

## CHAPTER 2

# The Neural Bases of Emotion and Emotion Regulation: A Valuation Perspective

**Kevin N. Ochsner**  
**James J. Gross**

The observation that emotions can be powerful forces for good and for ill has motivated researchers' efforts to understand how emotions arise and how they are regulated (Gross, 2007; Kalisch, 2009; Ochsner & Gross, 2005, 2008; Phillips, Ladouceur, & Drevets, 2008; Quirk & Beer, 2006). In particular, neuroscience research recently has made great strides in describing the neural systems that give rise to emotional responses and that permit their regulation. At the same time, parallel progress has been made in delineating the neural bases of related abilities, including affective learning, affective decision making, and expectancies, beliefs, and placebo effects (Cunningham & Zelazo, 2007; Hartley & Phelps, 2010; Murray, O'Doherty, & Schoenbaum, 2007; Pessoa, 2008; Rangel, Camerer, & Montague, 2008). It is becoming evident that the neural systems implicated across these various literatures—including those concerned with emotion and emotion regulation—are strikingly similar. This suggests that any account of the neural bases of emotion and its regulation—or related abilities—should be informed by these similarities. Such an integrated framework would be both more robust and more translatable to multiple

basic and clinical contexts. Our goal in this chapter is to provide such a framework.

Our starting point is the assertion that *goal-directed (motivated) behavior* may be defined as behavior that aims to decrease the probability of states of either our bodies or of the world that have negative value for us (e.g., putting on a sweater when we are cold; picking up trash in the park), or increase the probability of states that have positive value for us (e.g., opening a can of soup to eat when we are hungry; arranging to have coffee with a friend).

The determination of value occurs dynamically at many levels of the brain, at different time scales, and with respect to many features in the environment (Leventhal, 1984; Rangel et al., 2008; Scherer, 2001). A sudden loss of blood pressure may occasion a valuation, as may the smell of dinner being prepared, an aggressive driver cutting one off, or a new way of thinking about a poem. If valuations are assessments of what is bad for me (negative value) or good for me (positive value), computed for many different objects, then different types of valuation might be expected to give rise to different types of responses, and indeed, they do (Ortony, Clore, & Collins, 1988;

Scherer, Schorr, & Johnstone, 2001). One particularly important type of valuation is *emotion*, which arises when a situation is evaluated as relevant to an individual's goals, thereby triggering a loosely coordinated set of experiential, behavioral, and peripheral physiological responses (Mauss, Levenson, McCarter, Wilhelm, & Gross, 2005). Emotional responses such as joy, anger, and disgust all have at their core an evaluation of whether something is good for me or bad for me.

Given the major role that emotions play in shaping how we feel about and respond to the world around us, it is no surprise that emotions themselves can become the target of valuation. For example, we may feel angry at a child's impolite behavior, and judge our anger as either inappropriate (having negative value) or appropriate (having positive value), depending on the age of the child. In this and in similar cases, we assign negative or positive value to the valuation process itself, thereby energizing processes that tend to make the emotion in question either less or more likely to occur, depending on whether the valuation is negative or positive. When individuals influence their emotions in this way, they are engaging in *emotion regulation*.

Our framework therefore holds that emotions arise via the valuation of internal or external stimuli, and that emotion regulation arises via the valuation of the emotion itself. From this perspective, emotion and emotion regulation both have valuation at their core.

This three-part chapter uses a valuation perspective to integrate diverse findings in current neuroscience research regarding emotion, emotion regulation, affective learning, decision making, and expectancy. In the first part, we propose a multilevel framework that analyzes emotion and emotion regulation in terms of valuation. In the second part we use this framework to understand current research on emotion and its regulation. Finally, in the third part we explore the general utility of this framework by giving examples of how it can be extended to account for current research on related phenomena, including affective learning, decision making, and expectancy effects.

## The Functional Architecture of Valuation

---

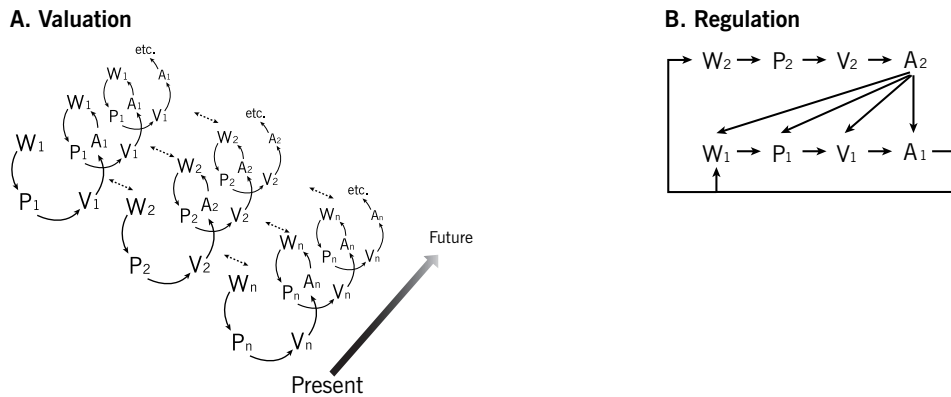
According to the framework we propose here, valuation can be schematized as the three-stage processing cycle outlined in Figure 2.1A. As detailed below, a *perception stage* takes various kinds of stimuli as inputs; a *valuation stage* dynamically appraises the value of these stimuli given current goals, context, and prior experience with similar stimuli; and an *action stage* comprises valuation-appropriate responses ranging from covert adjustments of low-level sensory (e.g., increased pupil dilation) or higher-level cognitive processes (e.g., shifts in effortful attention) to overt adjustments of a wide range of response systems (e.g., facial behavior, postural adjustments, sympathetic nervous system activation). This perception–valuation–action (PVA) sequence repeats as the new state of the world, resulting from the action, becomes the input for the next PVA sequence, thus setting in motion a new PVA cycle. Because multiple PVA cycles are typically running at any given time, these cycles interact, and it is these processing dynamics that give rise to behavior.

### **PVA Components: The Perception Stage**

A PVA sequence is initiated by an external or internal stimulus that can vary in complexity from low-level perceptual features (like eye whites or low spatial frequencies) or physiological responses (e.g., a racing heart) to organized perceptual exemplars (e.g., objects or scenes) to abstract constructs such as the self. In this initial *perception* stage of the sequence, sensory systems (e.g., thalamus plus primary and secondary sensory cortices) encode these types of sensory inputs and pass them along to systems for computing value (Kravitz, Saleem, Baker, & Mishkin, 2011).

### **PVA Components: The Valuation Stage**

Valuations are subserved by an overlapping set of interacting brain systems that compute the badness or goodness of perceptual inputs (Hamann, Ely, Hoffman, & Kilts, 2002; Ochsner & Barrett, 2001; Rangel et



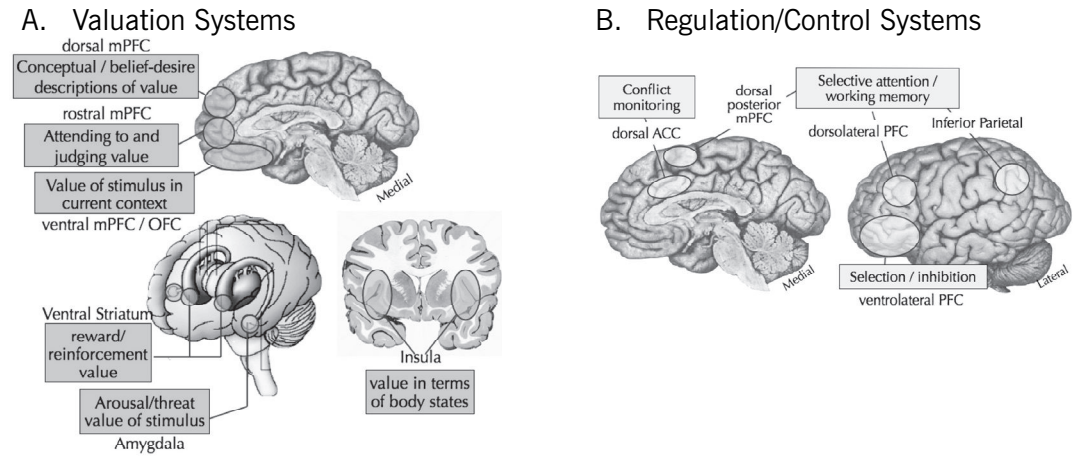
**FIGURE 2.1A.** The perception–valuation–action (PVA) processing cycle that comprises the fundamental building block of emotion and other types of valuation. As described in the text, multiple PVA cycles can operate at once, here represented by subscripts 1 to  $n$ . Each cycle involves individual PVA sequences that iteratively feed into one another across time (shown here progressively spiraling into the future), thereby comprising a PVA cycle. For each cycle, some set of internal and external stimuli comprising an initial state of the world ( $W$ ) is represented perceptually ( $P$ ), values are placed upon the stimuli ( $V$ ), and associated action links ( $A$ ) that are activated result in a new state of the world that feeds into the next iteration of the PVA processing cycle. Note that here we place emphasis on the three-stage ( $P$ - $V$ - $A$ ) processing cycle, and the world ( $W$ ) is considered to be the result of a prior action and the input for the next PVA sequence. PVAs can interact with one another, exciting or inhibiting each other’s activation (schematically shown here by double-headed arrows between PVAs). *Emotions* are specific types of PVA sequences that involve specific types of perceptions, valuations, and actions. The neural systems supporting valuation are shown in Figure 2.2A and elaborated in the text and in Figure 2.3.

**FIGURE 2.1B.** How PVA sequences instantiate regulation. To illustrate how PVA sequences enable regulation, we zoom in on two PVA sequences, PVA<sub>1</sub> and PVA<sub>2</sub>. As shown here, *emotion regulation* (or value regulation more generally) is a functional relationship between two PVA sequences in which one (PVA<sub>1</sub>) is “generating emotion” and the other (PVA<sub>2</sub>) is taking the first PVA as its “ $P$ ,” valuing it (negatively or positively), and targeting that first PVA for change via its “ $A$ .” The “ $A$ ” of PVA<sub>2</sub> enacts an emotion regulation strategy that influences one or more steps of PVA<sub>1</sub>. As described in the text, five types of regulatory strategies may be distinguished. Each regulatory strategy depends on different combinations of cognitive control systems (see text, Figure 2.2B, and Figure 2.3) whose regulatory effects can be understood in terms of the stage of the PVA sequence that is targeted for change. On this view, *emotion regulation* is a type of valuation in which the valuation process is itself the target of valuation.

al., 2008; Rolls, 1999), thereby providing a common currency for comparing various objects and events (Levy & Glimcher, 2011). In this chapter we use *valuation* as an umbrella term to connote the same kinds of underlying processes that emotion theorists would describe using the term *appraisal* and attitude researchers would describe using the term *evaluation*. Targets of valuation range from primary reinforcers—objects that are innately seen as “bad” or “good,” such as

a sweet drink, to secondary reinforcers—objects that derive their negative or positive value from their association with primary reinforcers, such as an A+ written at the top of one’s term paper (Rangel et al., 2008; Rolls, 1999). Figure 2.2A shows the brain regions associated with valuation processes.

Multiple valuations are computed for a given stimulus, and these vary along a continuum of representational complexity, with more complex valuations typically taking



**FIGURE 2.2A.** Neural systems supporting valuation. Medial (top), lateral (bottom left), and coronal (bottom right) views of the brain showing systems implicated in different types of valuation processes that can be arrayed along a continuum from *core level valuations* (amygdala, ventral striatum) that consist of links between stimuli and reinforcers, to *contextual level valuations* (vmPFC/OFC) that place these S-R links in their historical, social, and motivational context, to *conceptual level valuations* that represent the value of stimuli in belief–desire terms (rostral and dorsal medial PFC) that may be verbalizable and consciously reportable. The insula, implicated in the representation of body states, may play a role in representing the body states associated with all three types of valuation. See text and Figure 2.3 for examples of how these systems play roles in specific types of valuation and emotion.

**FIGURE 2.2B.** Neural systems supporting regulation. Medial (left) and lateral (right) views of the brain showing systems implicated in regulatory strategies that can be used to regulate valuation in general, and emotion in particular. Regions include: the dorsal anterior cingulate cortex (dACC), implicated in monitoring conflicts between desired and actual actions, posterior and dlPFC and inferior parietal cortex, implicated in holding control strategies and goals in mind and directing attention to relevant perceptual inputs, and vlPFC, implicated in selecting context-appropriate responses and inhibiting context-inappropriate responses. See text and Figure 2.3 for examples of how these systems play roles in specific types of emotion regulation and related phenomena.

longer to compute than less complex valuations (Leventhal, 1984; Scherer, 2001).

At the lowest level of this continuum, *core valuations* are made. These represent relatively direct associations between percepts and basic physiological and behavioral responses at the action stage (e.g., snake → fear response). Core valuation involves primarily subcortical and brainstem systems implicated in affective learning and responding. While many of these systems, including the ventral striatum, amygdala, and periaqueductal gray (PAG), receive inputs from a variety of sensory inputs (Keay & Bandler, 2001; Packard, 2009), and as such can be involved in the valuation

of a variety of stimuli, there is evidence that core valuations for pain sensations involve dedicated pathways from the thalamus to nociceptive regions of the midcingulate cortex and anterior insula (Willis & Westlund, 1997). In addition, while the ventral striatum and amygdala are typically linked with positive/appetitive and negative/aversive valuations, respectively, both human and animal studies suggest that subregions of each structure may play roles in both kinds of valuations (Delgado, Jou, LeDoux, & Phelps, 2009; Holland & Gallagher, 2004; Wager, Barrett, et al., 2008). The associations underlying core valuations can be (but are not always) activated automatically and

without conscious intent, and are implicit insofar as they are not directly accessible to awareness, although one can be aware of the actions they trigger, and thereby become aware of them indirectly. Core valuations typically are linked to stereotyped action impulses (Kober et al., 2008; LeDoux, 2000; Rolls, 1999; Russell & Barrett, 1999), and as such, can provide the basis for stimulus–response (S-R) links of the sort that underlie Pavlovian conditioning and other basic forms of affective responding that involve pleasure and pain (Rangel et al., 2008).

At an intermediate level, *contextual valuations* evaluate inputs that represent combinations of S-R links and at least three types of contextual information: the historical as well as current social and motivational contexts of the person (for an illustrative example, see the section “Emotion as a Type of PVA Sequence”). This computational step involves at least three regions. The first comprises the orbitofrontal cortex (OFC) and ventromedial prefrontal cortex (vmPFC) (Ongur, Ferry, & Price, 2003; Price, 1999), whose inputs include the output of both the core valuation level and the medial temporal lobe (MTL) and the cortical associative memory systems, which provide temporal and spatial context (Davachi, 2006; Murray et al., 2007). Second is the superior temporal sulcus/temporoparietal junction (STS/TPJ), which itself is a multisensory zone that integrates expectancies with feedback, and reorients attention accordingly, including when expectations must be adjusted about the beliefs, actions, and intentions of others (Saxe, 2006; Young, Camprodon, Hauser, Pascual-Leone, & Saxe, 2010). Third is the anterior insula (AI), which integrates and makes available to awareness information about current body states, especially as they pertain to one’s current affective state (Craig, 2003; Harrison, Gray, Gianaros, & Critchley, 2010; Kurth, Zilles, Fox, Laird, & Eickhoff, 2010; Zaki, Davis, & Ochsner, 2012). Contextual valuations indicate whether an object is good or bad in the present context, and therefore whether it should be sought or avoided at the present time. One commonly studied form of contextual valuation is fear extinction, in which an organism learns that a stimulus that previously predicted an aversive outcome (and was therefore negatively valued) no longer does so (and in the present

temporal context, can be valued less negatively; Quirk & Beer, 2006). More generally, contextual valuations play key roles in other forms of affective learning, in determining whether the value of stimuli change across contexts, and in subjective awareness of one’s affective states (Craig, 2009; Cunningham, Raye, & Johnson, 2004; Holland & Gallagher, 2004; Lieberman, Jarcho, & Satpute, 2004; Rangel et al., 2008; Schoenbaum, Saddoris, & Stalnaker, 2007). Contextual valuations influence behavior either by activating action impulses themselves or—as detailed below in the section on emotion regulation—by influencing which core valuations are expressed via actions (Ochsner, Ray, et al., 2009).

At the highest level of this continuum, *conceptual valuations* represent appraisals of stimuli that are abstract and often verbalizable. By this we mean representations of evaluations and affective states that abstracted across exemplars and contexts and are accessible to awareness in the form of “belief–desire” language. For example, a conceptual valuation of a snake may involve activation of a conceptual representation of “fear,” which one can verbalize using that word.

We propose that this level involves at least four regions. First, the rostromedial (rmPFC) and dorsomedial (dmPFC) prefrontal regions implicated in attending to and explicitly judging the value of stimuli and use of categories and belief–desire language to elaborate semantically the affective value of a wide range of stimuli, from simple objects to the self (Cato et al., 2004; Lindquist & Barrett, 2008; Lindquist, Wager, Kober, Bliss-Moreau, & Barrett, 2012; Mitchell, 2009; Olsson & Ochsner, 2008; Zysset, Huber, Ferstl, & von Cramon, 2002). An unresolved question about medial PFC (mPFC) is whether different subregions are involved in making judgments (whether evaluative or not) about others, the self, and/or stimuli in general (Denny, Kober, Wager, & Ochsner, 2012; Ferstl & von Cramon, 2002; Zysset, Huber, Samson, Ferstl, & von Cramon, 2003). For our present purposes, we consider mPFC to be critical for using conceptual information to elaborate the affective meaning of stimuli, whether the stimulus triggering the valuation and emotion is the self, another person, or some other object/

event/situation. A third region involved in conceptual valuation is the ventrolateral prefrontal cortex (vlPFC), which helps select desired and inhibit undesired value representations (Aron, Robbins, & Poldrack, 2004; Badre & Wagner, 2007; Barrett, 2006; Gallagher & Frith, 2003; Lieberman et al., 2007; Lindquist & Barrett, 2008; Mitchell, 2009; Olsson & Ochsner, 2008; Thompson-Schill, Bedny, & Goldberg, 2005). Finally, regions of the anterior insula that support introspective awareness of body states also may be integral to awareness of body states and use of conceptual knowledge about them to make judgments about one's current affective states (Craig, 2009; Damasio, Damasio, & Tranel, 2013; Gray et al., 2012; Harrison et al., 2010; Zaki et al., 2012). Conceptual valuations influence behavior either by activating action impulses themselves or—as detailed below in the section on regulation—influencing which contextual and core valuations are expressed via actions (Ochsner, Ray, et al., 2009). We propose that conceptual valuations play key roles in introspection about and self-reports of affective states, in mental state attribution, and in judgments about the values of stimuli and actions that involve conscious reasoning about their value (Kalisch, Wiech, Critchley, & Dolan, 2006; Mitchell, 2009; Olsson & Ochsner, 2008).

### **PVA Components: The Action Stage**

At any given level of valuation, the action impulses associated with a PVA sequence can be either *mental* (e.g., retrieving information from memory, forming a mental image, or introspecting about one's mood) or *physical* (e.g., including overt behaviors such as shifts of gaze or starting to run, and autonomic/physiological responses such as heart rate increases or the release of stress hormones; Levenson, 1999). Although elaborating the brain systems supporting the action stage is not the focus of this chapter, it likely involves subcortical and cortical regions involved in selecting motor actions, as well as initiating autonomic responses (e.g., the PAG, primary motor and supplementary motor areas, cingulate motor regions, and insula) (Buhle et al., 2012; Critchley, 2005; Dum, Levinthal, & Strick, 2009; Mobbs et al., 2009).

### **PVA Operating Principles: Processing Dynamics**

As multiple valuations are computed at different levels and time scales—each with its own associated action impulses—only a subset of the possible actions associated with a percept and its valuations can be enacted. What determines which actions are expressed, whether mental (e.g., thoughts and feelings) or physical (e.g., smiling and hugging)?

One factor is the existing structure of the PVA sequences an individual possesses at any given moment in time. This factor has been addressed primarily in psychological and computational models of associative memory networks that suggest the P's, V's, and A's of all currently activated PVAs mutually excite and/or inhibit one another in such a way that the most activated action tendency or (a set of equally activated) tendencies “win” and are manifested as mental and/or physical actions (Desimone & Duncan, 1995; Barrett, Ochsner, & Gross, 2007; Maas, 2000; Miller & Cohen, 2001). The schematic PVA sequences of Figure 2.1A illustrate the possible kinds of links that may exist between P, V, and A nodes.

A second factor is the multiple contextual and historical considerations that determine the level of activation for each PVA sequence and whether they have inhibitory or excitatory links with other PVAs—including the stimuli that are (or have been) present as inputs, their activation history (which determines the strength of links within and across PVAs, and hence their relative ease of activation [Anderson, 1983; Neely, 1991]), and whether they are in the focus of attention (which enhances activity, especially at the perception stage [Pessoa, Kastner, & Ungerleider, 2003; Polk, Drake, Jonides, Smith, & Smith, 2008]).

At any given moment, an individual's affective response comprises the profile of activation across all PVAs—at all levels—that may combine or cancel one another depending on the nature of their connections and levels of activation (Barrett, Mesquita, Ochsner, & Gross, 2007; Scherer, 2001). As described below, depending on the circumstances, core, contextual, and/or conceptual PVAs may be activated most strongly and lead to action.

### **PVA Operating Principles: Interacting Networks**

As our process-level description makes clear, the PVA sequence is continually unfolding in real time for multiple stimuli as multiple levels of analysis. This means that networks of interacting brain systems underlie each stage of the PVA sequence, as well as the interactions among stages. This follows from the fact that an individual's affective response comprises the profile of activation across all PVAs, at all levels, which in turn follows from the idea that the P, V, and A stages all involve multiple brain systems working together to compute the perceptual, evaluative, and action components of one's response to a given stimulus.

Thus, the totality of one's valuation of a stimulus cannot be understood in terms of the activation of a single brain system. That said, most of what we know about the functions of brain systems implicated in the P, V, and A stages comes from studies employing analytic techniques (e.g., simple contrasts) designed to isolate the contributions to behavior of single regions rather than integrated networks. Increasingly, however, various kinds of connectivity, network, and multivoxel pattern analyses are being used to describe the task-varying functional relationships among regions that define them as critical for aspects of the P, V, and A stages (Kober et al., 2008). For example, we and others have used mediation and structural equation modeling to describe the ways in which prefrontal control regions regulate emotional response via their impact on subcortical regions that trigger affective responses (Johnstone, van Reekum, Urry, Kalin, & Davidson, 2007; Kober et al., 2010; Urry et al., 2006; Wager, Barrett, et al., 2008; for review, see Ochsner, Silvers, & Buhle, 2012). As such analytic techniques mature, we expect that our framework will be able to describe more precisely the functional interactions governing the P, V, and A stages, as well as their interactions.

### **A Valuation Perspective on Emotion and Emotion Regulation**

Emotions are particular types of valuation that (1) have a well-specified object (i.e.,

one is angry about something), (2) unfold over seconds to minutes, and (3) involve coordinated changes in subjective experience, behavior, and physiology (Barrett et al., 2007; Mauss et al., 2005; Scherer et al., 2001). In keeping with our overall goal of showing how the valuation framework is broadly applicable, in the sections that follow we employ an expansive view of emotion.

### **Emotion as a Type of PVA Sequence**

Imagine you are a commuter in a crowded New York subway car. Across from you sit a sleepy-eyed old man, a muscular teen, and an attractive woman. As the subway rattles toward your stop, the teen removes a knife from his pocket, shifting it from hand to hand.

In our framework, emotional reactions to the knife-wielding teen may be conceived of as specific kinds of PVA sequences derived from particular perceptions, valuations, and associated action impulses (Ortony et al., 1988; Scherer et al., 2001). Thus, an initial response may reflect a core-level valuation of the teen and his knife as potentially threatening by the amygdala and related regions, which triggers corresponding action impulses that mobilize you to avoid harm (e.g., increased heart rate, behavioral readiness to fight or flee; LeDoux, 2000; Phelps, 2006). At the contextual level, the action outputs of core-level PVA sequences become perceptual inputs that are integrated with other inputs representing the *historical* (episodic) context of, for example, having prior subway conversations with the teen (via MTL inputs), the *social* context of multiple other passengers being present (via STS/TPJ inputs), and the *motivational* context of current stress and bodily complaints (via AI and other subcortical inputs). As time passes, activation of the contextual-level PVAs, which dictate other courses of action, can begin to build, and the initial valuation may evolve dynamically into valuations of the teen as relatively innocuous or highly dangerous, depending on whether the teen previously indicated he has a role as a thug in a school play or is on medication for a delusional disorder (historical context), whether he elicits calm or anxious reactions from

other passengers (social context), or whether you are stressed from work or just had a great day (motivational context). Then, the action outputs of activated contextual-level PVAs are taken as inputs to systems (rmPFC, and/or vlPFC) that compute a valuation of the teen in belief–desire terms that can—at the action stage—be introspectively accessed or reported to others as the thoughts and feelings you attribute to yourself or others, including, for example, the thoughts that you yourself are brave, that the knife-wielder looks aggressive, and that the old man and young woman seem calm.

The order in which these valuation systems is activated, and their interplay, is not fixed and depends on the circumstances of your encounter with a stimulus. For example, if you are sitting on the subway, and the teen enters from the opposite end of the car and does not pose an immediate threat, then conceptual valuation systems might evaluate his intentions (“Is he dangerous?”) and your own level of fear (“I’m not scared—yet”). As the teen moves closer, contextual systems might be most active as you evaluate the goodness or badness of potential courses of action based on your changing motivational state (increasing anxiety), history (the seat next to you was just vacated, and the teen moves toward this open seat) and the apparent anxiety of your fellow passengers (who look increasingly afraid). Finally, as the teen moves even closer and the threat level is very high, activation in core valuation systems may escalate to promote defensive actions such as freezing, escape or fighting (Mobbs et al., 2007).

The key idea is that, taken together, all of these PVAs, however they were activated, and each with their associated mental and physical action tendencies, comprise an emotional response.

### ***Emotion Regulation as a Type of PVA Sequence***

As noted earlier, emotions themselves are sometimes the target of valuation. For example, in the previous subway example, we might wish to protect our view of ourselves as brave and, as a consequence, desire to decrease our fear responses. To do this, we can take as objects of valuation the action outputs of PVAs that comprise a

fear response. When we do this—thereby activating a goal to influence the nature of the emotional response—we are engaging in emotion regulation. As described below, this involves interactions among regions implicated in cognitive control (i.e., regulation) and/or valuation.

In our framework, emotion regulation is initiated when a PVA cycle that gives rise to emotion becomes the object of valuation (see Figure 2.1B). We propose that this typically happens across levels of valuation, as a higher-level PVA places a good or bad valuation on a lower-level PVA (although it also can happen between PVAs at a single level). It also can happen if there is a high level of conflict between active PVAs, such as whether the impulse to flee a potentially dangerous situation conflicts with the impulse to freeze, and a clear set of emotional responses isn’t activated. We propose that when this happens, the level of conflict constitutes an input to the next PVA cycle, and evaluation of that conflict triggers an appropriate course of regulatory action.

One key feature of our framework is the idea that some of the prefrontal systems that support emotion regulation are involved in the control of nonaffective forms of behavior as well (Miller & Cohen, 2001; Ochsner & Gross, 2005). These systems (see Figure 2.2B) include dorsal and ventrolateral prefrontal regions that support selective attention, working memory, and retrieval from semantic memory; cingulate regions that monitor conflicts between competing As and the need for continued control; medial regions that support mental state attribution; and ventromedial prefrontal regions that place contextual constraints on the expression of core-level PVAs (Miller, 2000; Ochsner & Gross, 2005; Olsson & Ochsner, 2008; Wager, Jonides, & Reading, 2004; Wager & Smith, 2003). As detailed below, the regulatory actions supported by these systems comprise different types of “As” in PVA sequences that place a value on one’s current affective state.

### ***Distinguishing among Emotion Regulation Processes***

We have previously argued that emotion regulation processes can be differentiated into five families according to which stage



of the emotion generation sequence they target. In the context of the present framework, this idea is expressed by suggesting that emotion regulatory processes differ in the stage of the PVA sequence at which they have their primary impact (see Figure 2.3). Some strategies influence the situation-dependent perceptual inputs (*situation selection*, *situation modification*, and *attention deployment*). Others influence the valuation step itself (*cognitive change*). Still others influence the response output associated with activated action sequences (*response modulation*). By impacting different states of the PVA cycle, different strategies impact emotional responding in different ways, as detailed below.

*Situation selection* refers to altering the inputs to the PVA sequence through decisions about whether to expose oneself to a given situation/stimulus based on its projected affective impact. For example, calling to mind the image of the subway might lead to a negative evaluation, and a feeling of fear. This feeling might motivate a higher-level PVA that would trigger a decision to take an alternative means of transportation in order to decrease the probability of the negative experiences that one associates with taking the subway. More generally, situation selection can take many forms, for example, when a socially anxious individual avoids a social event. To date, the neural bases of situation selection have been studied only with avoidance conditioning tasks in which an animal learns to select an action (e.g., running in a wheel when a light is illuminated predicts an upcoming shock) that enables it to avoid experiencing a noxious stimulus (that prevents shock administration). Rodent studies have shown this involves modulation of two core valuation systems, the striatum and amygdala (Everitt et al., 1999; LeDoux & Gorman, 2001), and one human imaging study (Delgado et al., 2009) indicates that it also engages vlPFC and dorsolateral prefrontal cortex (dlPFC) regions involved in cognitive control that presumably modulate the core valuation systems.

*Situation modification* refers to altering the situation one is in, thereby modifying inputs to the PVA sequence, and changing the emotion (e.g., sitting further away from the teen or exiting the subway). We would expect that prefrontal systems

should be involved in the selection of escape behaviors—especially in the kinds of emotionally arousing situations humans face in everyday life. Although this hypothesis has not been tested, the involvement of prefrontal regions is suggested by behavioral studies in humans showing that emotion can be regulated by deliberately changing situation-dependent stimulus inputs in the service of explicit regulatory goals. For example, either physically or mentally, using visual imagery, one can move closer to or further away from an emotion-eliciting stimulus (e.g., making oneself feel more positive by approaching a pleasant stimulus or less negative by withdrawing from an unpleasant one; Davis, Gross, & Ochsner, 2011; Muhlberger, Neumann, Wieser, & Pauli, 2008; Williams & Bargh, 2008).

*Attentional deployment* refers to altering the inputs to the PVA sequence by increasing or decreasing attention to them (e.g., looking away from the teen and at the man or woman). While this can gate specific stimuli wholly into or out of the PVA stream, thereby promoting or preventing responses to them, we propose that more graded changes in attention to stimuli may result in correspondingly graded levels of activation of their associated PVA sequences. This strategy involves interactions between cognitive control systems and valuation systems, with particular involvement of dorsal PFC and inferior parietal regions associated with selective attention (Pessoa et al., 2003), and in some cases rmPFC regions implicated in attending to and explicitly judging the value of stimuli (Bishop, 2007; Egner, Etkin, Gale, & Hirsch, 2008; Etkin, Egner, Peraza, Kandel, & Hirsch, 2006; Lane et al., 1998; Ochsner, Hughes, Robertson, Cooper, & Gabrieli, 2009). A growing but somewhat inconsistent imaging literature shows that, by and large, when a task manipulation diminishes attention to an affectively arousing stimulus, activation increases in PFC regions implicated in cognitive control (suggesting that cognitive control systems are involved in manipulating attention), and activity decreases in regions implicated in core (e.g., amygdala, PAG), contextual (e.g., insula) or conceptual (e.g., mPFC) valuation (e.g., Ochsner & Gross, 2005; Pessoa, 2009). While it is clear that the specific valuation systems modulated by attentional deploy-

Neural Systems			Emotion Regulation Strategies			Related Phenomena			
			Attentional Deployment	Cognitive Change (Reappraisal)	Response Modulation (e.g., Expressive Suppression)	Affective Learning (e.g., Fear Extinction)	Affective Decisions (e.g., Intertemporal Choice)	Expectancies (e.g., Placebo Effects)	
Region	Type of System	Processes							
dorsolateral PFC	Control	selective attention/ working memory	↑	↑	↑		↑	↑	
dorsal posterior mPFC			↑	↑	↑				
inferior parietal			↑	↑				↑	
dorsal ACC			performance monitoring	↑	↑	↑	↑		↓
ventrolateral PFC			selection/ inhibition	↑	↑	↑		↑	↑
dorsal mPFC	Conceptual Valuation	conceptual/ categorical valuations		↑				↑	
rostral mPFC		attention to valuation	↑	↓				↓	
ventromedial PFC/OFC	Contextual Valuation	value of stimulus in current context	?	?		↑	↑↓	↑	
ventral striatum		reward/ reinforcement value		↑↓				↑	
amygdala	Core Valuation	arousal (and threat) value of stimulus	↓	↑↓	↑	↓		↓	
insula		Valuation	representation and awareness of body states for all types of valuation		↑↓	↑	↑	↑↓	↓
PVA Cycle Illustrations			$\begin{matrix} W_1 \rightarrow P_1 \rightarrow V_1 \rightarrow A_1 \\ \swarrow \quad \searrow \\ W_2 \rightarrow P_2 \rightarrow V_2 \rightarrow A_2 \end{matrix}$	$\begin{matrix} W_1 \rightarrow P_1 \rightarrow V_1 \rightarrow A_1 \\ \swarrow \quad \searrow \\ W_2 \rightarrow P_2 \rightarrow V_2 \rightarrow A_2 \end{matrix}$	$\begin{matrix} W_1 \rightarrow P_1 \rightarrow V_1 \rightarrow A_1 \\ \swarrow \quad \searrow \\ W_2 \rightarrow P_2 \rightarrow V_2 \rightarrow A_2 \end{matrix}$	$\begin{matrix} W_1 \rightarrow P_1 \rightarrow V_1 \rightarrow A_1 \\ \swarrow \quad \searrow \\ W_2 \rightarrow P_2 \rightarrow V_2 \rightarrow A_2 \end{matrix}$	$\begin{matrix} W_1 \rightarrow P_1 \rightarrow V_1 \rightarrow A_1 \\ \swarrow \quad \searrow \\ W_2 \rightarrow P_2 \rightarrow V_2 \rightarrow A_2 \end{matrix}$	$\begin{matrix} W_1 \rightarrow P_1 \rightarrow V_1 \rightarrow A_1 \\ \swarrow \quad \searrow \\ W_2 \rightarrow P_2 \rightarrow V_2 \rightarrow A_2 \end{matrix}$	

**FIGURE 2.3.** Neural systems for valuation and control postulated by the valuation framework presented in the chapter (left-hand columns), as well as the roles these neural systems play in three kinds of emotion regulation strategies (center columns, see text) and three kinds of related phenomena (right-hand columns, see text). Up arrows indicate increased activation, down arrows indicate decreased activation, and “?” indicates involvement in some (but not the majority) of the studies. The final row diagrams, in PVA terms, how each emotion regulation strategy or related phenomenon might operate (see text for details). The three center columns show, for each emotion regulation strategy, how control actions impact either attention paid to particular stimuli at the perception stage (attentional deployment), how one values those stimuli (reappraisal), or what actions one takes as a consequence of this valuation (response modulation). The three right-hand columns show for related phenomena how initial valuations (e.g., threat) may be overridden if one learns new valuations (e.g., safe) for a stimulus (extinction) one may select among choice options as a function of their relative valuations, with control actions coming into play when the choice options are similarly valued and/or in conflict (intertemporal choice), or a placebo may influence the valuation of a painful stimulus via the action of control processes (placebo effects).

ment depend on the sensory qualities of the stimulus, distraction from pain modulates nociceptive regions of insula and cingulate cortex (Frankenstein, Richter, McIntyre, & Remy, 2001; Tracey et al., 2002), whereas distraction from an aversive image modulates the amygdala (McRae et al., 2010; Pessoa, 2009); for example, cross-study variability in attentional deployment strategies and the lack of a common metric for determining how much any given strategy diminishes attention to a stimulus in one study compared to others (see Ochsner & Gross, 2005, for a detailed review) have limited the conclusions that can be drawn about when and how specific cognitive control systems are involved.

*Cognitive change* refers to altering the subjective meaning and/or perceived self-relevance of the present situation (e.g., thinking of the knife as a stage prop or that knife-tossing is an innocent way of passing time). The framework suggests that this strategy should involve interactions between cognitive control systems that can be used deliberately to change one's interpretation of a stimulus and valuation systems that trigger an affective response. Of note here is the fact that the framework predicts that conceptual valuation systems can play a role on either side of this regulatory equation: on the one hand, being the target of cognitive control systems that seek to change one's high-level conceptual valuation of a stimulus, and on the other, assisting those cognitive control systems in reformulating the attributions one makes about the nature of one's own beliefs, desires, and feelings (e.g., "I'm feeling less afraid now")—or those expressed by others (e.g., "The subway passengers are anxious about the crowding, not the teen")—as one deliberately changes his or her interpretation of an emotion-eliciting stimulus. Research on cognitive change—referred to in the literature as "reappraisal"—consistently supports the predictions of the framework: When engaging in a cognitive change strategy, activation is observed in IPFC and cingulate PFC regions associated with cognitive control, as well as mPFC regions associated with conceptual valuation (albeit primarily when up-regulating emotional responses) and at the same time increasing or decreasing activity in core (e.g., amygdala, striatum) and/or contextual (e.g., insula) valuation

systems (e.g., Kober et al., 2010; Ochsner et al., 2004; Urry et al., 2006; Wager, Davidson, Hughes, Lindquist, & Ochsner, 2008; reviewed in Kalisch, 2009; Ochsner & Gross, 2005, 2008) in accordance with one's regulatory goals.

Finally, *response modulation* refers to targeting behavioral manifestations of emotion (e.g., playing it cool by not showing fear of the knife-wielding teen). Human research primarily has focused on one exemplar of this strategy, *expressive suppression*, which involves hiding behavioral manifestations of emotion (Gross, 1998). Behaviorally, expressive suppression effectively reduces facial expressions of emotion, but the effort and attention required to do so trigger autonomic responses, impair memory for visual cues, and can negatively impact social interactions (Butler et al., 2003; Gross, 1998; Richards & Gross, 2000). In keeping with these findings, an initial imaging study showed that suppressing the expression of disgust activated two key PFC regions associated with cognitive control (dlPFC associated with maintaining goals, and vlPFC associated with response selection and inhibition more generally; Aron et al., 2004; Badre & Wagner, 2007; Thompson-Schill et al., 2005), and *increased* activation in core (amygdala) and contextual (insula) valuation regions associated with detection of threats and awareness of body states (Goldin, McRae, Ramel, & Gross, 2008). This supports the idea that expressive suppression, like other strategies, depends on interactions between cognitive control and valuation regions, and may have neural bases similar to those supporting response inhibition more generally (Aron et al., 2004).

### Applications of the Valuation Perspective

The neural systems implicated in emotion and emotion regulation play key roles in other phenomena that involve valuation and cognitive control (Hartley & Phelps, 2010; Murray et al., 2007; Pessoa, 2008; Phillips et al., 2008; Rangel et al., 2008). We believe it is important that any account of emotion and emotion regulation use terminology and concepts that are broadly applicable to allied phenomena as well.

With this in mind, we illustrate in this section the broad applicability of our valuation perspective on emotion and emotion regulation by showing how it can provide a framework for describing the mechanisms underlying three types of related phenomena that traditionally are considered in relatively separate literatures. This has the dual benefits of broadening the framework to account for aspects of related phenomena it was not initially formulated to address, and in so doing, making the framework more robust and generally applicable.

### ***Affective or Emotional Learning***

As noted in the earlier section on the PVA processing dynamics, our valuation perspective allows learning to occur by updating the valuations placed on stimuli with each iteration of the PVA sequence. To account more broadly for various forms of affective or emotional learning, we can elaborate the way in which this updating process occurs.

When encountering a stimulus, one's current valuation of it sets an expectation for the outcome states of the world that should follow from execution of the associated action impulse(s). These outcomes become inputs to the next PVA, which evaluates discrepancies between the expected and actual outcomes. If this valuation is negative (i.e., when the discrepancy is large and/or important in light of currently active goals), this valuation triggers learning and updating processes that change links between a stimulus and its valuation (P-V) or between a valuation and an action (V-A)—or between separate PVA sequences—so that future valuations are more accurate (Delgado, Olsson, & Phelps, 2006; Rangel et al., 2008; Schultz, Dayan, & Montague, 1997). Each change is small, so that one's value expectations for a stimulus at a given moment in time are a function of one's prior experiences with it, biased more heavily toward recent experiences. While this value updating process typically is studied in the context of conditioning, reward, and affective learning, it fits neatly within our valuation framework as the way that changes in the contingency between actions and outcomes can adaptively alter the valuations that drive the actions.

To illustrate this, we can use our subway example to consider one of the most studied

examples of value updating, namely, extinction of a fear response. We discussed extinction earlier as an example of contextual valuation in which an organism learns that a previously feared stimulus need no longer be feared in the current temporal context. In that section, however, we did not explain how the organism learns this contextual association. Here we propose that value updating is the learning mechanism.

The subway example can help make this concrete. Recall that the knife-wielding teen initially elicits a threat valuation and fear response involving amygdala-mediated core level PVAs. If the expected outcome does not transpire (i.e., the teen takes no harmful actions), however, then over time a new contextual-level PVA is acquired by ventromedial/orbitomedial PFC systems indicating the teen is not a threat. The longer the teen takes no harmful action, the stronger this PVA becomes. Ultimately, even though the knife still connotes threat at the core level, the contextual PVA wins out for expression in behavior (see the section on PVA processing dynamics). Because the core-level PVA itself remains unchanged, a fear response can be quickly reinstated in the future should the teen become truly threatening (Bouton, 2004; LeDoux, 1993). The framework can be similarly applied to other cases in which one learns, or already has learned, that a given emotional impulse is inappropriate or unnecessary in the current context, as in reversal of learned appetitive or aversive associations (Bouton, 2004; Corcoran & Quirk, 2007; Schoenbaum et al., 2007).

As this example makes clear, affective learning and the types of regulatory strategies reviewed earlier are not mutually exclusive and may in many contexts work together. For example, the act of reappraising can be seen as a way of cognitively creating a discrepancy between an expected internal outcome (e.g., a fear response) associated with a given percept (e.g., the knife-wielding teen) and the response that actually occurs (e.g., calmness). This discrepancy could activate learning processes that weaken core-level PVA representations of the teen as threatening, build new contextual-level representations of the teen as nonthreatening, and strengthen conceptual-level PVAs of the teen as an actor. In this way, reappraisal—and by extension other regulatory strategies—

can be seen as providing top-down “teaching” inputs to outcome-driven regulatory processes that typically are triggered by external cues (cf. Delgado, Gillis, & Phelps, 2008; Delgado, Nearing, LeDoux, & Phelps, 2008).

### **Affective Decision Making**

Our valuation perspective also may be applied to affect-laden decision making. Affective decisions require a choice between options that are associated with different expected rewards or punishments. In our framework, these expectations are reflected in the values computed for choice options at various levels of the valuation hierarchy. To the extent that the play of activation and inhibition across PVA sequences associated with choice options results in a core-, contextual-, or conceptual-level valuation determining the behavioral output, then the choice option associated with that valuation will be selected. However, in some cases, this play of activation fails to determine clearly a most highly valued selection, and cognitive control processes may be engaged in order to construct, hold in mind, and implement top-down processes that influence PVAs associated with choice options. This commonly happens when choice options are similarly valued and/or conflict with one another, but it also may happen when the valuation process itself becomes a target of valuation (e.g., when there is a negative valuation of an attractive response option).

To illustrate (see Figure 2.3), consider how the framework accounts for a commonly studied choice dilemma in behavioral economics and neuroeconomics known as “intertemporal choice” (or as delay of gratification in the developmental literature; Mischel, Shoda, & Rodriguez, 1989). This dilemma involves choosing between a smaller reward available now or a larger reward available at some point in the future. In our framework, selection of the immediate reward would be promoted by core-level (striatal) or contextual-level (medial/orbital frontal) valuation systems that represent the reward value of the currently available stimulus. By contrast, picking the delayed reward would require the use of lateral prefrontal cognitive control systems in order to maintain a representation of the delayed

reward in working memory and inhibit activation of PVAs for the immediately available choice option (Figner et al., 2011). In keeping with this account, human imaging studies have shown greater ventral striatal (VS) and/or vmPFC versus greater dlPFC activity when participants select immediate versus delayed rewards (McClure, Ericson, Laibson, Loewenstein, & Cohen, 2007; McClure, Laibson, Loewenstein, & Cohen, 2004), and a recent transcranial magnetic stimulation study showed that disruption of left—but not right—dlPFC led participants to “impulsively” select immediate rewards when they had shown a prior preference for the delayed reward (Figner et al., 2011). Strikingly, this result dovetails with the finding that a pathway from left dlPFC to the VS supports the use of reappraisal to diminish craving for desired substances (e.g., sugary/fattening foods) when participants think about the negative long term (e.g., diabetes) as opposed to the immediate (e.g., delicious taste) consequences of consuming them (Kober et al., 2010).

As these findings make clear, affective decision making and the regulatory strategies reviewed earlier may depend upon very similar neural systems and, as such, the line between them is not always clear. Indeed, intertemporal choices—and other choices that require selecting between options consistent with long- versus short-term goals—can be viewed as self-control tasks (Figner et al., 2011; Hare, Camerer, & Rangel, 2009; Wunderlich, Rangel, & O’Doherty, 2009) in which the decision to select an option consistent with a long-term goal is influenced by attention deployment and cognitive change strategies (Mischel et al., 1989). Our valuation perspective can also be applied to other types of choice dilemmas in which control and valuation processes interact to determine choice, including risky decision making (Gianotti et al., 2009), in which the choice is to be fair toward or to punish others (Knoch et al., 2008; Knoch, Pascual-Leone, Meyer, Treyer, & Fehr, 2006), and when the act of choice itself changes our valuations of stimuli via the value-updating process (Sharot, De Martino, & Dolan, 2009; Sharot, Shiner, & Dolan, 2010) as in cognitive dissonance reduction (Lieberman, Ochsner, Gilbert, & Schacter, 2001; Sharot et al., 2009; van Veen, Krug, Schooler, & Carter, 2009).

### **Expectancies, Beliefs, and Placebo Effects**

Our valuation framework also helps make sense of the growing imaging literatures on the ways in which expectancies and beliefs of various sorts—including placebo effects—influence responses to various kinds of affective stimuli (Wager, 2005). In these tasks, participants are given one of two kinds of explicit expectations. In studies of expectancies or anticipation, participants are told that an upcoming stimulus—whether a painful sensation, an image, or something else—will be of a particular intensity or kind. In placebo experiments, participants are told that a drug (e.g., a cream or a pill) will increase or decrease their subsequent responses to a stimulus. In either case, these expectations lead participants to experience the stimulus, when presented, as subjectively more similar to what they expected than would have been the case had they held no expectations or beliefs about its nature or the protective properties of a drug.

From the perspective of our framework, these phenomena all involve the top-down influence of cognitive control systems on valuation systems or the influence of higher level valuation systems on lower level valuation systems. Our interpretation of these effects is consistent with results of imaging studies of expectancies and placebo effects on pain responses. Such studies indicate that expectancies and placebo beliefs about pain are maintained in a combination of lateral prefrontal/parietal working memory systems and/or medial prefrontal systems (Atlas, Bolger, Lindquist, & Wager, 2010; Lieberman, Jarcho, Berman, et al., 2004; Wager, 2005; Wager, Atlas, Leotti, & Rilling, 2011) that in the framework could be described as representing either conceptual-level beliefs (e.g., “The cream on my forearm should lessen the pain”) or contextual-level expectations about the stimulus or placebo. According to our framework, these systems influence attention to and appraisal of the value of stimuli in contextual-level and/or core-level valuation systems (see Figure 2.3), modifying their levels of activation to be consistent with top-down beliefs (e.g., lessening activation of pain-sensitive valuations systems, including contextual-level regions (e.g., cingulate and insular cortex) and core-level regions (e.g., amygdala and

PAG) (Ploghaus, Becerra, Borras, & Borsook, 2003; Wager, 2005).

Thus, from the viewpoint of the framework, expectancies and beliefs operate much like two of the emotion regulation strategies described earlier—attention deployment and cognitive change—in that they alter lower-level inputs to PVA systems and/or the valuation process.

### **Summary**

---

One of the fundamental challenges faced by any animal is computing and expressing the value of stimuli in an accurate and timely manner. This is difficult, because the animal’s internal state and external environment change over time, and its information acquisition, processing, and response resources and capabilities are limited. To address these challenges, humans (and other animals) have developed a complex set of interacting valuation systems, each of which can be described in terms of a simplified P-V-A sequence, in which a particular perceptual input is valued (negatively or positively to a given degree), leading to an impulse to alter ongoing behavioral or cognitive responses. These P-V-A sequences run in parallel at various levels in the brain and compete for expression.

This process-oriented valuation framework suggests a number of directions for future research. One direction concerns the valuation systems. While Figures 2.2A and 2.3 feature three kinds of valuation systems (core, contextual, and conceptual), future work should clarify the number and kind of valuation systems, as well as the rules that govern their engagement in particular contexts. A second direction has to do with how the often-competing action impulses associated with different P-V-A sequences are coordinated. We have emphasized the role of competitive activation and inhibition, but how this and other processes lead to coordinated and sustained adaptive behavior rather than erratic and conflicting behavior is not yet clear. A third direction concerns the inputs and outputs of valuation systems. We have suggested that the class of P-V-A sequences whose inputs are other P-V-A sequences, and outputs that include the engagement of cognitive control processes are fundamental to emotion regula-

tion and self-control more generally. That said, the range of relevant inputs and outputs, and the malleability of input–output relations requires further study. A fourth direction concerns the efficacy of various forms of value regulation and how they are intermixed in everyday life. Which “pure” or “hybrid” forms of value regulation are most effective? A fifth direction concerns translation of what we learn to illuminate individual differences. In our framework, a given emotional response and regulation profile could involve individual differences in (1) the initial valuations placed on specific classes of stimuli by systems at the core, contextual, and/or conceptual levels; (2) the speed with which these valuations are made; (3) how quickly and easily one resolves conflicts between them to express emotional responses; (4) how quickly and effectively learning processes update these valuations given that some emotional responses may be more difficult to change than others; (5) the knowledge of how and when to deploy emotion regulatory strategies; and (6) the capacity and ability to deploy top-down control systems to implement these strategies. One important direction for future research is examining how each of these differences—and others—may interact to produce various forms of psychopathology.

Our goal in presenting this valuation framework is to provide a common platform for analyzing the neural systems that are important for many different types of valuation. The impetus for this framework came from the observation that neural systems implicated in emotion generation and emotion regulation overlapped in important ways with neural systems implicated in other literatures that typically are not considered side by side (see Figure 2.3). Across all these research domains an organism’s adaptive capacity crucially hinges on the coordination of multiple valuation systems in real time, and a key challenge for future research is delineating these PVA interactions, ideally with adequate specificity to permit more explicitly computational approaches. We believe that an explicitly integrative valuation framework represents a step in this direction, and holds out the possibility of better coordinating hitherto unconnected research literatures, while simultaneously deepening our understanding of each one.

## References

- Anderson, J. R. (1983). A spreading activation theory of memory. *Journal of Verbal Learning and Verbal Behavior*, 22(3), 261–295.
- Aron, A. R., Robbins, T. W., & Poldrack, R. A. (2004). Inhibition and the right inferior frontal cortex. *Trends in Cognitive Sciences*, 8(4), 170–177.
- Atlas, L. Y., Bolger, N., Lindquist, M. A., & Wager, T. D. (2010). Brain mediators of predictive cue effects on perceived pain. *Journal of Neuroscience*, 30(39), 12964–12977.
- Badre, D., & Wagner, A. D. (2007). Left ventrolateral prefrontal cortex and the cognitive control of memory. *Neuropsychologia*, 45(13), 2883–2901.
- Barrett, L. F. (2006). Solving the emotion paradox: Categorization and the experience of emotion. *Personality and Social Psychology Review*, 10(1), 20–46.
- Barrett, L. F., Mesquita, B., Ochsner, K. N., & Gross, J. J. (2007). The experience of emotion. *Annual Review of Psychology*, 58, 373–403.
- Barrett, L. F., Ochsner, K. N., & Gross, J. J. (2007). Automaticity and emotion. In J. A. Bargh (Ed.), *Social Psychology and the Unconscious* (pp. 173–218). New York: Psychology Press.
- Bishop, S. J. (2007). Neurocognitive mechanisms of anxiety: An integrative account. *Trends in Cognitive Sciences*, 11(7), 307–316.
- Bouton, M. E. (2004). Context and behavioral processes in extinction. *Learning and Memory*, 11(5), 485–494.
- Buhle, J. T., Kober, H., Ochsner, K. N., Mende-Siedlecki, P., Weber, J., Hughes, B. L., et al. (2012). Common representation of pain and negative emotion in the midbrain periaqueductal gray. *Social Cognitive and Affective Neuroscience*. [E-publication ahead of print]
- Butler, E. A., Egloff, B., Wilhelm, F. H., Smith, N. C., Erickson, E. A., & Gross, J. J. (2003). The social consequences of expressive suppression. *Emotion*, 3(1), 48–67.
- Cato, M. A., Crosson, B., Gokcay, D., Soltysik, D., Wierenga, C., Gopinath, K., et al. (2004). Processing words with emotional connotation: An fMRI study of time course and laterality in rostral frontal and retrosplenial cortices. *Journal of Cognitive Neuroscience*, 16(2), 167–177.
- Corcoran, K. A., & Quirk, G. J. (2007). Recalling safety: Cooperative functions of the ventromedial prefrontal cortex and the hippo-

- campus in extinction. *CNS Spectrums*, 12(3), 200–206.
- Craig, A. D. (2003). Interoception: The sense of the physiological condition of the body. *Current Opinion in Neurobiology*, 13(4), 500–505.
- Craig, A. D. (2009). How do you feel—now?: The anterior insula and human awareness. *Nature Reviews Neuroscience*, 10(1), 59–70.
- Critchley, H. D. (2005). Neural mechanisms of autonomic, affective, and cognitive integration. *Journal of Comparative Neurology*, 493(1), 154–166.
- Cunningham, W. A., Raye, C. L., & Johnson, M. K. (2004). Implicit and explicit evaluation: fMRI correlates of valence, emotional intensity, and control in the processing of attitudes. *Journal of Cognitive Neuroscience*, 16(10), 1717–1729.
- Cunningham, W. A., & Zelazo, P. D. (2007). Attitudes and evaluations: A social cognitive neuroscience perspective. *Trends in Cognitive Sciences*, 11(3), 97–104.
- Damasio, A., Damasio, H., & Tranel, D. (2013). Persistence of feelings and sentience after bilateral damage of the insula. *Cerebral Cortex*, 23(4), 833–846.
- Davachi, L. (2006). Item, context and relational episodic encoding in humans. *Current Opinion in Neurobiology*, 16(6), 693–700.
- Davis, J. I., Gross, J. J., & Ochsner, K. N. (2011). Psychological distance and emotional experience: What you see is what you get. *Emotion*, 11(2), 438–444.
- Delgado, M. R., Gillis, M. M., & Phelps, E. A. (2008). Regulating the expectation of reward via cognitive strategies. *Nature Neuroscience*, 11(8), 880–881.
- Delgado, M. R., Jou, R. L., LeDoux, J. E., & Phelps, E. A. (2009). Avoiding negative outcomes: Tracking the mechanisms of avoidance learning in humans during fear conditioning. *Frontiers in Behavioral Neuroscience*, 3, 33.
- Delgado, M. R., Nearing, K. I., Ledoux, J. E., & Phelps, E. A. (2008). Neural circuitry underlying the regulation of conditioned fear and its relation to extinction. *Neuron*, 59(5), 829–838.
- Delgado, M. R., Olsson, A., & Phelps, E. A. (2006). Extending animal models of fear conditioning to humans. *Biological Psychology*, 73(1), 39–48.
- Denny, B. T., Kober, H., Wager, T. D., & Ochsner, K. N. (2012). A meta-analysis of functional neuroimaging studies of self- and other judgments reveals a spatial gradient for mentalizing in medial prefrontal cortex. *Journal of Cognitive Neuroscience*, 24(8), 1742–1752.
- Desimone, R., & Duncan, J. (1995). Neural mechanisms of selective visual attention. *Annual Review of Neuroscience*, 18, 193–222.
- Dum, R. P., Levinthal, D. J., & Strick, P. L. (2009). The spinothalamic system targets motor and sensory areas in the cerebral cortex of monkeys. *Journal of Neuroscience*, 29(45), 14223–14235.
- Egner, T., Etkin, A., Gale, S., & Hirsch, J. (2008). Dissociable neural systems resolve conflict from emotional versus nonemotional distracters. *Cerebral Cortex*, 18(6), 1475–1484.
- Etkin, A., Egner, T., Peraza, D. M., Kandel, E. R., & Hirsch, J. (2006). Resolving emotional conflict: A role for the rostral anterior cingulate cortex in modulating activity in the amygdala. *Neuron*, 51(6), 871–882.
- Everitt, B. J., Parkinson, J. A., Olmstead, M. C., Arroyo, M., Robledo, P., & Robbins, T. W. (1999). Associative processes in addiction and reward: The role of amygdala–ventral striatal subsystems. *Annals of the New York Academy of Sciences*, 877, 412–438.
- Ferstl, E. C., & von Cramon, D. Y. (2002). What does the frontomedian cortex contribute to language processing: coherence or theory of mind? *NeuroImage*, 17(3), 1599–1612.
- Figner, B., Knoch, D., Johnson, E. J., Krosch, A. R., Lisanby, S. H., Fehr, E., et al. (2011). Lateral prefrontal cortex and self-control in intertemporal choice. *Nature Neuroscience*, 13(5), 538–539.
- Frankenstein, U. N., Richter, W., McIntyre, M. C., & Remy, F. (2001). Distraction modulates anterior cingulate gyrus activations during the cold pressor test. *NeuroImage*, 14(4), 827–836.
- Gallagher, H. L., & Frith, C. D. (2003). Functional imaging of “theory of mind.” *Trends in Cognitive Sciences*, 7(2), 77–83.
- Gianotti, L. R., Knoch, D., Faber, P. L., Lehmann, D., Pascual-Marqui, R. D., Diezi, C., et al. (2009). Tonic activity level in the right prefrontal cortex predicts individuals’ risk taking. *Psychological Science*, 20(1), 33–38.
- Goldin, P. R., McRae, K., Ramel, W., & Gross, J. J. (2008). The neural bases of emotion regulation: Reappraisal and suppression of negative emotion. *Biological Psychiatry*, 63(6), 577–586.
- Gray, M. A., Beacher, F. D., Minati, L., Nagai,



- Y., Kemp, A. H., Harrison, N. A., et al. (2012). Emotional appraisal is influenced by cardiac afferent information. *Emotion, 12*(1), 180–191.
- Gross, J. J. (1998). Antecedent- and response-focused emotion regulation: Divergent consequences for experience, expression, and physiology. *Journal of Personality and Social Psychology, 74*(1), 224–237.
- Gross, J. J. (2007). *The handbook of emotion regulation*. New York: Guilford Press.
- Hamann, S. B., Ely, T. D., Hoffman, J. M., & Kilts, C. D. (2002). Ecstasy and agony: Activation of the human amygdala in positive and negative emotion. *Psychological Science, 13*(2), 135–141.
- Hare, T. A., Camerer, C. F., & Rangel, A. (2009). Self-control in decision-making involves modulation of the vmPFC valuation system. *Science, 324*(5927), 646–648.
- Harrison, N. A., Gray, M. A., Gianaros, P. J., & Critchley, H. D. (2010). The embodiment of emotional feelings in the brain. *Journal of Neuroscience, 30*(38), 12878–12884.
- Hartley, C. A., & Phelps, E. A. (2010). Changing fear: The neurocircuitry of emotion regulation. *Neuropsychopharmacology, 35*(1), 136–146.
- Holland, P. C., & Gallagher, M. (2004). Amygdala–frontal interactions and reward expectancy. *Current Opinion in Neurobiology, 14*(2), 148–155.
- Johnstone, T., van Reekum, C. M., Urry, H. L., Kalin, N. H., & Davidson, R. J. (2007). Failure to regulate: Counterproductive recruitment of top-down prefrontal–subcortical circuitry in major depression. *Journal of Neuroscience, 27*(33), 8877–8884.
- Kalisch, R. (2009). The functional neuroanatomy of reappraisal: Time matters. *Neuroscience and Biobehavioral Reviews, 33*(8), 1215–1226.
- Kalisch, R., Wiech, K., Critchley, H. D., & Dolan, R. J. (2006). Levels of appraisal: A medial prefrontal role in high-level appraisal of emotional material. *NeuroImage, 30*(4), 1458–1466.
- Keay, K. A., & Bandler, R. (2001). Parallel circuits mediating distinct emotional coping reactions to different types of stress. *Neuroscience and Biobehavioral Reviews, 25*(7–8), 669–678.
- Knoch, D., Nitsche, M. A., Fischbacher, U., Eisenegger, C., Pascual-Leone, A., & Fehr, E. (2008). Studying the neurobiology of social interaction with transcranial direct current stimulation—the example of punishing unfairness. *Cerebral Cortex, 18*(9), 1987–1990.
- Knoch, D., Pascual-Leone, A., Meyer, K., Treyer, V., & Fehr, E. (2006). Diminishing reciprocal fairness by disrupting the right prefrontal cortex. *Science, 314*(5800), 829–832.
- Kober, H., Barrett, L. F., Joseph, J., Bliss-Moreau, E., Lindquist, K., & Wager, T. D. (2008). Functional grouping and cortical–subcortical interactions in emotion: A meta-analysis of neuroimaging studies. *NeuroImage, 42*(2), 998–1031.
- Kober, H., Mende-Siedlecki, P., Kross, E. F., Weber, J., Mischel, W., Hart, C. L., et al. (2010). Prefrontal–striatal pathway underlies cognitive regulation of craving. *Proceedings of the National Academy of Sciences USA, 107*(33), 14811–14816.
- Kravitz, D. J., Saleem, K. S., Baker, C. I., & Mishkin, M. (2011). A new neural framework for visuospatial processing. *Nature Reviews Neuroscience, 12*(4), 217–230.
- Kurth, F., Zilles, K., Fox, P. T., Laird, A. R., & Eickhoff, S. B. (2010). A link between the systems: Functional differentiation and integration within the human insula revealed by meta-analysis. *Brain Structure and Function, 214*(5–6), 519–534.
- Lane, R. D., Reiman, E. M., Axelrod, B., Yun, L. S., Holmes, A., & Schwartz, G. E. (1998). Neural correlates of levels of emotional awareness: Evidence of an interaction between emotion and attention in the anterior cingulate cortex. *Journal of Cognitive Neuroscience, 10*(4), 525–535.
- LeDoux, J. E. (1993). Emotional memory: In search of systems and synapses. *Annals of the New York Academy of Sciences, 702*, 149–157.
- LeDoux, J. E. (2000). Emotion circuits in the brain. *Annual Review of Neuroscience, 23*, 155–184.
- LeDoux, J. E., & Gorman, J. M. (2001). A call to action: Overcoming anxiety through active coping. *American Journal of Psychiatry, 158*(12), 1953–1955.
- Levenson, R. W. (1999). The intrapersonal functions of emotion [Special issue]. *Cognition and Emotion, 13*(5), 481–504.
- Leventhal, H. (1984). A perceptual–motor theory of emotion. *Advances in Experimental Social Psychology, 17*, 117–182.
- Levy, D. J., & Glimcher, P. W. (2011). Comparing apples and oranges: Using reward-specific

- and reward-general subjective value representation in the brain. *Journal of Neuroscience*, 31(41), 14693–14707.
- Lieberman, M. D., Eisenberger, N. I., Crockett, M. J., Tom, S. M., Pfeifer, J. H., & Way, B. M. (2007). Putting feelings into words: Affect labeling disrupts amygdala activity in response to affective stimuli. *Psychological Science*, 18(5), 421–428.
- Lieberman, M. D., Jarcho, J. M., Berman, S., Naliboff, B. D., Suyenobu, B. Y., Mandelkern, M., et al. (2004). The neural correlates of placebo effects: A disruption account. *NeuroImage*, 22(1), 447–455.
- Lieberman, M. D., Jarcho, J. M., & Satpute, A. B. (2004). Evidence-based and intuition-based self-knowledge: An fMRI study. *Journal of Personality and Social Psychology*, 87(4), 421–435.
- Lieberman, M. D., Ochsner, K. N., Gilbert, D. T., & Schacter, D. L. (2001). Do amnesics exhibit cognitive dissonance reduction?: The role of explicit memory and attention in attitude change. *Psychological Science*, 12(2), 135–140.
- Lindquist, K. A., & Barrett, L. F. (2008). Constructing emotion: The experience of fear as a conceptual act. *Psychological Science*, 19(9), 898–903.
- Lindquist, K. A., Wager, T. D., Kober, H., Bliss-Moreau, E., & Barrett, L. F. (2012). The brain basis of emotion: A meta-analytic review. *Behavioral and Brain Sciences*, 35(3), 121–143.
- Maas, W. (2000). On the computational power of winner-take-all. *Neural Computation*, 12(11), 2519–2535.
- Mauss, I. B., Levenson, R. W., McCarter, L., Wilhelm, F. H., & Gross, J. J. (2005). The tie that binds?: Coherence among emotion experience, behavior, and physiology. *Emotion*, 5(2), 175–190.
- McClure, S. M., Ericson, K. M., Laibson, D. I., Loewenstein, G., & Cohen, J. D. (2007). Time discounting for primary rewards. *Journal of Neuroscience*, 27(21), 5796–5804.
- McClure, S. M., Laibson, D. I., Loewenstein, G., & Cohen, J. D. (2004). Separate neural systems value immediate and delayed monetary rewards. *Science*, 306(5695), 503–507.
- McRae, K., Hughes, B., Chopra, S., Gabrieli, J. D., Gross, J. J., & Ochsner, K. N. (2010). The neural bases of distraction and reappraisal. *Journal of Cognitive Neuroscience*, 22(2), 248–262.
- Miller, E. K. (2000). The prefrontal cortex and cognitive control. *Nature Reviews Neuroscience*, 1(1), 59–65.
- Miller, E. K., & Cohen, J. D. (2001). An integrative theory of prefrontal cortex function. *Annual Review of Neuroscience*, 24, 167–202.
- Mischel, W., Shoda, Y., & Rodriguez, M. L. (1989). Delay of gratification in children. *Science*, 244(4907), 933–938.
- Mitchell, J. P. (2009). Inferences about mental states. *Philosophical Transactions of the Royal Society of London B: Biological Sciences*, 364(1521), 1309–1316.
- Mobbs, D., Hassabis, D., Seymour, B., Marchant, J. L., Weiskopf, N., Dolan, R. J., et al. (2009). Choking on the money: Reward-based performance decrements are associated with midbrain activity. *Psychological Science*, 20(8), 955–962.
- Mobbs, D., Petrovic, P., Marchant, J. L., Hassabis, D., Weiskopf, N., Seymour, B., et al. (2007). When fear is near: Threat imminence elicits prefrontal-periaqueductal gray shifts in humans. *Science*, 317(5841), 1079–1083.
- Muhlberger, A., Neumann, R., Wieser, M. J., & Pauli, P. (2008). The impact of changes in spatial distance on emotional responses. *Emotion*, 8(2), 192–198.
- Murray, E. A., O'Doherty, J. P., & Schoenbaum, G. (2007). What we know and do not know about the functions of the orbitofrontal cortex after 20 years of cross-species studies. *Journal of Neuroscience*, 27(31), 8166–8169.
- Neely, J. H. (1991). Semantic priming effects in visual word recognition: A selective review of current findings and theories. In D. Besner & G. Humphreys (Eds.), *Basic processes in reading: Visual word recognition* (pp. 264–336). Hillsdale, NJ: Erlbaum.
- Ochsner, K. N., & Barrett, L. F. (2001). A multiprocess perspective on the neuroscience of emotion. In T. J. Mayne & G. A. Bonanno (Eds.), *Emotions: Current issues and future directions* (pp. 38–81). New York: Guilford Press.
- Ochsner, K. N., & Gross, J. J. (2005). The cognitive control of emotion. *Trends in Cognitive Sciences*, 9(5), 242–249.
- Ochsner, K. N., & Gross, J. J. (2008). Cognitive emotion regulation: Insights from social cognitive and affective neuroscience. *Currents Directions in Psychological Science*, 17(1), 153–158.
- Ochsner, K. N., Hughes, B., Robertson, E. R.,

- Cooper, J. C., & Gabrieli, J. D. (2009). Neural systems supporting the control of affective and cognitive conflicts. *Journal of Cognitive Neuroscience*, 21(9), 1842–1855.
- Ochsner, K. N., Ray, R. D., Cooper, J. C., Robertson, E. R., Chopra, S., Gabrieli, J. D. E., et al. (2004). For better or for worse: Neural systems supporting the cognitive down- and up-regulation of negative emotion. *NeuroImage*, 23(2), 483–499.
- Ochsner, K. N., Ray, R. R., Hughes, B., McRae, K., Cooper, J. C., Weber, J., et al. (2009). Bottom-up and top-down processes in emotion generation: Common and distinct neural mechanisms. *Psychological Science*, 20(11), 1322–1331.
- Ochsner, K. N., Silvers, J. A., & Buhle, J. T. (2012). Functional imaging studies of emotion regulation: A synthetic review and evolving model of the cognitive control of emotion. *Annals of the New York Academy of Sciences*, 1251, E1–E24.
- Olsson, A., & Ochsner, K. N. (2008). The role of social cognition in emotion. *Trends in Cognitive Sciences*, 12(2), 65–71.
- Ongur, D., Ferry, A. T., & Price, J. L. (2003). Architectonic subdivision of the human orbital and medial prefrontal cortex. *Journal of Comparative Neurology*, 460(3), 425–449.
- Ortony, A., Clore, G. L., & Collins, A. (1988). *The cognitive structure of emotions*. New York: Cambridge University Press.
- Packard, M. G. (2009). Anxiety, cognition, and habit: A multiple memory systems perspective. *Brain Research*, 1293, 121–128.
- Pessoa, L. (2008). On the relationship between emotion and cognition. *Nature Reviews Neuroscience*, 9(2), 148–158.
- Pessoa, L. (2009). How do emotion and motivation direct executive control? *Trends in Cognitive Sciences*, 13(4), 160–166.
- Pessoa, L., Kastner, S., & Ungerleider, L. G. (2003). Neuroimaging studies of attention: From modulation of sensory processing to top-down control. *Journal of Neuroscience*, 23(10), 3990–3998.
- Phelps, E. A. (2006). Emotion and cognition: Insights from studies of the human amygdala. *Annual Review of Psychology*, 57, 27–53.
- Phillips, M. L., Ladouceur, C. D., & Drevets, W. C. (2008). A neural model of voluntary and automatic emotion regulation: Implications for understanding the pathophysiology and neurodevelopment of bipolar disorder. *Molecular Psychiatry*, 13(9), 829, 833–857.
- Ploghaus, A., Becerra, L., Borras, C., & Borsook, D. (2003). Neural circuitry underlying pain modulation: Expectation, hypnosis, placebo. *Trends in Cognitive Sciences*, 7(5), 197–200.
- Polk, T. A., Drake, R. M., Jonides, J. J., Smith, M. R., & Smith, E. E. (2008). Attention enhances the neural processing of relevant features and suppresses the processing of irrelevant features in humans: A functional magnetic resonance imaging study of the Stroop task. *Journal of Neuroscience*, 28(51), 13786–13792.
- Price, J. L. (1999). Prefrontal cortical networks related to visceral function and mood. *Annals of the New York Academy of Sciences*, 877, 383–396.
- Quirk, G. J., & Beer, J. S. (2006). Prefrontal involvement in the regulation of emotion: Convergence of rat and human studies. *Current Opinion in Neurobiology*, 16(6), 723–727.
- Rangel, A., Camerer, C., & Montague, P. R. (2008). A framework for studying the neurobiology of value-based decision making. *Nature Reviews Neuroscience*, 9(7), 545–556.
- Richards, J. M., & Gross, J. J. (2000). Emotion regulation and memory: The cognitive costs of keeping one's cool. *Journal of Personality and Social Psychology*, 79(3), 410–424.
- Rolls, E. T. (1999). *The brain and emotion*. Oxford, UK: Oxford University Press.
- Russell, J. A., & Barrett, L. F. (1999). Core affect, prototypical emotional episodes, and other things called emotion: Dissecting the elephant. *Journal of Personality and Social Psychology*, 76(5), 805–819.
- Saxe, R. (2006). Uniquely human social cognition. *Current Opinion in Neurobiology*, 16(2), 235–239.
- Scherer, K. R. (2001). Appraisal considered as a process of multilevel sequential checking. In K. R. Scherer & A. Schorr (Eds.), *Appraisal processes in emotion: Theory, methods, research* (pp. 92–120). New York: Oxford University Press.
- Scherer, K. R., Schorr, A., & Johnstone, T. (Eds.). (2001). *Appraisal processes in emotion: Theory, methods, research*. New York: Oxford University Press.
- Schoenbaum, G., Saddoris, M. P., & Stalnaker, T. A. (2007). Reconciling the roles of orbitofrontal cortex in reversal learning and the encoding of outcome expectancies. *Annals of the New York Academy of Sciences*, 1121, 320–335.

- Schultz, W., Dayan, P., & Montague, P. R. (1997). A neural substrate of prediction and reward. *Science*, 275(5306), 1593–1599.
- Sharot, T., De Martino, B., & Dolan, R. J. (2009). How choice reveals and shapes expected hedonic outcome. *Journal of Neuroscience*, 29(12), 3760–3765.
- Sharot, T., Shiner, T., & Dolan, R. J. (2010). Experience and choice shape expected aversive outcomes. *Journal of Neuroscience*, 30(27), 9209–9215.
- Thompson-Schill, S. L., Bedny, M., & Goldberg, R. F. (2005). The frontal lobes and the regulation of mental activity. *Current Opinion in Neurobiology*, 15(2), 219–224.
- Tracey, I., Ploghaus, A., Gati, J. S., Clare, S., Smith, S., Menon, R. S., et al. (2002). Imaging attentional modulation of pain in the periaqueductal gray in humans. *Journal of Neuroscience*, 22(7), 2748–2752.
- Urry, H. L., van Reekum, C. M., Johnstone, T., Kalin, N. H., Thurow, M. E., Schaefer, H. S., et al. (2006). Amygdala and ventromedial prefrontal cortex are inversely coupled during regulation of negative affect and predict the diurnal pattern of cortisol secretion among older adults. *Journal of Neuroscience*, 26(16), 4415–4425.
- van Veen, V., Krug, M. K., Schooler, J. W., & Carter, C. S. (2009). Neural activity predicts attitude change in cognitive dissonance. *Nature Neuroscience*, 12(11), 1469–1474.
- Wager, T. D. (2005). The neural bases of placebo effects in pain. *Current Directions in Psychological Science*, 14(4), 175–179.
- Wager, T. D., Atlas, L. Y., Leotti, L. A., & Rilling, J. K. (2011). Predicting individual differences in placebo analgesia: Contributions of brain activity during anticipation and pain experience. *Journal of Neuroscience*, 31(2), 439–452.
- Wager, T. D., Barrett, L. F., Bliss-Moreau, E., Lindquist, K., Duncan, S., Kober, H., et al. (2008). The neuroimaging of emotion. In M. Lewis, J. M. Haviland-Jones, & L. F. Barrett (Eds.), *The handbook of emotion* (3rd ed., pp. 249–271). New York: Guilford Press.
- Wager, T. D., Davidson, M. L., Hughes, B. L., Lindquist, M. A., & Ochsner, K. N. (2008). Prefrontal–subcortical pathways mediating successful emotion regulation. *Neuron*, 59(6), 1037–1050.
- Wager, T. D., Jonides, J., & Reading, S. (2004). Neuroimaging studies of shifting attention: A meta-analysis. *NeuroImage*, 22(4), 1679–1693.
- Wager, T. D., & Smith, E. E. (2003). Neuroimaging studies of working memory: A meta-analysis. *Cognitive, Affective, and Behavioral Neuroscience*, 3(4), 255–274.
- Williams, L. E., & Bargh, J. A. (2008). Keeping one's distance: The influence of spatial distance cues on affect and evaluation. *Psychological Science*, 19(3), 302–308.
- Willis, W. D., & Westlund, K. N. (1997). Neuroanatomy of the pain system and of the pathways that modulate pain. *Journal of Clinical Neurophysiology*, 14(1), 2–31.
- Wunderlich, K., Rangel, A., & O'Doherty, J. P. (2009). Neural computations underlying action-based decision making in the human brain. *Proceedings of the National Academy of Sciences USA*, 106(40), 17199–17204.
- Young, L., Camprodon, J. A., Hauser, M., Pascual-Leone, A., & Saxe, R. (2010). Disruption of the right temporoparietal junction with transcranial magnetic stimulation reduces the role of beliefs in moral judgments. *Proceedings of the National Academy of Sciences USA*, 107(15), 6753–6758.
- Zaki, J., Davis, J. I., & Ochsner, K. N. (2012). Overlapping activity in anterior insula during interoception and emotional experience. *NeuroImage*, 62(1), 493–499.
- Zysset, S., Huber, O., Ferstl, E., & von Cramon, D. Y. (2002). The anterior frontomedian cortex and evaluative judgment: An fMRI study. *NeuroImage*, 15(4), 983–991.
- Zysset, S., Huber, O., Samson, A., Ferstl, E. C., & von Cramon, D. Y. (2003). Functional specialization within the anterior medial prefrontal cortex: A functional magnetic resonance imaging study with human subjects. *Neuroscience Letters*, 335(3), 183–186.