

# Integration of Emotion and Cognitive Control

Jeremy R. Gray

Yale University

---

**ABSTRACT**—*Emotion is easily typecast as the nemesis of self-control. However, recent advances suggest a more nuanced view in which emotion and cognitive control are integrated, at times working in harmony. Emotional states can enhance high-level cognition, and can modulate the neural mechanisms that support cognitive control. Such an integrated neural organization might be adaptive: Emotional states could help resolve control dilemmas, facilitating the transition of the whole system into a more unified, situationally appropriate control state. This perspective is intriguing because control dilemmas are pervasive in human affairs (e.g., balancing risk vs. reward, short-term vs. long-term effects, and personal advantage vs. group advantage). Although many challenging questions remain, understanding emotion-cognition interactions at multiple levels of analysis is a realistic and exciting scientific goal.*

**KEYWORDS**—*emotion-cognition interactions; control dilemma*

---

In the heat of an emotional moment, our ability to deliberately regulate our thoughts and behavior can be diminished. And yet, emotion can sometimes be beneficial. For example, feeling angry can provide the impetus to confront a more powerful individual about a transgression. Such examples suggest that emotion and cognition are integrated, working together. If emotion has selective effects on cognitive control, enhancing some functions and impairing others, this would suggest a true integration of emotion and cognitive control. An integrated perspective is consonant in broad outline with other theoretical perspectives, including recent approaches to emotional intelligence (Salovey, Mayer, & Caruso, 2002) and self-regulation (Luu & Tucker, in press; Tomarken & Keener, 1998; Tucker & Williamson, 1984).

## WHAT IS INTEGRATION?

In trying to understand a complex system, such as the human mind or even a baseball team, a powerful scientific approach is to identify the parts that do specialized jobs. Taking each part or player in isolation is important, but it does not provide a complete understanding of the whole. How do the parts work together? How does one player function

in the context of the others? These are questions about integration, about how specifically the parts of a system influence each other.

Integration of function is in some sense the opposite of specialization of function (but specialized parts are often integrated). Specialization means that two functions are distinct or separable, like a baseball pitcher and the catcher. Integration means that two functions are not completely separable: The pitcher and catcher need to coordinate their efforts closely. They actively communicate and influence each other's behavior in highly specific ways. A baseball team is more than the people on a field; it is also their organization. In this review, I suggest that emotional states and cognitive control are on the same team, not just players on the same field; they are separable but not completely separable. But what would count as scientific evidence for such a Zen-like state of affairs?

In a study examining the effects of emotion on brain activity (Gray, Braver, & Raichle, 2002), colleagues and I elaborated a formal test for integration of emotion and cognition (or any two psychological processes). Intuitively, our operational definition of integration requires strong evidence that the whole is not just the sum of the parts. The test requires evidence that neural activity in a single brain region is influenced by two processes (e.g., by emotion and by cognitive control), but the influence of one process is ambiguous unless the other is taken into account.

Psychologically, integration is concerned with the intimacy of interactions among mental subprocesses. If the subprocesses of emotion (different emotional states) and of cognitive control (different control functions) can influence each other selectively, rather than only in a diffuse, global, or nonspecific manner, emotion and cognitive control are integrated. That is, the existence of selective interactions implies something interesting about the underlying mental architecture: Although the two systems may be largely separable or distinct, they are also inseparable, in a strong sense. They intertwine so closely that at times it is impossible to discern which is doing what, and yet both are clearly contributing to the overall function. Understanding the team requires understanding not only each player in isolation, but also each player in the context of the others.

To say that emotion and cognitive control are integrated is to say that their components, or subprocesses, can have selective effects on each other. Some organizational complexity is necessary to allow selective effects to happen. Because complexity typically comes with a price, organizational complexity is not likely to be retained unless it is useful. That is, if integration is present, it is reasonable to think that it may be functional or adaptive, and not simply incidental.

---

Address correspondence to Jeremy Gray, Department of Psychology, Yale University, Box 208205, New Haven, CT 06520; e-mail: jeremy.gray@yale.edu.

## WHY SHOULD EMOTION AND COGNITIVE CONTROL BE INTEGRATED?

One function of emotional states could be to help establish different modes of information processing (e.g., Gray, 1999, 2001; Tomarken & Keener, 1998; Tucker & Williamson, 1984). Emotional states could transiently enhance or impair some abilities but not others, doing so relatively rapidly, flexibly, and reversibly. In this way, emotional states could adaptively bias the overall control of behavior to meet situation-specific demands. Such emotion-cognition interactions would be selective, and thus require an integrated mental architecture. But what exactly would the overall system or organism gain by having an internal organization in which emotional states support different modes of information processing?

Many times, the best thing to do depends critically on the situation. Emotion might provide a modulatory bias to help resolve control dilemmas, prioritizing some cognitive abilities over others. Emotional states may be a way to convert diverse, fairly abstract contextual cues into an overall assessment of the situation and into an embodied, coordinated response, with emotion tuning the overall cognitive system to respond as effectively as possible to the situation. That is, a function of emotional states may be to modulate cognitive processing in a situation-specific way, dynamically setting processing priorities among conflicting alternatives or trade-offs. The conflicts I am referring to are not simply about which course of action to take, but about the processing dynamics of the whole system. Committing the system to a particular mode may enhance a particular constellation of functions but preclude or impair other functions. A control system flexible enough to have more than one such control state needs some way of selecting the best state to be in. Flexibility is useful in enabling the organism to fit its activity to its environment, but is a double-edged sword. Flexibility also opens the door to being conflicted, to experiencing control dilemmas.

Consider the example of conflict between short-term and long-term outcomes of a given action. If a choice involves a small but immediate cost in return for a larger but delayed gain, should you make the investment? There is a tension between short-term and long-term effects. Emotion might help tip the balance, resolving the dilemma. Using a task from the behavioral economics literature, I predicted and found that threat-related emotional states can bias people to prioritize immediate gains, even at an overall cost (Gray, 1999). Undergraduates seeing aversive images or reporting exam stress performed significantly worse than control subjects in neutral conditions (i.e., nonstressed subjects and subjects who viewed neutral images), showing a bias toward maximizing the short-term outcome. When people are genuinely threatened, they may need to choose what is better in the short term, even if it means incurring a larger long-term cost. An emotional state may help people act in what would be considered an impulsive way under ordinary circumstances.

Beyond short-term versus long-term conflict, there are many other types of control dilemmas. Consider, for example, engaging in (or approaching) a situation versus withdrawing from it when one feels both motivations at the same time, responding very quickly versus responding more accurately, paying attention to the big picture or “forest” rather than the details or “trees,” making a decision quickly and expediently versus after in-depth analysis, and trading off between self-interest and group interest (altruism). The effects of emotion on some of these forms of mental processing have been explored and

documented. However, the larger perspective—that emotion can help to resolve control dilemmas—is more general and to my knowledge has not been elaborated previously. In the next section, I review evidence for integration of emotion and cognitive control, focusing on two classes of emotion: those that involve the motivation to approach and those that involve the motivation to withdraw (Davidson, 1998).

## EVIDENCE FOR INTEGRATION OF EMOTION AND COGNITIVE CONTROL

Some emotions are like fires, seemingly started by a motivational spark to either approach or withdraw from a situation. Such emotions are action oriented, or goal directed (Carver, Sutton, & Scheier, 2000; Davidson, 1998). Subjectively, these emotions are urgent. Because they are goal directed, these emotions might influence the cognitive and neural mechanisms that support action control and goal-directed behavior, including cognitive control and parts of the brain that support it (including the lateral prefrontal cortex; Gray, 2001; Gray et al., 2002; Heller, 1990; Tomarken & Keener, 1998).

A key idea implicit in this broad perspective is that experimentally induced approach- and withdrawal-related emotional states can have selective effects on cognitive control (Gray, 2001). I tested this idea by asking participants to watch short videos (intended to induce an emotional state) and then perform a memory task on a computer. The task was like a very boring video game in which participants needed to keep a list of three items in mind. Every few seconds, participants had to update their mental list, adding a new item and dropping the oldest, and pressing a button to indicate if the one they dropped matched the new one. This task, which most people find to be quite challenging, is a test of working memory, or the active maintenance and manipulation of information in mind, and working memory is a form of cognitive control. For methodological reasons, I used verbal and nonverbal (spatial) versions of the working memory task, although the research question was not about verbal and nonverbal processing, but rather about whether emotion can have selective effects on cognitive control.

An approach-related state (amusement, induced by comedy videos) enhanced verbal working memory performance but impaired spatial working memory performance. In contrast, a withdrawal-related state (anxiety, induced by horror videos) had exactly the opposite effect. That mild anxiety actually enhanced performance on the spatial task is surprising even to many research psychologists. These results naturally lead to a further question: Why should mild anxiety enhance spatial working memory, and why should mild amusement enhance verbal working memory? The data support integration, but do not indicate why the effect should be in the direction observed (for discussion of several possible reasons, see Gray, 2001).

Moreover, the more emotionally engaged with the videos participants became, the stronger their reported emotional state and the stronger the influence on performance. Critically, individual differences in self-reported approach and withdrawal disposition, assessed by responses to a questionnaire, predicted which people would experience a particular emotion more strongly and show a stronger influence of that emotion on task performance. To my knowledge, this was the first methodologically rigorous test of the idea that induced emotional states have selective effects on cognitive control, broadly construed (including high-level, or “executive,” function).

In a follow-up study, colleagues and I provided evidence for integration of emotion and cognitive control using functional brain

imaging (Gray et al., 2002). As predicted, we found that induced emotion modulated task-related neural activity within the lateral prefrontal cortex, a region of the brain that is critical for cognitive control (Braver, Cohen, & Barch, 2002). The main finding was that some brain areas showed a selective effect: The influence of a particular emotion (amusement or anxiety, induced by the same videos as before) depended on the type of cognitive-control task (verbal, non-verbal), so the results met strict criteria for demonstrating integration. Moreover, how strongly the emotion induction modulated activity in lateral prefrontal cortex was correlated with how strongly the emotion induction modulated task performance, a finding consistent with this brain area having a causal role in influencing performance on the task. The mere existence of a region with this highly specific profile of activity and relation to behavioral performance suggests that emotional states and higher cognition are truly integrated. At some point of processing, functional specialization is lost and emotion and cognition conjointly and equally contribute to the control of thought and behavior.

### FUTURE DIRECTIONS

By drawing increasingly specific distinctions, research into the interactions of emotion and cognition is poised to make major advances. Several difficult yet tractable questions regarding emotional states, cognitive control, and their interactions are likely to receive increasing attention in psychology and neuroscience. Related work in behavioral economics, philosophy, artificial intelligence, and robotics will probably be indispensable for a complete account, with progress in one area facilitating progress in others.

A role for emotional states in the resolution of control dilemmas is a novel and theoretically attractive possibility. Empirically, it is best supported in the case of approach- and withdrawal-related emotion (Gray, 1999, 2001; Gray et al., 2002), yet emerging work suggests a wider generality. Of course, far more research is required to adequately test and delimit this hypothesis. Other functions of emotion, including affective responses to the outcomes of one's actions (Carver & Scheier, 1990; Luu & Tucker, in press), are likely to be critical as well to a complete understanding.

An integrated perspective strongly implies not only that emotion should be able to modulate cognitive control, but also the reverse: that cognitive control should be able to modulate emotion (cf. Gross, 2002; Salovey et al., 2002). It will be very interesting to explicitly examine bidirectional influences between emotion and cognitive control.

Individual differences in personality are strongly related to emotional reactivity and emotion regulation (Carver et al., 2000; Davidson, 1998; Salovey et al., 2002). Intriguingly, aspects of personality appear to be related to differences in cognitive control as well (Gray & Braver, 2002; Revelle, 1993). Such variation provides a potentially rich and relatively untapped source of information about the relationship between emotion and cognitive control.

A number of lofty yet very human aspects of mental life, including empathy, beliefs, attitudes, the self, altruism, creativity, decision making, and moral reasoning, appear to involve a true marriage of cognitive and affective abilities. That subjectively experienced emotional states and cognitive control are integrated adds still more impetus to an emerging and positive vision of human nature: Emotion is a Major League player on the team of your mind-brain-and-body.

---

### Recommended Reading

- Carver, C.S., Sutton, S.K., & Scheier, M.F. (2000). (See References)  
 Gray, J.R. (2001). (See References)  
 Gray, J.R., Braver, T.S., & Raichle, M.E. (2002). (See References)  
 Tomarken, A.J., & Keener, A.D. (1998). (See References)  
 Tucker, D.M., & Williamson, P.A. (1984). (See References)
- 

**Acknowledgments**—The preparation of this review was supported by grants from the National Science Foundation and National Institute of Mental Health. I thank Todd S. Braver and Marcus E. Raichle for related discussions, and Alexandre Schaefer and Elizabeth Christil for helpful comments.

### REFERENCES

- Braver, T.S., Cohen, J.D., & Barch, D.M. (2002). The role of the prefrontal cortex in normal and disordered cognitive control: A cognitive neuroscience perspective. In D.T. Stuss & R.T. Knight (Eds.), *Principles of frontal lobe function* (pp. 428–448). Oxford, England: Oxford University Press.
- Carver, C.S., & Scheier, M.F. (1990). Origins and functions of positive and negative affect: A control-process view. *Psychological Review*, *97*, 19–35.
- Carver, C.S., Sutton, S.K., & Scheier, M.F. (2000). Action, emotion, and personality: Emerging conceptual integration. *Personality and Social Psychology Bulletin*, *26*, 741–751.
- Davidson, R.J. (1998). Affective style and affective disorders: Perspectives from affective neuroscience. *Cognition and Emotion*, *12*, 307–330.
- Gray, J.R. (1999). A bias toward short-term thinking in threat-related negative emotional states. *Personality and Social Psychology Bulletin*, *25*, 65–75.
- Gray, J.R. (2001). Emotional modulation of cognitive control: Approach-withdrawal states double-dissociate spatial from verbal two-back task performance. *Journal of Experimental Psychology: General*, *130*, 436–452.
- Gray, J.R., & Braver, T.S. (2002). Personality predicts working memory related activation in the caudal anterior cingulate cortex. *Cognitive, Affective, & Behavioral Neuroscience*, *2*, 64–75.
- Gray, J.R., Braver, T.S., & Raichle, M.E. (2002). Integration of emotion and cognition in the lateral prefrontal cortex. *Proceedings of the National Academy of Sciences, USA*, *99*, 4115–4120.
- Gross, J.J. (2002). Emotion regulation: Affective, cognitive, and social consequences. *Psychophysiology*, *39*, 281–291.
- Heller, W. (1990). The neuropsychology of emotion: Developmental patterns and implications for psychopathology. In N. Stein, B.L. Leventhal, & T. Trabasso (Eds.), *Psychological and biological approaches to emotion* (pp. 167–211). Hillsdale, NJ: Erlbaum.
- Luu, P., & Tucker, D.M. (in press). Self-regulation by the medial frontal cortex: Limbic representation of motive set-points. In M. Beauregard (Ed.), *Consciousness, emotional self-regulation and the brain*. Amsterdam: John Benjamins.
- Revelle, W. (1993). Individual differences in personality and motivation: 'Non-cognitive' determinants of cognitive performance. In A. Baddeley & L. Weiskrantz (Eds.), *Attention: Selection, awareness, and control* (pp. 346–373). New York: Oxford University Press.
- Salovey, P., Mayer, J.D., & Caruso, D. (2002). The positive psychology of emotional intelligence. In C.R. Snyder & S.J. Lopez (Eds.), *The handbook of positive psychology* (pp. 159–171). New York: Oxford University Press.
- Tomarken, A.J., & Keener, A.D. (1998). Frontal brain asymmetry and depression: A self-regulatory perspective. *Cognition and Emotion*, *12*, 387–420.
- Tucker, D.M., & Williamson, P.A. (1984). Asymmetric neural control systems in human self-regulation. *Psychological Review*, *91*, 185–215.