social anxiety than to other forms (Mogg & Bradley, 2002). The attentional bias toward threatening faces observed in anxious individuals is accompanied by an enhanced N2pc (i.e., posterior N2, associated with attentional selection; Eimer, 1996) component of the ERP (Fox, Derakshan, & Shoker, 2008), as well as by increased activation of the right dorsolateral PFC (Telzer et al., 2008). Together, these findings suggest that the negativity bias in anxiety is subserved by both selective attention to and greater attention demand for threatening faces.

Additional neuroimaging studies examining threat bias in anxious individuals have implicated the amygdala, such that individuals with generalized social phobia exhibit greater activation of the amygdala to negative (i.e., fearful, angry, disgusted) than to positive (i.e., happy) faces (Phan, Fitzgerald, Nathan, & Tancer, 2006), amygdala activation to fearful faces in adolescents correlates with social dimensions of anxiety, including peer rejection and humiliation (Killgore & Yurgelun-Todd, 2005), and children with anxiety disorders show greater amygdala activation to fearful faces than do normal controls (Thomas et al., 2001). These studies suggest that anxiety (and social anxiety in particular) may increase the relevance of threat-relevant social stimuli, as the amygdala has been implicated in processing stimuli of biological importance.

Depression also biases attention toward threatening faces on the dot-probe task, such that individuals with major depressive disorder (MDD) show maintained attention to angry as opposed to neutral faces (Leyman, De Raedt, Schacht, & Koster, 2007), and this bias seems to persist even following treatment for depression (Joormann & Gotlib, 2007). Furthermore, depressed patients show greater activation of the amygdala to sad faces than do healthy controls (Neumeister et al., 2006; Fu et al., 2008), and amygdala activation to sad (Fu et al., 2004) and masked fearful (Sheline, Barch, Donnelly, Ollinger, Snyder, & Mintun, 2001) faces decreases with treatment for depression. This pattern of amygdala activation can be seen in at-risk adolescents as well, suggesting that increased amygdala reactivity to negative facial expressions may reflect vulnerability for major depression (Monk et al., 2008). Finally, depressed individuals exhibit a predisposition to interpret neutral faces as negative, and this negative interpretation bias correlates with amygdala reactivity (Dannowski et al., 2007).

Comparing the patterns of data for anxious and depressed participants, one might conclude that the attentional bias toward negative faces is similar if not identical in the two disorders, with the possible exceptions that the bias tends to be stronger for “threatening” expressions in anxiety (i.e., anger) and for sad expressions in depression. Examining effects for happy faces, however, delineates the two affective disorders. Whereas anxiety does not seem to be associated with any specific pattern of responses to happy faces, adolescents at risk for depression show decreased activation of the nucleus accumbens when viewing happy faces (Monk et al., 2008), depressed adults require higher intensity expressions to correctly identify happiness (Joormann & Gotlib, 2006), depressed adults show superior memory for sad faces and inferior memory for happy faces (Ridout, Astell, Reid, Glen, & O’Carroll, 2003), and depressive mood is associated with longer response times to finding a happy face in a crowd of distractors, suggesting that attention to happy facial expressions is reduced in depression (Suslow, Junghanns, & Arolt, 2001). In sum, although an attentional bias toward negative faces is observed in both anxiety and depression, only depressed participants also exhibit a concomitant difficulty in attending to, processing, and remembering positive faces. The ESM predicts and provides a theoretical explanation for this pattern of results, as well as imparting a framework for the study of the affective mechanisms that underlie affective disorders.

Future Directions and Remaining Questions

We have here reviewed the current status of research on the structure of evaluative space. The principles of the ESM provide a road map for future investigations in multiple arenas, such as testing theories of the mechanisms underlying emotional disorders and examining the relationships between feeling states and physiological responses. The ESM’s *postulate of functional separability*, which states that positivity and negativity are independent at underlying stages of processing, gives rise to a series of unique predictions regarding both healthy and dysregulated emotional processes. For example, the ESM predicts that at low levels of affective input positivity outweighs negativity (the *positivity offset*) and at relatively high levels of affective input negativity outweighs positivity (the *negativity bias*). An important corollary of these predictions is that a thorough understanding of emotional processes requires observation at multiple levels of input – it is not enough to look at responses to extreme stimuli. Applied to the theories of depression, the ESM might therefore suggest that depression could result from (a) strong responses to very aversive stimuli, (b) weak responses to very appetitive stimuli, (c) strong responses to mildly aversive stimuli, (d) weak responses to mildly appetitive stimuli, or (e) some combination of the above. The pattern of responding observed for an individual may be critical for treatment of the disorder, and may also shed light on the nature of comorbidities (e.g., with anxiety disorders or substance abuse).

Furthermore, the ESM has implications for psychophysiological and neuroscience research. Existing evidence supports the utility of approaching the study of basic emotional processes from a dimensional approach, as both physiological (e.g., ANS function; Cacioppo et al., 2000) and neural (cf. Wager et al., 2003) data differentiate between positive and negative affective states. Research on the positivity offset and negativity bias predicts that responses to equally extreme pleasant and unpleasant stimuli may have unequal effects on physiological reactivity. In addition, the *heterarchical organization* postulate suggests that limiting the study of emotional responses to one level of the neuraxis, such as basic reflexes (e.g., emotion-modulated startle response) or cortical activation (e.g., ERPs, fMRI), will fail to truly capture the full spectrum of reactivity of the affect system. In sum, the postulates of the Evaluative Space Model have the ability to direct and guide future research on the structure of affective space, as well as its representation in the brain and body and, ultimately, its implications for affective disorders.

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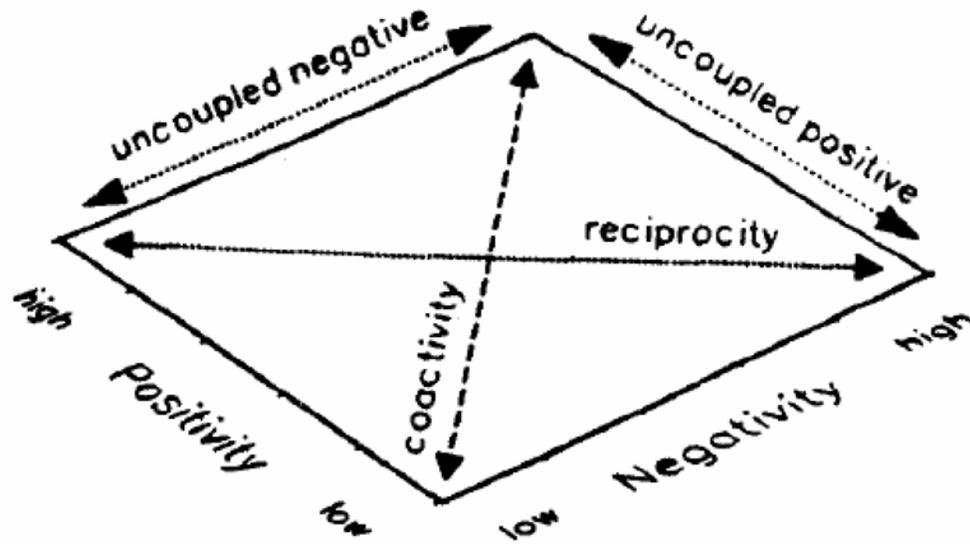


Figure 1.

The bivariate evaluative plane. The left axis represents the level of excitatory activation of positive evaluative processes (labeled positivity), and the right axis represents the level of excitatory activation of negative evaluative processes (labeled negativity). Along each axis, the level of activity increases with movement away from the front axis intersection. The dotted diagonal extending from the left to the right axis intersections represents the diagonal of reciprocal control (labeled reciprocity). The dashed diagonal extending from the back to the front axis intersections depicts the diagonal of nonreciprocal control (labeled coactivity). The arrows alongside the axes represent uncoupled changes in positive or in negative evaluative processing. These diagonals and axes, and vectors parallel to them, illustrate the major modes of evaluative activation.

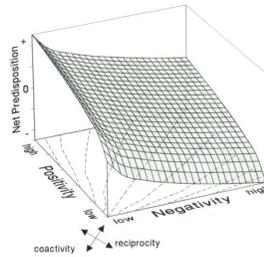


Figure 2.

Illustrative bivariate evaluative space and its associated affective response surface. This surface represents the net predisposition of an individual toward (+) or away from (–) the target stimulus. This net predisposition is expressed in relative units and the axis dimensions are in relative units of activation. The point on the surface overlying the left axis intersection represents a maximally positive predisposition, and the point on the surface overlying the right axis intersection represents a maximally negative predisposition. Each of the points overlying the dashed diagonal extending from the back to the front axis intersections represent the same middling predisposition. Thus, the nonreciprocal diagonal on the evaluative plane – which represents different evaluative processes (e.g., neutral to ambivalent) – yields the same middling expression on the affective response surface. Dashed lines (including the coactivity diagonal) represent isocontours on the evaluative plane, which depict many-to-one mappings between the affective response surface and the underlying evaluative space. These isocontours are illustrative rather than exhaustive. Adapted from Cacioppo, J. T., & Berntson, G. G. (1994).

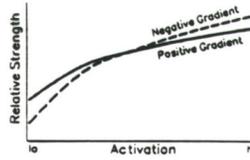


Figure 3.

Activation functions for positive and negative dimensions of affective processing; the x-axis represents affective input, whereas the y-axis represents output of the system. The ESM proposes that there are two asymmetries in affective processing: the positivity offset is the result of greater positive than negative affect at low levels of emotional input; the negativity bias is the result of stronger responses to negative than to equally extreme positive input. (Adapted from Cacioppo & Berntson, 1994).

Table 1

A brief description of the ESM postulates. Note that this is an incomplete list; readers interested in the full breadth of the model should turn to Cacioppo, Bernston, Norris & Gollan (in press).

Postulate	Definition	Additional Detail
Level of organization	There are distinctions among both positive and negative emotions, but positive emotions are more similar to each other than they are to negative emotions, and vice versa	A single valence continuum does not capture the structure and operating characteristics of affect system
Functional separability	Positivity and negativity are not equivalent in their constitution, operations, or consequences	There is a superordinate dimensional structure representing appetitive predispositions, positive affects, and emotions, as well as a superordinate dimensional structure representing defensive predispositions, negative affects, and emotions
Energetic efficiency	Behavior in future encounters with target stimuli will tend to be more expected and stable when organized in terms of a bipolar evaluative dimension	Behavioral and cognitive efficiency and a reduction in stress is served by mental representations of general action predispositions toward classes of stimuli
Evaluative activation	Affect is a joint function of positively and negatively valent activation functions	
Antagonistic effects	Directional response effects of positive affect (approach) are generally opposite to those of negative affect (avoidance)	
Modes of evaluative activation	Positivity and negativity can be reciprocally activated, independently activated or co-activated	At high levels of coactivation (which minimizes the dynamic range, reduces response lability, and maximizes directional flexibility), energy expenditure is taxing over long periods of time; eliciting circumstances tend to be avoided
Parallel evaluative processing	The ability to achieve coactivation of positivity and negativity by attending to positive and negative features of a stimulus simultaneously (e.g., bittersweet, disappointing wines)	
Oscillation (or low-pass filtering)	The ability to achieve coactivation of positivity and negativity by oscillating between positive and negative stimuli with sufficient speed that results in the sustained activation of positivity and negativity	Even though there can be an oscillation between positive and negative activation, if the speed of presentation is faster than the low pass filter cutoff, the activation of each cannot follow the speed of the oscillations and coactivation (ambivalence) results
Distinct activation functions	The partial segregation of the positive and negative evaluative channels allows for distinct activation functions for positivity and negativity	
Positivity offset	The offset (intercept) for the positive activation function is higher than that of the negative activation function	Motivation to approach is stronger than the motivation to withdraw at very low levels of evaluative activation; this promotes exploratory behavior – without a positivity offset, a person in a neutral environment is unlikely to approach novel stimuli
Negativity bias	The gain for the negative activation function is higher than that of the positive activation function	Motivation to withdraw is stronger than the motivation to approach at very high levels of evaluative activation; it is more difficult to overcome a fatal assault than to return to an opportunity unpursued
Recalibration	The activation functions for positivity and negativity are capable of the same kind of recalibrations based on salient contextual and accessible stimuli: as is seen in receptor mechanisms	Both sensitivity to small variations among stimuli and a dynamic range suitable to detect a wide array of affective stimuli are preserved.
Affective dispositions	There are measurable individual differences in the positivity offset and negativity bias	These individual differences have a biological basis

Postulate	Definition	Additional Detail
Heterarchical organization	There is a continuum of neuraxial organization that extends throughout the central nervous system in a heterarchical structure, ranging from the frontal lobes to the spinal cord	Rostral, in contrast to caudal, neurobehavioral organizations are slower, more serial-like; susceptible to more contextual control; potentiate greater response flexibility; and manifest multiple modes of appetitive and aversive activation