

Neurobiology of Personality Disorders

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CHAPTER

5 Minding the Emotional Thermostat: Integrating Social Cognitive and Affective Neuroscience Evidence to Form a Model of the Cognitive Control of Emotion

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Abstract

This chapter takes a social cognitive affective neuroscience approach to describe the processes and systems to give rise to emotion and the volitional control of emotion. It provides a detailed description of the processes that underlie the regulation of emotion. It introduces and synthesizes the brain structures involved in emotion processing and regulation. There is a particular focus on the role of the ventrolateral, dorsolateral and dorsomedial prefrontal cortex, amygdala, ventral striatum and insula, and on cognitive strategies such as reappraisal. It provides a critical framework for understanding the underlying behavioral and neural basis for the affect dysregulation observed across personality disorders, and summarizes future directions for this area of investigation.

Keywords: [social cognitive affective neuroscience](#), [emotion](#), [control of emotion](#), [personality disorders](#), [amygdala](#), [insula](#), [ventral striatum](#), [ventrolateral PFC](#), [dorsolateral PFC](#), [dorsomedial PFC](#)

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Every day brings with it some inevitable variation in emotional temperature: the rising heat of anger in response to an insult; the coolness of detached, analytical reflection on how such a situation may be de-escalated, and the temperate quotidian moments in between. Like we are able to adjust the thermostat of a room in an attempt to change its temperature, we are also able to attempt to adjust our own emotional temperature through a variety of means. However, unlike adjusting a thermostat on a wall, our internal emotional adjustments may be conscious or unconscious, may require persistent effort over time, and may or may not be successful in changing how we feel.

Despite how perplexing these changes in temperature may seem, the rapidly burgeoning field of affective neuroscience has begun to provide critical insight into the functional neural architecture and mechanisms

that subserve these ubiquitous emotional states. The goal of this chapter is to provide a brief overview of the literature on the neural bases of the generation and regulation of emotion, and, in so doing, substantiate and elaborate a model of the cognitive control of emotion that has been given previously (Ochsner & Gross, 2005, 2008; Ochsner, Silvers, & Buhle, 2012).

Given the plethora of means of regulating emotion, both implicit (i.e., not requiring conscious attention) and explicit (i.e., requiring conscious effort); the model organisms in which these processes may be examined (e.g., humans, nonhuman primates, rodents), the developmental as well as psychopathological state of the target population, and the substantial extant literatures on each, given space limitations this chapter will necessarily be circumscribed in its scope. In particular, our aim is to integrate evidence from basic social cognitive and affective neuroscience research involving healthy adult humans in order to establish a model of the neural mechanisms that underlie and guide both the generation and regulation of emotion—a model that may provide a point of reference when considering the neural mechanisms underlying various forms of psychopathology, a striking number of which involve some deficit in generating, experiencing, and/or regulating emotion (Berking, Ebert, Cuijpers, & Hofmann, 2013; Berking et al., 2008; Denny, Silvers, & Ochsner, 2009; Gross, 2013; Gross & Munoz, 1995).

p. 96 We devote particular focus to one explicit emotion regulation strategy, reappraisal, given that it has been particularly informative theoretically as well as relatively well studied (Buhle et al., 2014; Ochsner & Gross, 2008; Ochsner et al., 2012). To that end, after briefly reviewing the theoretical framework that underlies social cognitive and affective neuroscience research, the first two parts of this chapter present evidence for a model of cognitive control of emotion with a focus on processes and neural systems involved in emotion generation and regulation, respectively. The final part of the chapter highlights the relevance of this model to psychopathology and other future directions.

Theoretical Framework

Prior to presenting evidence for a model of the cognitive control of emotion, it is important to establish the overarching framework on which this evidence rests. In order to make inferences about the affective and cognitive processes, a multilevel approach is employed involving measurement of both behavior and neural activity. Measuring behavior involves analyzing self-reports of emotional experience (whether under the instruction to regulate or not) and measuring neural activity involves using a functional neuroimaging modality (typically functional magnetic resonance imaging [fMRI]) in order to establish which brain regions and systems are involved in subserving emotion generation and/or emotion regulation. In this way, by examining the interrelationship and patterns of converging evidence between the empirical data at hand across multiple levels of analysis (e.g., behavior; fMRI), one may make inferences about the underlying affective and cognitive processes involved (see Ochsner, 2007; Ochsner et al., 2012 for a more in-depth discussion).

Processes and Systems Involved in Emotion Generation

A useful framework for understanding the generation of an emotion can be found in the process model described by James Gross (Gross, 1998b; Gross & Thompson, 2007). Therein, emotions are taken to be response tendencies that arise in characteristic patterns during the evaluation (i.e., appraisal) of emotional stimuli in one's environment (Gross, 1998a, 1998b). As described in the framework previously, these response tendencies occur at several levels of analysis, including behavior, experience, and physiology. As the name implies, these response tendencies are likely to be expressed as emotional responses in the absence of any intervening conscious or unconscious regulation. Indeed, as we discuss later in the section on emotion regulation, this appraisal process inherent to the generation of an emotion may be modulated prior to the full expression of an emotional response.

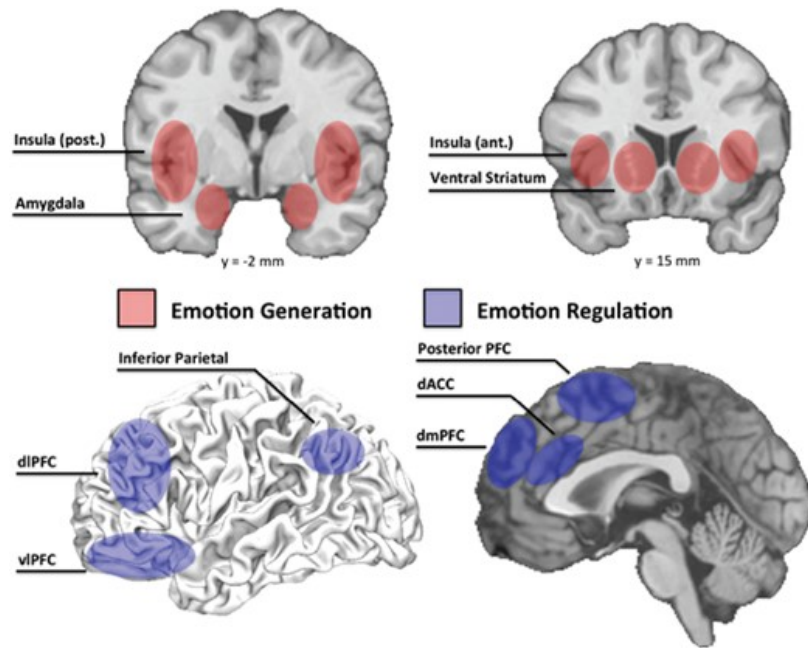
But how is this process of emotion generation subserved by the healthy adult brain? The extraordinary volume of human functional neuroimaging studies that have been published in the last 20 years (>5,000) has shed considerable light on this question. However, in synthesizing a model of emotion generation from this rich corpus of neuroscience data, it is essential to consider two theoretical accounts of the linkage between neuroimaging data and different emotional states: namely, whether discrete emotions (e.g., happiness, sadness, anger, fear) are each linked to discrete anatomical regions (or discrete networks of regions) in the brain that cannot be further reduced, or rather, whether such discrete emotional states arise from common progenitor regions and networks and achieve differentiation via variation in neuronal communication among the nodes of the network (Lindquist, Wager, Kober, Bliss-Moreau, & Barrett, 2012).

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↳ The former account, termed a *locationist* view, has intuitive appeal, and it was consistent with the results of many studies of the neural basis of emotional experience that connected discrete regions (e.g., the insula) with the processing of specific emotions (e.g., disgust). However, recent quantitative meta-analyses have provided support for the latter account, termed a *psychological constructionist* view, showing that the neural mechanisms underlying the generation and expression of diverse discrete emotions largely rely on common neural architecture (Kober et al., 2008; Lindquist et al., 2012).

These quantitative meta-analyses have informed our model of the principal brain regions involved in emotion generation. This model is summarized in Figure 5.1, highlighting brain regions that have been principally associated with emotion generation and experience (shown in red): the amygdala, the insula, and the ventral striatum. Critically, as discussed later, these regions each subserve generalized affective processes that contribute to the expression of diverse specific emotions in a manner consistent with the psychological constructionist viewpoint. We next consider each of these regions in more detail.

Figure 5.1



Model of the principal brain regions involved in emotion generation.

Amygdala

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The amygdalae, located bilaterally in the anterior portion of the ventral medial temporal lobes, have long been known from experimental work in animals to play a key role in emotion, attention, and memory (LeDoux, 1995, 2000). Early work in rodents on the functional contribution of the amygdala emphasized its critical role in the acquisition and expression of conditioned fear (Maren, Aharonov, & Fanselow, 1996; Quirk, Repa, & LeDoux, 1995). Extensive work in humans has further substantiated the role of the amygdala in facilitating conditioned fear responses (LaBar, Gatenby, Gore, LeDoux, & Phelps, 1998; LaBar, LeDoux, Spencer, & Phelps, 1995; Phelps, 2006; Phelps et al., 2001). Indeed, a vast human neuroimaging literature on the amygdala has evolved, with clear evidence for the amygdala being likewise involved in the appraisal of fearful expressions (Hariri, Tessitore, Mattay, Fera, & Weinberger, 2002; Whalen et al., 1998; Whalen et al., 2001) as well as threatening and unpleasant scenes (Hariri, Mattay, Tessitore, Fera, & Weinberger, 2003; Ochsner, Bunge, Gross, & Gabrieli, 2002; Ochsner et al., 2004). Moreover, amygdala activity has also been observed during the observation of sadness as well as appraisal of fearful and threatening information (Levesque et al., 2003; Wang, McCarthy, Song, & Labar, 2005).

While these results initially suggested that the amygdala may serve a specialized role in the detection of negative emotion, additional work has clarified that the amygdala is also significantly attuned to the appraisal of positively valenced stimuli as well, including pleasant faces and scenes (Kim & Hamann, 2007; Yang et al., 2002) as well as sexually arousing stimuli (Beauregard, Levesque, & Bourgouin, 2001; Hamann, Ely, Hoffman, & Kilts, 2002). Indeed, a quantitative meta-analysis of 148 functional neuroimaging studies of emotion has substantiated the amygdala's role in appraising both negatively and positively valenced information (Sergeur, Chochol, & Armony, 2008). Amygdala activity has further been shown to predict the magnitude of self-reported emotional responses (Ochsner, Ray, et al., 2009; Wager, Davidson, Hughes, Lindquist, & Ochsner, 2008) and is the most reliably modulated target of cognitive control (Buhle et al., 2014; Ochsner & Gross, 2008). Thus our model holds the predominant, contemporary view that the amygdala is involved in a more generalized assessment of the arousal and salience of a stimulus (Ochsner et al., 2012).

Insula

The insula, located deep within the lateral sulcus of the cortex, is associated with diverse psychological and physiological phenomena, including somatosensation, motor association, and language, as well a key role in emotional awareness and integration (Augustine, 1996; Craig, 2003, 2009; Wager & Barrett, 2004) and thus represents a key node in our model. Indeed, the insula and amygdala frequently coactivate in response to emotional stimuli (Etkin & Wager, 2010; Kober et al., 2008; Stein et al., 2007) and share substantial structural connectivity as well (Flynn, Benson, & Ardila, 1999; Mesulam & Mufson, 1982b; Mufson, Mesulam, & Pandya, 1981).

Early functional neuroimaging studies highlighted the role of insula in processing disgust experiences in particular (Damasio et al., 2000; Phillips et al., 2004; Phillips et al., 1997; Wicker et al., 2003), suggesting again a more specialized, locationist account of its involvement in emotion. However, as with the amygdala, more recent research has indicated that the insula is also involved in appraising positive stimuli, including pleasant music, voices, and faces (Craig, 2009; Hennenlotter et al., 2005; Johnstone, van Reekum, Oakes, & Davidson, 2006; Koelsch, Fritz, v. Cramon, Muller, & Friederici, 2006), and in integrating affective information (Menon & Uddin, 2010; Singer, Critchley, & Preusschoff, 2009).

Evidence for some functional specialization within insula has been provided by structural (Mesulam & Mufson, 1982a, 1982b) and functional (Deen, Pitskel, & Pelphrey, 2011) connectivity work as well as neuroimaging meta-analyses (Wager & Barrett, 2004). This work has suggested an anterior–posterior distinction, with posterior insula being particularly attuned to processing primary visceral somatosensations from the body, while the more anterior portion has been particularly associated with interoceptive awareness and emotional and motivational states (Craig, 2009; Wager & Barrett, 2004). Functionally, the anterior–posterior distinction is not absolute, however (Denny et al., 2014; Flynn et al., 1999) and may be best thought of as a gradient (Ochsner et al., 2012). Thus in our model the insula is associated with affective and somatosensory integration.

Ventral Striatum

A final region consistently recruited during emotion generation is the ventral striatum, including the nucleus accumbens, which has been consistently linked to processing the anticipation of reward (Ablner, Walter, Erk, Kammerer, & Spitzer, 2006; Knutson, Adams, Fong, & Hommer, 2001; Knutson & Cooper, 2005; O’Doherty et al., 2004). This representation of future reward is elicited by predictive cues, which are often abstract, that one learns to associate with a rewarding outcome (Knutson & Cooper, 2005; O’Doherty et al., 2004). Thus the ventral striatum is taken to represent the reward value of a stimulus in our model.

Processes and Systems Involved in Emotion Regulation

In the next section we turn our attention to mechanisms by which emotional responses may be modified once the emotion generative process is underway. Returning to the process model of Gross (1998b), once an emotional stimulus has been appraised (i.e., evaluated) as salient, the emotional response tendencies that determine the final shape of the emotional response may be modulated in various ways through the application of different emotion regulation strategies. As described, the initial determination of salience value draws upon the integrated functioning of the brain regions involved in emotion generation, including amygdala, insula, and the ventral striatum.

How then can emotional responses be modified once the appraisal process is underway? In Gross’s model (Gross, 1998b; Gross & Thompson, 2007), an important distinction is made between antecedent-focused

strategies (i.e., reshaping emotional response tendencies prior to the onset of an emotional response) versus response-focused strategies. Five main strategies are considered and briefly described here. As an example, imagine that you happen to see the aftermath of a gruesome car accident just ahead of you while driving down the highway. While your appraisal of this situation need not necessarily be conscious in order to engage the systems described previously in generating an emotional response, imagine that you are conscious of the upcoming scene. As such, you could take several routes to successful emotion regulation. Two antecedent-focused regulatory strategies include *situation selection* and *situation modification*; for this example, you may thus choose to take the next exit immediately and entirely change your surroundings (situation selection) or continue down the road but drive by the scene as fast as possible (situation modification). Alternatively, another antecedent-focused strategy is *attentional deployment*, whereby you could change what aspects of the situation you allow to flow through your attentional gates. For example, you might selectively attend to certain aspects of the situation, such as the highway and the overhead signs, rather than the emergency along the side of the road. Another means of attentional deployment is via distraction, whereby you continue to appraise an emotional situation while bearing other information in mind as well. In the example, to distract yourself, you may continue to observe the car wreck while at the same time considering your upcoming meeting (in addition to maintaining focus on the road).

A fourth and final antecedent-focused emotion regulation strategy is *cognitive change*, which involves changing the meaning of an emotion-eliciting stimulus. One well-studied exemplar is reappraisal, which involves cognitively reframing an emotional event in a way that modulates one's emotional response to it. Thus one could use reappraisal to upregulate or to downregulate either positive or negative emotion, though the majority of the reappraisal literature to date has focused on down-regulation of negative emotion (Ochsner & Gross, 2008; Ochsner et al., 2012). Two principal tactics one could use to implement the reappraisal strategy are reinterpretation and psychological distancing (Denny & Ochsner, 2014; McRae, Ciesielski, & Gross, 2012; Ochsner & Gross, 2008). Reinterpretation involves mentally changing the meaning of the actions, context, or outcomes of an emotion-eliciting situation, whereas psychological distancing involves changing one's construal of an event to be more distant (e.g., by appraising an event as an objective, impartial observer). Thus, for the car wreck example, if you were reinterpreting the situation you may think to yourself about how highly skilled the paramedics on the scene are and how it is very possible that the victims will survive. If you were employing psychological distancing, you would also be employing reappraisal, but in that case you may choose to focus on viewing the scene as a news reporter might, simply gathering information about how many cars were involved, how many people appear to have been involved, and whether anyone appears hurt. Last, a fifth emotion regulation strategy you might employ is a response-focused strategy, *response modulation*, meaning a strategy that targets the behavioral expression of emotion, rather than modifying the antecedents to an emotional response (i.e., modifying the situations, aspects, or meanings of an event, as described earlier; Gross, 1998a; Gross, 1998b; Gross & Thompson, 2007). A quintessential response-focused strategy is expressive suppression (Gross, 1998a); in our example, this would entail focusing on "keeping a poker face" and not showing any outward emotion while passing the car accident.

In this chapter, in describing the neural systems involved in emotion regulation, we give particular attention to describing the neural mechanisms that support reappraisal. Reappraisal is examined in depth as a paradigm case of emotion regulation for several reasons. First, reappraisal is the best-studied strategy in the emotion regulation literature (Buhle et al., 2014; Ochsner et al., 2012), with over 50 functional neuroimaging studies of reappraisal completed to date. Second, part of the reason for this investigational interest stems from reappraisal's relative advantages as a strategy. Reappraisal has been shown to reliably modulate emotional experience without increasing sympathetic arousal, in contrast to expressive suppression, which has been associated with increased sympathetic arousal, poorer memory for emotional events, and reduced well-being relative to reappraisal (Gross, 1998a, 2002; Gross & John, 2003; Richards & Gross, 2000). Further, reappraisal effects on behavior and neural activity have been shown to endure beyond

initial regulation (Denny, Inhoff, Zerubavel, Davachi, & Ochsner, 2015; Denny & Ochsner, 2014; Kross & Ayduk, 2008; Walter et al., 2009) in contrast to other strategies like distraction (Kross & Ayduk, 2008; Thiruchselvam, Blechert, Sheppes, Rydstrom, & Gross, 2011). Finally, improving emotion regulation efficacy is a crucial target of many clinical therapies for mood, anxiety, and personality disorders (Berking et al., 2013; Berking et al., 2008; Denny et al., 2009; Ochsner et al., 2012). Reappraisal, in particular, is a key ingredient of several forms of cognitive-behavioral therapy, and understanding the neural mechanisms and trainability of reappraisal may assist in the development and refinement of novel cognitive therapies (Denny & Ochsner, 2014), as discussed in the “Conclusion and Future Directions” section of this chapter.

Thus what follows is our model of the principal brain regions involved in emotion regulation via reappraisal. This model has been informed by recent meta-analyses of functional neuroimaging studies of reappraisal (Buhle et al., 2014; Ochsner et al., 2012) and is summarized in Figure 5.1, with regulation-related regions highlighted in blue. These include several regions in the prefrontal cortex (PFC), including the ventrolateral PFC, dorsolateral PFC, posterior PFC, dorsomedial PFC, as well as the inferior parietal cortex and dorsal anterior cingulate cortex (dACC). We next discuss these regions associated with implementing reappraisal in more detail according to their grouping into four subsystems based on patterns of coactivation during cognitive control tasks (Ochsner & Gross, 2005; Ochsner et al., 2012).

Ventrolateral PFC

Ventrolateral PFC has been particularly implicated in the selection of goal-appropriate responses and the inhibition of goal-inappropriate responses during cognitive control and semantic memory retrieval (Aron, Robbins, & Poldrack, 2004, 2014; Badre, Poldrack, Pare-Blagoev, Insler, & Wagner, 2005), thus functioning as an important mental “brake” (Aron et al., 2014). Thus one would expect ventrolateral PFC to be reliably active during reappraisal implementation, where choosing a relevant and effective reconstrual of an emotional stimulus—and inhibiting the appraisal to which one is predisposed as well as many unhelpful or irrelevant reappraisals—would be of great importance. Indeed, this is the case, as ventrolateral PFC activity has been consistently observed in reappraisal tasks (Buhle et al., 2014; Ochsner et al., 2012).

Moreover, ventrolateral PFC activity during reappraisal implementation has been shown to predict the magnitude of amygdala activity attenuation (Johnstone, van Reekum, Urry, Kalin, & Davidson, 2007; Ochsner et al., 2002) as well as increases in self-reported reappraisal success (Wager et al., 2008). Wager and colleagues unpacked this positive relationship between ventrolateral PFC activity and reappraisal success further, showing the existence of two separable mediation pathways underlying this effect, each incorporating a mediator region that has been highlighted earlier as being involved in emotion generation. In one pathway, right ventrolateral PFC activity predicted greater reappraisal success in a relationship mediated by ventral striatum activity; right ventrolateral PFC activity predicted greater ventral striatum activity during reappraisal to downregulate negative emotion, and greater ventral striatum activity predicted greater reappraisal success. In another pathway, right ventrolateral PFC activity predicted reduced reappraisal success in a relationship mediated by amygdala activity; right ventrolateral PFC activity predicted greater amygdala activity during reappraisal to downregulate negative emotion, and greater amygdala activity predicted poorer reappraisal success (Wager et al., 2008). Thus, while there has not been a universally consistent association between ventrolateral PFC activity and amygdala activity during reappraisal implementation (which may be due to variance in reappraisal tactics and stimuli), there has been a consistent association between ventrolateral PFC and both the selection of appropriate regulation responses as well as the inhibition of potentially unhelpful, negative thoughts, leading to overall reappraisal success. Thus in our model ventrolateral PFC plays a key role in appropriate response selection and inhibition.

Dorsolateral PFC, Posterior PFC, and Inferior Parietal Cortex

In the cognitive control literature, dorsolateral PFC, posterior PFC around Brodmann area 8, and inferior parietal cortex have all been implicated in selective attention and maintenance of information in working memory (Miller, 2000; Owen, McMillan, Laird, & Bullmore, 2005; Wager, Jonides, & Reading, 2004; Wager & Smith, 2003). These areas are all likewise reliably activated in reappraisal tasks (Buhle et al., 2014), consistent with the idea that reappraisal involves focusing attention on reappraisal-relevant aspects of a stimulus and holding relevant information in mind about the stimulus itself as well as information about the particular tactic or tactics to be used.

Further, in a manner similar to ventrolateral PFC, dorsolateral PFC has been shown to predict reappraisal success in a relationship mediated by an emotion generation region mentioned earlier. In a recent study by Kober and colleagues (2010), dorsolateral PFC activity when attempting to downregulate responses to appetitive cues (for either enticing food or for cigarettes among cigarette smokers) was associated with greater reappraisal success (i.e., less reported craving) in a relationship mediated by ventral striatum activity. In particular, greater dorsolateral PFC activity during reappraisal predicted less ventral striatum activity, and less ventral striatum activity predicted greater reappraisal success. The direction of these effects make sense in this context, given the presence of an appetitive rather than an aversive stimulus, and are thus consistent with the mediation study reviewed earlier involving ventrolateral PFC, ventral striatum, and reappraisal success (Wager et al., 2008). The existence of analogous mediated relationships involving posterior PFC and inferior parietal cortex is unclear, although we would make similar predictions for each. Thus, in our model, dorsolateral PFC, posterior PFC, and inferior parietal cortex are associated with selective attention and working memory.

Dorsomedial PFC

One of the functions most consistently associated with medial PFC is mentalizing, which refers to thoughts and inferences about one's own or someone else's mental state. In a recent meta-analysis of 107 functional neuroimaging studies, we have shown that in addition to medial PFC being robustly associated with mentalizing, a functional gradient exists such that relatively ventral aspects of medial PFC process self-focused mentalizing, while relatively dorsal aspects of medial PFC process other-focused mentalizing (Denny, Kober, Wager, & Ochsner, 2012). In the context of reappraisal, where dorsomedial PFC activity is often observed (Buhle et al., 2014), such a relationship makes sense, for both the association with mentalizing in general and for mentalizing about others in particular. Indeed, reappraisals—particularly using the \hookrightarrow reinterpretation tactic—involve mentalizing about how someone else may feel, or will feel, after a reconstrual of a situation that involves changing the actions, context, or outcomes. Therefore, in our model dorsomedial PFC plays an important role in supporting mentalizing about oneself and, especially, about others.

dACC

Finally, we review the role of the dACC. Across cognitive, affective, and social domains, dACC activity has consistently been associated with conflict monitoring (Botvinick, Cohen, & Carter, 2004; Botvinick, Nystrom, Fissell, Carter, & Cohen, 1999; Ochsner, Hughes, Robertson, Cooper, & Gabrieli, 2009; Zaki, Hennigan, Weber, & Ochsner, 2010). Conflict monitoring refers to the process of attending to and selecting among competing environmental inputs and the appropriate responses that are associated with each. In the context of reappraisal, where dACC activity is frequently observed (Buhle et al., 2014), this could involve evaluating multiple, potentially mutually exclusive reconstructions in the process of selecting the most appropriate one, and then ensuring that one's reappraisal is indeed efficacious in changing one's emotional response. Thus dACC is taken to facilitate conflict monitoring in our model.

Conclusion and Future Directions

We have provided evidence for a model of the cognitive control of emotion that integrates evidence from the burgeoning social, cognitive, and affective neuroscience literature on the neural bases of emotion generation and emotion regulation. In this final section, we briefly outline several future directions that follow from the discussion of our model. First, as the pace of research into emotion regulation has greatly accelerated in recent years (Gross, 2013; Ochsner et al., 2012), it is becoming possible to refine models of emotion regulation to differentiate among different goals (i.e., to downregulate or upregulate emotion), strategies (e.g., reappraisal or attentional deployment), tactics (e.g., reinterpretation or distancing), and valences (i.e., regulating negative or positive emotion). Further, additional work is beginning to elucidate the temporal dynamics of emotion regulation, including reappraisal; thus, while there has been recent evidence for the longitudinal trainability of reappraisal in an experimental context (Denny & Ochsner, 2014), an exciting host of questions persist, including the optimal delivery methods for emotion regulation training (e.g., massed versus temporally distributed practice; repeated versus novel stimuli); the relative trainability of different strategies; examination of how long emotion regulation effects endure beyond training across multiple levels of analysis (e.g., behavior, psychophysiology, neurobiology); and, crucially, the adaptive translational impacts that may be observed in daily life (Berkman & Falk, 2013; Denny & Ochsner, 2014). Further, understanding how emotion regulation changes across the lifespan is likewise essential, providing an opportunity to understand the critical periods during which interventions might be most effectively initiated (Charles & Carstensen, 2014; Riediger & Klipker, 2014; Silvers, Buhle, & Ochsner, 2014).

However, the future directions most relevant to the aims of this book involve extending this model, derived from healthy adult data, to psychopathological populations, including personality disorder patients. Indeed, emotion regulation is a signal deficit in many forms of psychopathology (Denny et al., 2009; Gross & Munoz, 1995; Werner & Gross, 2009), and the refinement of cognitive-behavioral interventions aimed at improving emotion regulation skills represents a promising and ongoing project (Berking et al., 2013; Berking et al., 2008). In testing the applicability of this model to psychopathological populations, it will be fascinating to examine whether the neural mechanisms supporting emotion regulation in many forms of psychopathology are fundamentally the same as those in healthy adults, though involving gradiential differences in the activity of key nodes in a manner suggesting dimensional boundaries between groups, or rather whether the nodes most central to the phenomenology of certain mental disorders are fundamentally distinct from other mental disorders and from healthy populations in a manner supporting categorically distinct neurobiological models. For personality disorders in particular, preliminary evidence of at least partial mechanistic overlap exists, with hyperactivation of amygdala activity reported as an important component of the neurobiological basis of emotion generation and regulation in several disorders, including

borderline personality disorder (Herpertz et al., 2001; Koenigsberg et al., 2009; Schulze et al., 2011) and avoidant personality disorder (Denny et al., 2015).

Ultimately, gaining a robust understanding of the neurobiological bases of emotion generation and regulation across healthy and psychopathological populations offers myriad potential benefits. Certainly, the implications for treatment could be substantial. With this knowledge, we may be able to better target certain interventions to certain individuals at critical times and in ways that are most likely to improve health and well-being. And, of course, most fundamentally, we may be better able to characterize the nature of the disorders themselves.

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