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How Thinking Controls Feeling
A SOCIAL COGNITIVE NEUROSCIENCE APPROACH

Kevin N. Ochsner

In the movie *The Princess Bride*, a farm boy named Westley tells his beloved Princess Buttercup, "Life is pain, Highness. Anyone who says differently is selling something." Westley speaks these words disguised as the Man in Black, which befits his dark portrait of life as bleak, full of hardship and emotional distress. Like many memorable movie lines, these words have some truth to them. Indeed, there are times when our frustrations, disappointments, embarrassments, and losses can seem never-ending. For confirmation that life's woes are quite commonplace, we need look no further than the pages of any daily newspaper. In March 2005, searches on the *New York Times* website for the words "emotion" or "stress" respectively returned 7,438 and 8,510 articles since 1996. The fact that a vast majority of articles were common to both searches indicates that, when writing about emotion, the *Times* is chronicling not our joys but our sorrows.

But is life always pain? Perhaps not. In another instance of art imitating life, Westley himself sells a sunnier perspective to Buttercup—but only after having removed his Black Mask and revealing his true identity as the film's heroic protagonist. While navigating the dangers of the Fire Swamp, Buttercup despairs: "We'll never succeed. We may as well die here." Westley replies, "No, no. We have already succeeded . . . " and proceeds to recount how they already have overcome many Swamp obstacles and possess the skills necessary to avoid any others. The message here is that beneath our occasional Black Masks, we all possess the ability to look on the bright side. When faced with scary situations that we cannot escape, we can control our fears and anxieties by thinking differently.

This ability to change the way we feel by changing the way we think has long been a topic of interest for laypersons and psychologists alike, and it goes by many names. "Rationalization" is used colloquially when we doubt the rationalizer's ability or success in getting over a breakup, a loss, or a disappointment. "Spin" (or "issue framing") is used by politicians, marketers, and media to describe how they can manipulate the emotional impact of an event on the public by altering its interpretation. "Coping" is used by clinical researchers who examine the ability to carry on and even thrive in the face of trauma and loss. And "reappraisal" is used by social psychologists who study the contexts in which different cognitive strategies have different consequences for emotional responding.

For present purposes, these abilities can be referred to broadly as the *cognitive control of emotion*. Despite long-standing interest in this topic, only recently has neuroscience research begun to rigorously examine how thinking controls feeling. The goal of this chapter is to describe our approach to this issue, which employs functional magnetic resonance imaging (fMRI) to test hypotheses about the psychological and neural mechanisms of one form of cognitive control that is known as reappraisal. To achieve this end, the chapter is divided into three parts. The first describes the motivation for and nature of the social cognitive neuroscience approach that guides this research. The second describes a series of experiments that address the neural bases of reappraisal, with an emphasis on understanding how interactions between control systems and emotional appraisal systems give rise to successful emotion regulation. The third and last part places this work in a broader context and discusses future directions for research in this area.

THE SOCIAL COGNITIVE NEUROSCIENCE APPROACH

Social cognitive neuroscience integrates the theories and methods of social psychology and cognitive neuroscience to study phenomena at multiple levels of analysis (Lieberman, 2000; Ochsner, 2004; Ochsner & Lieberman, 2001). To illustrate how this approach has guided our research on the brain bases of reappraisal, it is useful to consider, first, neuroscience work on emotion and cognitive control that was available when our work began. After examining how the strengths and weaknesses of that work motivated our social cognitive neuroscience approach, this section considers the nature of the approach in more detail.

The Motivation for the Approach

Around the turn of the 21st century, when this line of research began, there were no functional imaging studies that had investigated the brain bases of reappraisal specifically and few that had examined any form of cognitive

control over emotion more generally. Therefore, to inform our thinking about the neural systems supporting reappraisal, it seemed prudent to examine closely extant cognitive neuroscience work on emotion and cognitive control and social psychological work on emotion and emotion regulation.

Comparison of cognitive neuroscientific and social psychological approaches to emotion, however, revealed an important and telling difference that can be highlighted by their answers to an age-old question: Would a rose by any other name smell as sweet? For cognitive neuroscience theories (and the behavioral neuroscience theories on which they were based), the answer to this question would be *yes*, because they tend to treat emotion as a property of a stimulus, like shape, size, or color. In this view, emotions are automatic response tendencies linked to specific stimulus properties (Feldman Barrett, Ochsner, & Gross, in press). Thus, in order to generate strong or weak or positive or negative emotions, one simply needs stimuli that have "big" or "small" or "pleasant" or "unpleasant" emotional properties. The implicit assumption here is that emotions can be manipulated in much the same way that one would use big or small stimuli to examine encoding of size, blue and red or gray stimuli to examine processing of color, sweet- as compared with neutral-scented flowers to examine processing of smell, and so on.

By contrast, for some social psychological theories (and clinical theories to which they are related), the answer to the question about a sweet smelling rose is *no*: If you believed the rose was another flower (e.g., a daisy) that is not so sweet smelling, then the rose under your nose would not smell as sweet. The reason is that emotion is thought to be a context-dependent process in which emotional responses depend on an interaction between stimulus properties and the way they are interpreted, or *appraised*, in terms of their significance to one's current goals, wants, or needs (Feldman Barrett et al., in press; Lazarus, 1991; Scherer, Schorr, & Johnstone, 2001; Smith & Ellsworth, 1985). In this view, the same stimulus (e.g., a blow to the back) could elicit different emotional responses (anger or sympathy) depending on the way in which it was appraised (as an intentional strike vs. the result of someone accidentally tripping and falling into you).

Both of these views have merit. On the one hand, in some circumstances our emotional responses may be driven in a bottom-up fashion by the rapid encoding of stimulus properties that have learned or intrinsic pleasant or unpleasant properties and associations. On the other hand, in many circumstances our emotional responses are importantly shaped by the top-down influences of stored knowledge, contextual information, and our deliberate attempts to reevaluate and reinterpret the meaning of emotionally evocative situations. Emotions, therefore, may derive from the interaction of both bottom-up and top-down processes (Feldman Barrett

et al., in press; Lazarus & Alfert, 1964; Ochsner & Feldman Barrett, 2001;
Scherer, 1984; Scherer et al., 2001).

Using the Approach to Develop a Social Cognitive Neuroscience Model of Emotion and Emotion Regulation

With these contrasting approaches in mind, my colleagues and I developed an
integrative approach that would draw on the cognitive neuroscience litera-
ture on emotion and cognitive control to identify brain systems that could be
involved in the bottom up and top-down appraisal of emotional stimuli.

During the past decade, human cognitive neuroscience research has
converged with a large animal literature to implicate one subcortical brain
structure in particular—the amygdala—in the bottom-up processing of
emotion. Prior animal work using conditioning paradigms has demon-
strated that the amygdala plays an essential role in associating neutral per-
ceptual stimuli with the physiological and behavioral responses that make
up a fear response (Davis, 1998; LeDoux, 2000). Human functional imag-
ing and neuropsychological studies similarly have demonstrated a role for
the amygdala in acquiring conditioned fear responses (e.g., Buchel &
Dolan, 2000; LaBar & LeDoux, 1996; Morris & Dolan, 2004; Phelps et
al., 1998) and have extended the amygdala's role to the preattentive detec-
tion of arousing, ambiguous, and potentially threatening stimuli (Anderson
& Phelps, 2001; Morris, Ohman, & Dolan, 1999; Whalen, Rauch, et al.,
1998), consolidating episodic memories for both positive and negative
arousing events (Hamann, 2001), recognizing facial expressions that signal
so-called basic emotions (especially fear; Adolphs et al., 2005; Calder, Law-
rence, & Young, 2001), identifying more subtle social cues that signal
boredom and flirtation (Adolphs, Sears, & Piven, 2001), and guiding judg-
ments of social targets that could be judged unfriendly or untrustworthy
(Adolphs, Tranel, & Damasio, 1998; Winston, Strange, O'Doherty, &
Dolan, 2002). Thus the amygdala appears crucial for perception of, mem-
ory for, and judgments about emotionally arousing stimuli, primarily
potentially threatening ones. On the basis of this accumulated evidence, we
reasoned that the amygdala should be an important structure for the
bottom-up generation of an aversive emotional response.

That being said, two important caveats are in order concerning the
amygdala's role in emotion. First, the amygdala does not appear to be cru-
cial for generating some nonverbal behavioral expressions of emotion and
may not play a direct role in emotional experience, as suggested by the fact
that even bilateral amygdala lesions do not substantially affect these capaci-
ties (Anderson & Phelps, 2000, 2002). Second, the amygdala is by no
means the only structure important for human emotion, and at least three
other structures may play important roles depending on the stimulus and
its context. As described in more detail elsewhere (Adolphs, 2003; Calder

et al., 2001; Feldman Barrett et al., in press; Ochsner & Feldman Barrett, 2001; Ochsner & Gross, 2005), the ventral striatum seems essential for the bottom-up encoding of stimuli that have learned or intrinsic reward value (Delgado, Nystrom, Fissell, Noll, & Fiez, 2000; Knutson, Fong, Adams, Varner, & Hommer, 2001; O'Doherty, Deichmann, Critchley, & Dolan, 2002); the anterior insula is involved in responses to aversive, and especially, disgusting stimuli (Calder et al., 2001), which may be related to its role in interoception and awareness of the viscera (Critchley, Wiens, Rotshtein, Ohman, & Dolan, 2004); and, finally, the orbitofrontal cortex is important for linking affective associations to currently active goals and response options so that the value of stimuli can be updated flexibly in a context-sensitive manner (Bechara, Damasio, & Damasio, 2000; Beer, Heerey, Keltner, Scabini, & Knight, 2003; Beer, Shimamura, & Knight, 2004; Fellows & Farah, 2004; Hornak et al., 2004). Thus, although our own work has focused primarily on the role of the amygdala in emotion and emotion regulation, it is important to recognize that other brain systems play important roles as well.

To identify brain systems associated with top-down emotional processing my colleagues and I turned to the large literature on cognitive control that had implicated two brain systems—the anterior cingulate cortex and the dorsolateral prefrontal cortex—in the ability to control language, spatial attention, and memory. According to models of cognitive control, lateral prefrontal and cingulate systems play complementary roles in the regulation of behavior. Lateral prefrontal cortex (PFC) is important for the selection, maintenance, and application of goal-directed strategies and supports such cognitive abilities as working memory, response inhibition, and executive control more generally (Banich et al., 2000; D'Esposito, Postle, Ballard, & Lease, 1999; Jonides, Smith, Marshuetz, Koeppe, & Reuter-Lorenz, 1998; Miller & Cohen, 2001; Wagner, Pare-Blagoev, Clark, & Poldrack, 2001). Dorsal regions of anterior cingulate cortex (dACC) and the neighboring supplementary motor area are thought to monitor the extent to which current behavior is staying on track, to signal the need for ongoing control by PFC, and to support the ability to detect (and therefore correct) errors and identify response conflicts more generally (Banich et al., 2000; Botvinick, Braver, Barch, Carter, & Cohen, 2001; Botvinick, Cohen, & Carter, 2004; Erickson et al., 2004; Milham et al., 2001; cf. Fellows & Farah, 2005). Working hand in hand, these two brain systems are thought to support control processes that enable us to keep in mind the information we want to have there and to keep out of mind the information we want left out (Bunge, Ochsner, Desmond, Glover, & Gabrieli, 2001). They do this by modulating activation in subcortical and posterior cortical systems that represent different kinds of visual, auditory, or spatial information and that enable us to remember phone numbers until we dial them, select the right words to say, ignore distracting traffic noise, and the like. In the context of emotion, my colleagues and I hypothesized that lateral PFC and

dACC could modulate brain structures involved in the bottom-up generation of emotion, such as the amygdala or insula.

One other prefrontal system may be important for top-down emotional processing. Guiding and altering our emotional responses on the basis of stored knowledge, online goals, and delivered strategies requires not just systems important for implementing control but systems important for the metacognitive monitoring of their operation. If lateral PFC and dACC are important for control, then the medial PFC (mPFC) appears to be important for monitoring (Ochsner, Beer, et al., 2006; Ochsner, Knierim, et al., 2004). MPFC, and especially its dorsal medial portion, is active when individuals evaluate their own emotional states (Gusnard, Akbudak, Shulman, & Raichle, 2001; Lane, Fink, Chau, & Dolan, 1997; K. N. Ochsner, Knierim, et al., 2004; Paradiso et al., 1999) or the emotional states of others (Ochsner, Knierim, et al., 2004), when we make attributions about the mental states of others more generally (Gallagher & Frith, 2003), and when we draw inferences about our own or another person's traits and dispositions (Kelley et al., 2002; Mitchell, Heatherton, & Macrae, 2002; Mitchell, Macrae, & Banaji, 2006; Ochsner et al., in press). Interestingly, dorsal mPFC is also involved in the delivered retrieval of context-appropriate emotional associations from memory in tasks that do not explicitly involve reference to mental states (Cato et al., 2004; Crosson et al., 1999). These data suggest that mPFC may be important when we draw inferences about how we feel, why we feel that way, whether we feel that way in general, and whether and why other people feel that way, as well. Thus mPFC may come into play as we track our own changing emotional responses and when we reason about emotional implications of another person's intentions, actions, and beliefs.

Taken together, these studies provide the foundation for our hypothetical model of the cognitive control of emotion. According to this model, prefrontal and cingulate systems guide the top-down appraisal of emotional stimuli initially encoded in a bottom-up fashion by the amygdala and related structures. In the following section, I summarize experiments that further develop and test this initial working model.

TOWARD A MODEL OF THE COGNITIVE CONTROL OF EMOTION

The far-reaching aim of our research is to develop a model of the cognitive control of emotion that makes reference to multiple levels of analysis (social, cognitive, and neural) and that can provide an account of both healthy normal and maladaptively abnormal emotional responding. The development of any such model is, of course, an iterative process in which theories generate hypotheses that turn into experiments that produce results, which in turn inform theories, and so on.

The Social Cognitive Neuroscience Approach

The essence of this *social cognitive neuroscience approach* is to use neuroscience data to constrain thinking about the psychological processes that give rise to a specific kind of experience or behavior. Neuroscience data can be said to constrain psychological theorizing insofar as it provides empirical observations that theories must take into account. Robust theories speak to multiple types of data at multiple levels of analysis. By collecting multiple types of data using different methods, we can converge on robust theories of this kind (Ochsner & Kosslyn, 1999).

Note that this way of thinking about neuroscience data as a kind of constraint does not afford them privileged status. Neuroscience data provide dependent variables (DVs) that are neither "better" nor "worse" than many other kinds of DVs that might be collected by any experimental psychologist. Indeed, psychologists use all types of DVs—including choice response times (RTs), self-reports, speed of walking down a hallway, or any other measure—to constrain theory in the sense described here. Data constrain theory by providing observations for which theories must account. In this sense, neuroscience data constrain theory.

This is not to say that all kinds of DVs provide the same kinds of constraints. RTs and the effects of hippocampal damage do tell us different things, as do self-reports of emotional experience and patterns of activation in the amygdala and insula. Our job, as always, is to figure out how to map these different kinds of DVs onto one another and to build theories that explain the relationships among DVs and theoretical constructs couched at different levels of analysis.

That being said, it is important to recognize that information transfer between neuroscience data and psychological theory is bidirectional. Without psychological theory, the hippocampus, for example, is just a bunch of neurons that fire away without rhyme or reason. And without neuroscience data, we might not have developed the notion that there are multiple memory systems, one of which depends critically on the integrity of the hippocampus and many of which do not (Davachi, in press; Schacter, 1997). The mutual constraints between psychological, cognitive, and neural levels of analysis provide the foundation for drawing strong inferences about the validity of psychological theories (Sarter, Berntson, & Cacioppo, 1996).

In this regard, social cognitive neuroscience experiments can be thought of as having two simultaneous goals: (1) to use careful, theory-guided, behavioral experiments to inform our knowledge of brain function and (2) to use knowledge about brain function to inform psychological theory (Ochsner, in press; Ochsner & Lieberman, 2001; Sarter et al., 1996). Cognitive neuroscience tends to emphasize the former, and social psychology the latter mode of investigation, but most every experiment is at least capable of doing both at once.

Although some neuroscientists might reify neuroscience data as perhaps better or more "true" than other types of data, neuroscience methods and the data they produce are better seen as valuable tools in the toolbox of techniques that psychologists can employ to address their questions of interest. The questions you may want to address may not directly benefit from the application or incorporation of neuroscience data, of course. But whatever type of data you collect may constrain theorizing in a similar way. One could ask: Do RT data just speak to the speed with which we can do things? Are accuracy data only about how accurately we can do things? In a literal sense, yes, but in a scientific sense, no. For psychologists of any stripe, DVs are there to tell us something about underlying processing mechanisms. And in that sense, imaging data, electroencephalographic and event-related potential data, neuropsychological data, and so forth, tell us something about processing mechanisms. It is up to our theories to explain what that something is, and multiple kinds of data can inform the construction of those theories.

## Two Kinds of Cognitive Control over Emotion

With this approach as a guide, in this section I present the current state of our model by describing experiments that examine two ways in which top-down cognitive processes can be used to regulate bottom-up emotion-generative processes (Ochsner, 2005; Ochsner & Gross, 2005). The first involves the controlled use of attention, and the second, the use of reappraisal to cognitively change the meaning of arousing inputs.

Controlled Attention

Attention is often called the selective aspect of information processing, by which is meant that attention enables us to gate the flow of informational inputs so that only selected stimuli receive further processing. When facing numerous stimuli that each can elicit a different emotional response, we can use selective attention to control the impact the stimuli have on us. By selectively attending to stimuli that generate desired responses and ignoring stimuli that generate undesired responses, we can control what we feel by resolving emotional conflicts.

My colleagues and I have examined the neural bases of this ability using variants of a classic interference paradigm known as the flanker task (Ochsner, Robertson, Cooper, & Gabrieli, 2006). In our affective version of the flanker task, participants viewed three words presented vertically in the center of the screen (see Figure 6.1, top). The participant's job was to judge whether the central target word was positive or negative and to ignore the distracting words that flanked it above and below. On congruent trials these words had the same valence (i.e. positive or negative) as the tar-
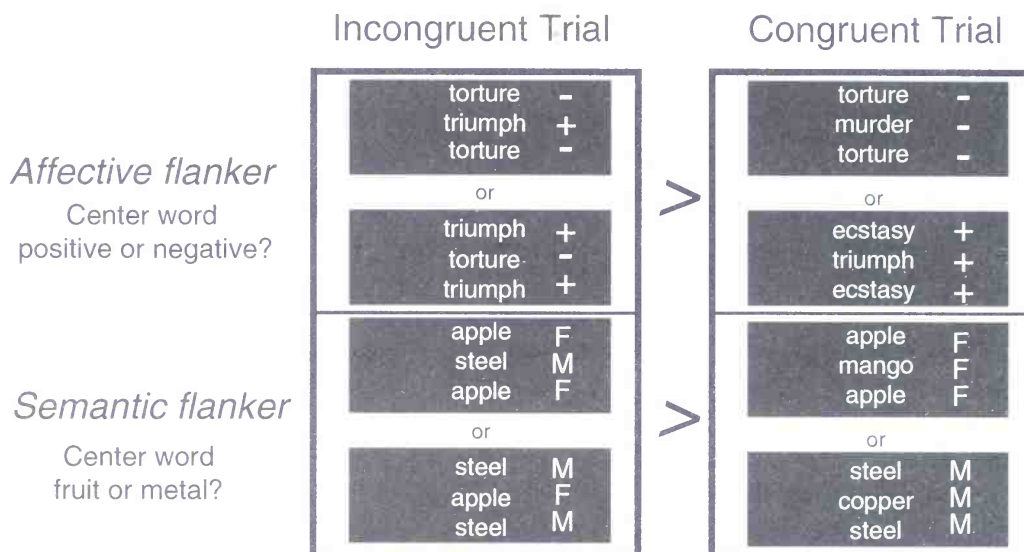
FIGURE 6.1. The structure of trials in the affective and semantic flanker tasks. For both tasks participants were instructed to attend to a central target word and to ignore distracting flanking words presented above and below it. They provided simple binary key-press responses to indicate either its valence (affective flanker) or its semantic category (semantic flanker). On incongruent trials flanking words had the opposite valence or were drawn from a different semantic category, and on congruent trials, words had the same valence or were drawn from the same semantic category. + and - symbols indicate the valence of words on the affective flanker task. M and F indicate the metal or fruit category of words on the semantic flanker task. The symbols were not present on the display during task completion and are provided solely for illustrative purposes.

get, and on incongruent trials these words had the opposite valence. By comparing patterns of brain activation on congruent, as compared with incongruent, trials for this task, we would be able to identify brain systems involved in resulting affective conflicts.

To determine whether the brain systems that support affective conflict resolution are similar to those involved in resolving cognitive conflicts, my colleagues and I compared activation during the affective flanker to activation during a semantic flanker task (see Figure 6.1, bottom). In this task participants again viewed an array of three vertically presented words that in this case were drawn from one of two emotionally neutral semantic categories—metals or fruit. Participants judged the category of the central target word as a metal or a fruit and ignored flanking words that were either from the same or the different category. In keeping with a large prior literature showing that response interference of various kinds slows reaction time, we found that responses were slower on incongruent than on congruent trials for both the affective and semantic flanker tasks.

The critical question was whether the use of selective attention to control affective conflict would involve neural systems similar to or different

from those used to resolve cognitive conflict. As the preceding literature review suggests, we had good reason to believe that cognitive conflict should recruit dACC and dorsal lateral PFC regions. Furthermore, there had been suggestions that rostral regions of ACC and adjacent mPFC generally are involved in emotion (e.g., Bush, Luu, & Posner, 2000), in contrast to the cognitive functions of dACC. There were thus two competing hypotheses: Affective conflict could depend on rostral ACC and mPFC, whereas cognitive conflict would depend on dACC; or both types of conflict could recruit dACC regions sensitive to any type of response conflict, and there would be additional response-type-specific regions recruited, which could include mPFC.

The results clearly supported the latter hypothesis. As illustrated schematically in Figure 6.2, incongruent as compared with congruent trials for both the affective and semantic flanker tasks activated common regions of dACC and bilateral dorsal lateral PFC, in keeping with recruitment of these regions in numerous tasks involving cognitive control and response conflict of other kinds (e.g., Banich et al., 2000; Botvinick et al., 2004; Milham et al., 2001; Wager, Jonides, & Reading, 2004; Wager & Smith, 2003).

Interestingly, at the group level, rostral ACC/mPFC was not more active for affective as compared with cognitive conflict. In some cases failures to observe activation of brain systems in overall group contrasts can be attributable to individual differences in the extent to which specific pro-
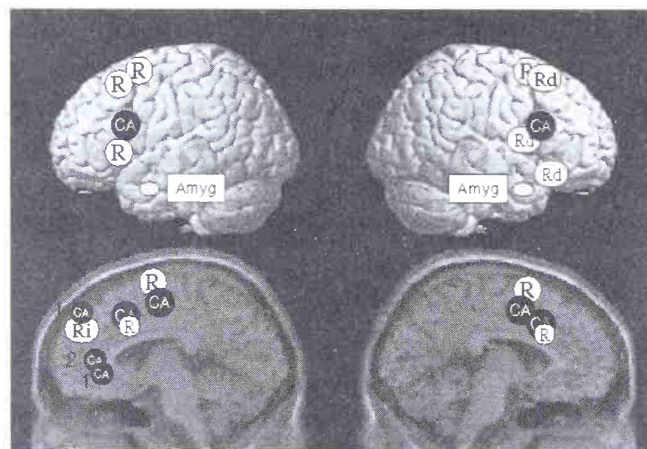
FIGURE 6.2. Lateral (top panels) and medial (bottom panels) cortical regions involved in attentional control (designated by CA), reappraisal in general (designated by R), reappraisal to increase negative emotion (designated by Ri) or reappraisal to decrease negative emotion (designated by Rd). The location of the amygdala, whose activation can be modulated up or down by reappraisal, is indicated by the white circle labeled Amyg. The amygdala is a subcortical structure located on the medial wall of the temporal lobe, and its approximate location beneath the surface of the lateral temporal cortex is indicated here. See text for details of functional interpretations for activated regions.

cesses are engaged. To account for the possibility that individual differences in the tendency to generate and experience emotion could influence activations, this experiment included questionnaires indexing individual differences in trait anxiety (Spielberger, Gorsuch, Lushemne, Vagg, & Jacobs, 1983) and alexithymia (Bagby, Parker, & Taylor, 1994). "Alexithymia" refers to the inability to understand and represent in awareness one's emotional states. Normal individuals differ in the extent to which they are able to recognize their own feelings, although severe emotion recognition deficits may warrant clinical intervention (Lane, Ahern, Schwartz, & Kaszniak, 1997; Lane, Sechrest, Riedel, Shapiro, & Kaszniak, 2000; Sifneos, 1996). We found that both individual difference measures predicted activation during affective conflict. Individuals with high trait anxiety tended to activate dorsal mPFC regions associated with thinking about emotional implications of words and reasoning about affective states (Cato et al., 2004; Ochsner et al., 2005), as well as ventral mPFC regions associated with using affective associations to guide behavior (Ochsner & Gross, 2005). Highly alexithymic individuals *failed* to activate rostral ACC/mPFC regions associated with self-awareness of emotional states. These findings are consistent with the idea that what is special about emotional conflict is not a special mechanism for resolving competing affective responses per se but rather the fact that emotional conflicts elicit awareness of the emotional qualities of conflict-arousing stimuli. Whereas individuals who are highly anxious elaborate and represent in awareness the affective properties of stimuli, alexithymic individuals fail to do so.

The results of this experiment thus support the working model of the cognitive control of emotion by demonstrating that PFC and dACC systems implement domain-general control processes that can be applied to regulating affective or cognitive conflicts and that the extent to which one engages medial systems involved in appraising the emotional value of a stimulus can depend on individual differences in one's ability and tendency to engage specific evaluative processes. These results are also consistent with other studies that have investigated conflicts between competing emotional and cognitive responses (but not affective conflicts per se) that have associated rostral ACC and mPFC with processing the affective connotations of words despite the fact that one is trying to ignore them (Compton et al., 2003; Mohanty et al., 2005; Shin et al., 2001; Whalen, Bush, et al., 1998) and with individual differences in trait anxiety (Bishop, Duncan, Brett, & Lawrence, 2004).

Controlled Appraisal

Although we may possess the capacity to ignore stimuli that elicit undesirable emotional responses, it is neither always possible nor always desirable to do so. For example, one cannot (or at least should not!) ignore a failing grade on an exam, and it might be perilous to ignore critical remarks made

by one's relationship partner. To cope with such trying times, one can use cognition to control how one appraises the meaning of aversive stimuli. Thus that failing grade can be construed as a useful wake-up call and reminder to promote good study habits, and apparently critical remarks can be construed appropriately as unintended by-products of your partner's bad day at work (rather than as intentional barbs).

The controlled appraisal of stimuli isn't used only to turn off aversive feelings, however. In some cases, we may turn up the aversive volume by focusing on and elaborating negative appraisals of an event. This may be our conscious goal, as when we try to quell giddiness before an event in which is important to be serious or when we enhance our aggressive impulses before participating in a sporting event. But it may also be the unintended consequence of our conscious thoughts that involve worry, rumination, and anxiety.

To investigate the use of cognitive control to both generate and regulate negative emotion in these ways, we have conducted a series of studies using a simple laboratory paradigm meant to model everyday uses of controlled appraisal. Participants are exposed to a series of emotionally evocative photographs drawn from Peter Lang's International Affective Picture System (IAPS; Lang, Greenwald, Bradley, & Hamm, 1993). The high-arousal negative photographs used in the studies described here typically elicit feelings of disgust, shock, anxiety, and occasionally sadness. As illustrated in Figure 6.3, each photograph is presented in a multipart trial that begins with an instruction word in the center of the screen. This instruction word indicates that participants should either (one baseline trial) simply Look at a stimulus and let themselves respond naturally or reappraise the stimulus in a specified way. Across studies, the means and ends of reappraisal are systematically manipulated, as described subsequently. While

Instructional cue	Photo period	Affect rating	Intertrial interval
2 secs	10 secs	4 secs	4 secs
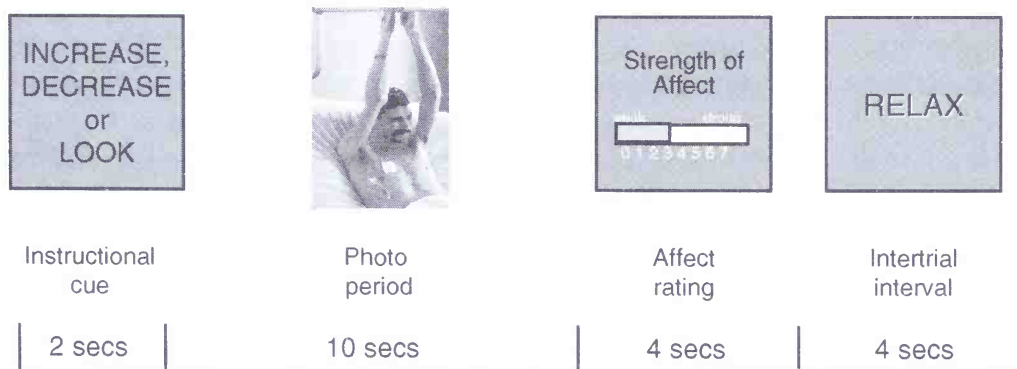
FIGURE 6.3. The structure of trials in a standard reappraisal task. An instructional cue indicates whether participants are to simply look at a stimulus and let themselves respond naturally (baseline trials) or to use some type of reappraisal (described in the text) to either increase or decrease their negative emotion.

the photograph is on the screen, for approximately 8–10 seconds, participants follow the instruction specified by the cue. After the photograph disappears, participants have an opportunity to rate the strength of their current negative affect, from weak to strong, using a scale that appears at the screen's center. Finally, there is an intertrial interval during which participants can relax before the next trial begins.

Contrasting Bottom-Up versus Top-Down Routes to Emotion Generation.   To examine the generation of negative emotion, we used this paradigm to contrast bottom-up and top-down routes to emotional appraisal (Ochsner et al., 2006). A bottom-up route to emotional appraisal was modeled using baseline "Look" trials with aversive, as compared with neutral, photographs. By asking participants to respond naturally to photos with intrinsic or culturally learned aversive properties (such as a gunshot wound or a Ku Klux Klan member) as compared with neutral properties (e.g., a neutral facial expression or an office setting), we hypothesized that systems involved in the bottom-up generation of an emotion should be engaged. A top-down route to emotional appraisal was modeled by asking participants to "Increase" their negative responses to neutral photographs. By asking participants to think in negative ways about the context, affects, and outcomes depicted in each photo, we hypothesized that systems involved in a top-down generation of an emotion should be engaged.

The results generally supported the working model (see Figure 6.3). "Look" trials using aversive as compared with neutral photos activated the amygdala bilaterally, as well as a right lateral PFC region associated with sustained attention (Wager, Jonides, & Reading, 2004) and extrastriate visual areas associated with heightened attention to visual inputs (Lane, Chua, & Dolan, 1999). By contrast, "Increase" trials with aversive photos, as compared with "Look" trials with aversive photos, activated the left amygdala, left lateral PFC, and bilateral dACC and mPFC. These results are consistent with the idea that bottom-up and top-down routes to emotional appraisal both depend on amygdala-mediated processes that presumably identify and encode arousing stimuli. In the bottom-up case, the arousal signal comes from properties of the stimulus, whereas in the top-down case the arousal signal comes from one's controlled appraisal of what the stimulus means in the absence of any intrinsically aversive perceptual cues.

These results fit with those from other studies that examine how other ways of manipulating top-down appraisals can modulate processing in bottom-up emotion systems (for a review, see Ochsner & Gross, 2005). For example, anticipation of pleasant or aversive stimuli (e.g., Knutson, Adams, Fong, & Hommer, 2001; O'Doherty et al., 2002; Phelps et al., 2001; Ploghaus et al., 1999; Wager, Rilling, et al., 2004) and placebo-induced beliefs (Lieberman et al., 2004; Petrovic, Kalso, Petersson, & Ingvar, 2002; Wager, Rilling, et al., 2004) have been shown to involve

recruitment of lateral and medial PFC systems in combination with modulation of amygdala, insula, and ventral striatum.

Contrasting the Up- and Down-Regulation of Negative Emotion. The basic paradigm illustrated in Figure 6.2 also has been used to ask questions about the neural systems engaged when we use reappraisal to cognitively turn up or turn down our negative emotions (Ochsner, Bunge, Gross, & Gabrieli, 2002; Ochsner, Ray, et al., 2004). Two important questions concern the relationship between the up- and down-regulation of emotion: Are similar top-down control systems engaged? And do they modulate the same bottom-up appraisal systems, albeit in different ways? One hypothesis is that both types of reappraisal rely on a common core set of control systems, including dACC and PFC, used to generate and maintain reappraisal strategies of whatever kind. These control systems could be flexibly deployed to modulate processing in the amygdala in accordance with the goal of reappraisal—turning it up or down as need be. An alternative hypothesis is that each type of reappraisal involves different types of cognitive operations and, as a result, should recruit different top-down control systems. Up-regulation may involve the elaboration and retrieval of emotional associations, which has been associated with dorsal mPFC, whereas down-regulation may involve response inhibitory mechanisms associated with right lateral PFC. To discriminate between these alternative hypotheses, we asked participants to complete three types of trials with aversive photos: baseline Look trials similar to those described previously and Increase and Decrease trials, in which participants appraised the context, affects, and outcomes depicted in photos in either increasingly negative or neutralizing ways.

Imaging results suggested that both hypotheses were correct (Ochsner, Ray, et al., 2004; see also Ochsner et al., 2002). As illustrated schematically in Figure 6.3, both Increase and Decrease (as compared to Look) trials activated left lateral PFC, dACC, and dorsal mPFC regions associated with controlled appraisal of the meaning of a stimulus. Of particular interest is the common reliance of reappraisal and—in the experiment described previously—top-down appraisal on left inferior prefrontal regions known to be important for retrieving information from semantic memory and rehearsing it in verbal working memory (Smith, Jonides, Marshuetz, & Koeppe, 1998; Wagner et al., 2001). This finding is consistent with an account of reappraisal as a deliberately constructed internal narrative that re-represents the meaning of stimuli in goal-congruent ways. In addition, both Increase and Decrease trials modulated the left amygdala, with activity enhanced during photo presentation on Increase trials and diminished during photo presentation on Decrease trials. These data suggest that there is a common functional architecture supporting different types of reappraisal.

Direct comparisons of activity on Increase and Decrease trials revealed neural systems differentially associated with each type of reappraisal.

Increase trials differentially recruited a region of left dorsal mPFC associated with accessing the affective connotations of words and reasoning about one's own or other people's affective mental states (Cato et al., 2004; Ochsner, Knierim, et al., 2004). Decrease trials differentially recruited right dorsolateral and orbitofrontal regions associated with response inhibition (Konishi et al., 1999) and with updating the motivational value of stimuli (O'Doherty, Critchley, Deichmann, & Dolan, 2003).

Converging evidence supporting these findings comes from a growing number of studies that have also begun to investigate related forms of cognitive reappraisal. In general, these studies have found that interactions between top-down control and bottom-up appraisal systems are involved when individuals maintain responses to aversive stimuli after the stimuli disappear (Schaefer et al., 2002); or when they are instructed to "suppress" sexual arousal (Beauregard, Levesque, & Bourgouin, 2001), sadness (Levesque et al., 2003; Levesque et al., 2004), or negative emotion (Phan et al., 2005) or to distance themselves from painful inputs (Kalisch et al., 2005).

Contrasting Self- and Other-Focused Emotional Appraisal. Although studies of cognitive reappraisal generally support the idea that the top-down control of emotion involves prefrontal and cingulate control systems, the precise systems recruited across studies have varied. One reason for this inconsistency could be variability in the specific kinds of reappraisal that participants have been asked to employ. If different types of reappraisal strategies involve qualitatively different types of processing about qualitatively different types of information, it might be expected that different reappraisal strategies would depend on related but distinct control systems. This possibility is consistent with results of the experiments described earlier and also is consistent with the literature on content and process specificity in PFC for different varieties of working memory (D'Esposito et al., 1999; Smith & Jonides, 1998) or episodic memory (Cabeza & Nyberg, 2000; Tulving, 2002).

To investigate this possibility, participants in the Increase/Decrease experiments described earlier were divided into two groups that achieved their emotion regulatory goals using one of two qualitatively distinct reappraisal strategies. Participants assigned to the self-focus group were asked to modulate their negative feelings by either increasing their sense of personal connection to the image (e.g., by imagining it could be a loved one or themselves depicted in the photo) or decreasing their sense of personal connection to the image by adopting a distant, detached, and clinical third-person perspective while viewing it. Participants assigned to the situation-focus group were asked to modulate their negative feelings by reinterpreting the context, affects, and outcomes of pictured persons in increasingly or decreasingly negative ways. We hypothesized that a self-focused strategy might differentially depend on mPFC systems involved in monitoring the

extent to which a stimulus is relevant to the self (e.g., Kelley et al., 2002; Ochsner et al., 2006). By contrast, a situation-focused strategy might differentially depend on lateral PFC systems involved in maintaining and manipulating perceptual information (Smith & Jonides, 1998) and in retrieving information about emotion-eliciting contexts from semantic memory (Wagner et al., 2001).

Imaging results provided mixed support for these hypotheses. On the one hand, when negative emotion was increased, there were no differences in activation between the two groups. In retrospect, a lack of difference might be expected, given the way in which my colleagues and I allowed participants to increase their negative emotion in the self-focus group. Participants in this group were asked to reinterpret the outcomes and affects that they themselves or another person could experience, which is very similar to what participants in the situation-focus group were instructed to do. On the other hand, when negative emotion was decreased, our hypotheses were supported: Self-focus participants differentially recruited mPFC, whereas situation-focus participants differentially recruited left lateral PFC.

Although other studies have yet to directly compare and contrast neural systems recruited by qualitatively different kinds of reappraisal strategies, converging evidence is emerging that generally supports the association of mPFC with self-focused (or "me"-focused) processing and lateral PFC with perceptually focused processing. For example, my colleagues and I have shown that when participants view emotionally evocative photographs, mPFC is recruited both when they are asked to appraise their own emotional reactions to the photos and when they appraise emotional states of the central characters depicted in the photos. However, greater mPFC activity is observed for self-focused appraisals, whereas greater left PFC activity is observed for other-focused appraisals. Additional support for this medial–lateral distinction comes from a study of "cold" cognitive control over working memory showing that during task performance individuals high in self-consciousness tend to differentially recruit dorsal mPFC, whereas individuals who are extroverted tend to differentially recruit lateral PFC (Eisenberger, Lieberman, & Satpute, 2005). In a broader context, although this distinction is consistent with a general role for mPFC in metacognitive processing, which by definition involves a high degree of self-awareness, it remains for future work to directly compare appraisal modes that involve internally as compared with externally focused processing.

EXTENSIONS AND FUTURE DIRECTIONS

A primary goal of this chapter is to illustrate the benefits of a social cognitive neuroscience approach by describing the ways in which it has been employed in studying the use of cognition to control the ways in which emotionally evocative stimuli are appraised. Toward that end, we built a

working model of the cognitive control of emotion whose initial formulation drew on both cognitive neuroscience and social psychological theory and that was subsequently tested using experiments that employed a social cognitive neuroscience approach. With this initial model in place, the goal of this section is to examine its implications for understanding individual differences in emotion regulatory capacities, to discuss broader questions about the relationships between emotion generation and regulation, and to consider some important questions on the research horizon.

Individual Differences: From Basic Processes to Normal and Abnormal Variation

A comprehensive model of emotion regulation should be able to account for both normal and abnormal variability. The structure of our model suggests a simple way in which such variability could be taken into account: Individuals could vary in the extent to which bottom-up processes tend to generate emotional responses and experiences, the extent to which they possess a repertoire of control strategies and effective top-down processes that can be used to implement them, or some combination of the two. By characterizing bottom-up and top-down emotion processing both psychologically and neurally, we may ultimately be able to account for the normal development of regulatory ability and its breakdown in psychiatric disorders such as depression.

Development

Consider, for example, that between the ages of 8 and 12, working memory and inhibitory capacity undergo a tremendous developmental growth spurt (Bunge, Dudukovic, Thomason, Vaidya, & Gabrieli, 2002; Nelson et al., 2000) and that at about this same time, myelination of the prefrontal cortex increases rapidly as well (Luna et al., 2001). To the extent that the control systems that support response inhibition and working memory are similar to the systems underlying the use of controlled attention or appraisal to regulate emotion, we might expect the interdependence of cognitive control and prefrontal integrity to be mirrored in the emotional domain, as well. My colleagues and I have begun investigating this issue, using the reappraisal task described in the previous section to investigate the capacity to regulate emotion in children ages 8–12, adolescents ages 13–17, and young adults ages 18–22. Initial behavioral results suggest that children have difficulty decreasing their negative emotion using situation-focused reappraisal strategies, whereas the performance of adolescents matches the effective regulation demonstrated by young adults (Ochsner et al., 2006). It remains to be seen whether children recruit different brain systems in an effort to achieve successful regulation. The results of another study examining the attempted "suppression" of sadness in 8- to 10-year-old girls may offer a

preliminary answer to this question. When told to "suppress" emotional responses to sad or neutral film clips, children engaged lateral and medial PFC, dACC, and lateral orbitofrontal cortex (Levesque et al., 2004). Although this study did not include an adult comparison group, the authors note that in a previously reported study using adults in the same paradigm they observed fewer regions of prefrontal activation. This suggests that children may need to recruit additional regions to support emotion regulatory strategies.

Dysregulation

The development of cognitive neuroscience applications to psychiatric disorders has proceeded rapidly in the past 15–20 years. For numerous disorders, PET and fMRI studies have been used to identify an underlying "pathophysiology." Initial studies simply compared resting activation in patients with resting activation in controls and identified, for example, relative hyperactivation of the amygdala and hypoactivation of left PFC in depression (Drevets, Gadde, & Krishman, 1997). A problem with such studies, however, is that they do not control the psychological processes engaged by participants, and so it is not clear exactly why resting differences are obtained in between-groups comparisons. Is the scanned environment simply more aversive for a depressed person? Are they attempting to regulate but failing to do so? It is not clear. A second generation of studies constrained the experimental setting by contrasting activation to symptom-provoking stimuli—such as negative trait words in the case of depression, or contamination-related stimuli in the case of obsessive–compulsive disorder—to activation to neutral stimuli of the same type that did not have strong affective associations. By and large, these studies have identified activations in so-called "limbic" structures involved in emotion, including the amygdala, striatum, insula, and orbitofrontal cortex, among others (Breiter et al., 1996; Liberzon et al., 1999; Rauch, Savage, Alpert, Fischman, & Jenike, 1997). Although these studies can directly relate patterns of brain activation to the presence of specific stimuli, they do not control the nature of the appraisal processes participants engage in. As a consequence, results are ambiguous with respect to whether activations do or do not reflect attempts to control the way stimuli are appraised. A third generation of studies has borrowed paradigms from the cognitive neuroscience literature that are known to isolate specific computational processes associated with specific brain systems. These paradigms have begun to identify disorder-specific dysfunction in specific types of recognition, memory, attention, inhibitory, and emotional functions (Bremner et al., 1999; Mohanty et al., 2005; Perlstein, Dixit, Carter, Noll, & Cohen, 2003; Phillips, Drevets, Rauch, & Lane, 2003a, 2003b; Russell et al., 2000).

To date, however, few published studies have investigated the use of cognition to regulate emotional responses. Given that problems with emo-

tion regulation characterize almost every mood, personality, and anxiety disorder listed in the *Diagnostic and Statistical Manual of Mental Disorders* (DSM-IV-TR; American Psychiatric Association, 2000), the importance of understanding the neural bases of emotion regulation is clear. In our own work, my colleagues and I have begun to address this question in the context of depression. Using the reappraisal paradigm described numerous times earlier, we have sought to determine whether depression involves a tendency to generate abnormally strong negative responses, a failure to generate normal positive responses, diminished ability to down-regulate negative responses, or diminished ability to up-regulate positive responses. Initial behavioral results suggest that depressed individuals may be able to cognitively reappraise negative and aversive photographs just as well as controls when using a situation-focused reappraisal strategy.

If this result holds, it raises an intriguing question: If individuals with depression are able to down-regulate their negative and up-regulate their positive emotional responses in a laboratory paradigm, then why do they experience a preponderance of negative affect in everyday life? One might speculate that there are at least two important differences between the lab and the real world. First, our typical reappraisal paradigm elicits feelings of disgust, shock, and anxiety using stimuli that are not highly self relevant and that could be expected to elicit normative negative reactions in all viewers. It is possible, therefore, that depression-relevant, and perhaps idiosyncratically selected, stimuli would pose a greater regulatory challenge for individuals with depression. Second, it is possible that a situation-focused reappraisal strategy draws on processes unimpaired by depression. A self-focused strategy that asks participants to either engage with or disengage from emotional stimuli may be more related to the kinds of self-referential thought that are hallmarks of depressive thinking (Nolen-Hoeksema, 2000; Teasdale et al., 2002). It remains for future research to directly compare individuals with depression and controls in their ability to regulate responses to self-relevant and normatively negative stimuli using self-focused or situation-focused reappraisal strategies.

That being said, it is important to note that individuals with depression are able to benefit from cognitive-behavioral therapies (Teasdale et al., 2002; Teasdale et al., 2001), which suggests that the ability to reappraise—even in negative self-referential contexts—may be intact in depression. An individual-differences analysis of data from our Increase–Decrease study suggests that this may be the case (Ray et al., 2006). In that study we asked participants to complete various measures of the tendency to ruminate, which has been associated with risk for and problems with depression (Nolen-Hoeksema, 2000). Rumination refers to the turning over in one's mind of typically aversive events with the hope of gaining some insight into them. Interestingly, the tendency to ruminate predicted greater increases in amygdala activity on Increase trials and greater decreases in amygdala activity on Decrease trials. Furthermore, when participants decreased nega-

tive emotion, the tendency to ruminate was associated with decreases in activation of mPFC regions associated with self-referential processing (e.g., Ray et al., 2005), which suggests that ruminators tended to engage in self-referential processing during the baseline Look condition. These results rather intriguingly suggest that if depression is associated with rumination and if rumination is associated with greater ability to modulate amygdala activation via reappraisal, then individuals with depression might, paradoxically, possess greater capacity to regulate emotion than do controls; their problem may be that they typically are using this capacity to make themselves feel worse rather than better.

Boundary Conditions: What Do We Mean by Emotion Regulation?

The reader may have noticed that the terms "appraisal" and "reappraisal" have been used somewhat interchangeably throughout this chapter. This flexible usage of terms has both theoretical and empirical motivations. The theoretical motivation stems from the fact that the original definition of reappraisal was meant to convey that a stimulus has been appraised a second time, thereby redirecting an emotional response that already had been generated (Lazarus, 1991). Thus reappraisal is nothing more than appraisal "done over again" in a particular context. The empirical motivation stems from the repeated finding—both in my and my colleagues' work and in that of others—that similar systems are involved in the controlled appraisal of a stimulus to generate emotion and the controlled reappraisal of a stimulus to alter an ongoing emotion. The implication of this similarity is that the differential usage of the terms "appraisal" and "reappraisal" is somewhat artificial, although it still may be useful. What is important is to realize that the typical uses of the terms are limited. In common usage, "appraisal" is used to refer to the bottom-up generation of an emotional response, whereas "reappraisal" is used to refer to the top-down regulation of that response. This chapter suggests that the conflation of bottom-up and top-down processing with appraisal and reappraisal is neither theoretically nor empirically supported and, instead, that one can think of controlled appraisal processes as serving both generative and regulatory functions.

Future Directions

Although there appears to be some support for our initial formulation of a model—or functional architecture—for the cognitive control of emotion, the questions that remain to be answered far outnumber those that already have been addressed. At least three kinds of issues are salient. First, the great majority of research on use of cognition to control emotion has used negative stimuli. Whether it involves experiencing pain, viewing an aversive photograph, or expecting that one of the two soon will occur, there has been a

decidedly sinister bent to extant research. Future work should address the relationship between the neural dynamics underlying the control of negative responses and those underlying the control of positive responses. Second, although work is beginning to investigate the ways in which types of control may fractionate into qualitatively different subtypes of control, little work has addressed this issue. It is possible, for example, that some strategies will differ in terms of the kinds of processing that are engaged in (e.g., those involving a self as compared with situation/perceptual/external focus), whereas others will differ because of the mental operations needed to transform responses to distinct kinds of stimuli (e.g., physically painful shock as compared with an aversive sound, odor, or visual image). Third, it will be important for future work to extend basic models to understanding both normal and abnormal individual differences in emotion and emotion control. Only by doing that will we be able to understand how it is that we can remove our "black masks" and see the world through the optimistic eyes of those whose appraisals permit effective emotion control.

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