Afterword: *How do emotion and cognition interact?*

Alexander J. Shackman
Department of Psychology, Neuroscience and Cognitive Science Program, and Maryland Neuroimaging Center, University of Maryland, College Park, MD USA

Regina C. Lapate
Department of Psychology and Helen Wills Neuroscience Institute, University of California, Berkeley, CA USA

Please cite as:
Shackman, A. J. & Lapate, R. C. (*in press*). Afterword: How do emotion and cognition interact? In Fox, A. S., Lapate, R. C., Shackman, A. J. & Davidson, R. J. (Eds.). *The nature of emotion: Fundamental questions* (2nd edition). New York: Oxford University Press.

Address Correspondence to:
Alexander J. Shackman (shackman@umd.edu)
3123g BPS
Department of Psychology
University of Maryland, College Park, MD 20742 USA

Emotion and cognition seem fundamentally different. Emotion is hot, bright, and quick; infused with feelings of pleasure or pain and manifesting in readily discerned changes in the body. By contrast, cognition is cold, gray, and slow; devoid of substantial hedonic, motivational, or somatomotor features. These differences in phenomenology and psychophysiology led classical thinkers and philosophers to treat emotion and cognition as distinct, often warring mental faculties. And yet the two decades since the publication of the first edition of the *Nature of Emotion* have witnessed the emergence and widespread adoption of powerful new tools for objectively assaying both the mind and the brain. What have these new data taught us about the interplay of emotion and cognition?

At the broadest level, Okon-Singer et al. remind us that emotional cues, states, moods, traits, and disorders can, and often do, influence key components of cognition, including attention, working memory, and cognitive control. Drawing on biased-competition models of cognition (Desimone & Duncan, 1995; Miller & Cohen, 2001), Pessoa suggests that affect can prejudice the competition for limited cognitive resources at virtually every level of the information-processing hierarchy, from perception to 'executive' cognition. Berggren & Derakshan argue that emotionally salient stimuli enjoy privileged access to attention and memory. Clore tells us that mood and affect confer "positive or negative value on whatever is in mind at the time;" that mood and emotion represent a kind of information that can bias judgments, evaluations, and choices in valence-congruent ways (see also Nettle & Bateson, 2012). Cools et al. make a related point, highlighting evidence that emotionally salient stimuli (e.g., emotional faces, Pavlovian cues) can bias instrumental approach and avoidance in a valence-congruent manner (i.e., positive stimuli facilitate approach and inhibit avoidance, whereas negative stimuli exert the opposite effect).

EMOTION CAN INFLUENCE COGNITION

Emotion Hijacks Attention

Several contributors emphasized the consequences of emotion for selective attention. Clore focuses on mood and affect, suggesting that a key function of affect is to capture attention and that "whatever seizes one's attention then becomes input for other mental processes." Okon-Singer et al. make a conceptually similar point: "Once lodged in working memory, threat-related information is poised to bias the stream of information processing…long after it is no longer present in the real world."

Berggren & Derakshan, Moaz & Bar-Haim, and Okon-Singer et al. focus on the perception of emotionally salient stimuli, such as faces. Staking out broadly similar positions, these authors tell us that emotional cues grab attention, that there are marked individual differences in the amount of attention allocated to such cues, and that hyper-vigilance for potentially threat-relevant information is a key feature of dispositional and some forms of pathological anxiety. Moaz & Bar-Haim and Okon-Singer et al. remind us that, in some cases, more complex patterns of initial vigilance followed by attentional avoidance have been observed. In particular, Moaz & Bar-Haim emphasize that behavioral evidence of avoidance (i.e., response time on probe tasks) has been consistently found in individuals exposed to physical threat in the laboratory (i.e., electric shock) and in the real world (i.e., rocket attack). On the other hand, Berggren & Derakshan and Okon-Singer et al. highlight electrophysiological work demonstrating that threat of shock non-specifically enhances early visual processing, consistent with heightened vigilance. Addressing this apparent impasse will require experiments that pair electrophysiology with reliable behavioral indexes of attention (Rodebaugh et al., *in press*). From a neurobiological perspective, Pessoa, Berggren & Derakshan, and Okon-Singer et al. suggest that emotion's influence on attention reflects the operation of circuits emanating from the amygdala. To this, Pessoa adds the orbitofrontal cortex and insula, cortical regions that, like the amygdala, are poised to influence the sensory processing stream via projections to neuromodulatory systems nestled in the basal forebrain. He also highlights the importance of the pulvinar and fronto-parietal network for biasing competition in favor of emotionally salient stimuli.

Emotion Sculpts Episodic Memory

Clore and Berggren & Derakshan describe several ways in which emotion can sculpt episodic memory (see also Yonelinas & Ritchey, 2015). Clore, in particular, argues that "emotion guides memory not only through attention at encoding and arousal during consolidation, but also through the way in which emotion schemas provide structure and confer meaning on events." Each emotion revolves around a distinctive antecedent or schema (e.g., loss for sadness, danger for fear; Frijda, 1994a, 1994b; Lazarus, 1994) and Clore suggests that these narratives can profoundly bias what gets stored, recalled, and inferred about emotional experiences.

Anxiety Disrupts Higher-Order Cognition

Berggren & Derakshan and Okon-Singer et al. review evidence that background states of stress and anxiety can disrupt on-going cognitive performance, including the short-term retention of information in working memory (Moran, 2016). Berggren & Derakshan emphasize that, like anxious states, anxious traits also tend to deleterious consequences for higher-order cognition (see also Derakshan & Eysenck, 2009; Eysenck, Derakshan, Santos, & Calvo, 2007). Pessoa notes that "emotion interferes with a wide range of cognitive operations because executive functions share common mechanisms – emotion acts on this common pool" of cognitive resources. He also reminds us that emotional states can have radically different consequences for cognition depending on whether the emotion is integral or incidental to on-going goals (i.e., irrelevant or relevant to on-going goals and tasks). Fear elicited by an approaching predator, for example, enhances attention to the impending danger (Davis & Whalen, 2001). In contrast, incidental states of fear or stress would generally be expected to disrupt on-going cognition and impair performance (Arnsten, 1998, 2009), as with test and examination anxiety (e.g., Beilock & Carr, 2005).

COGNITION CAN INFLUENCE EMOTION

Clore argues that reasoning and logic can be used to regulate affect. Okon-Singer et al. suggest that circuits involved in attention, working memory, and cognitive control play a crucial role in the regulation of emotion and the management of other aspects of motivated behavior, such as temptation and craving (see Question 7). Berggren & Derakshan appear to adopt a broadly similar position. Pessoa and Moaz & Bar-Haim suggest that the links between cognition and emotion are intimate and bi-directional. Along these lines, Berggren & Derakshan highlight evidence that elevated demands for cognitive resources can actually reduce the disruptive influence of threat-related cues, suggesting competition for a shared pool of attentional resources. Rolls suggests that higher-order cognitive systems can promote negative affect: "In humans, grief may be particularly and especially potent because it becomes represented in a system which can plan ahead, and understand the enduring implications of the loss" (see Question 7). Moaz & Bar-Haim and Okon-Singer et al. remind us that that attentional biases to threat-related cues are plastic, that these biases can be systematically retrained (e.g., Attention Bias Modification), and that such manipulations can have enduring consequences for both normal and pathological anxiety.

BUT 'EMOTION' AND 'COGNITION' MAY NOT BE FULLY DISSOCIABLE

An important question that emerges from the responses is whether emotion and cognition are really separable (see also the responses to Questions 1, 4, and 5). Rolls seems to adopt a traditional, dichotomous position, focusing on an emotional system and a separate reasoning system (that can generate complex, multi-step plans). Berggren & Derakshan stake out an intermediate position. From their perspective, emotion and cognition reflect separable systems, but these systems are massively interconnected and capable of extensive, bi-directional regulation. Okon-Singer and colleagues go a step further, noting that, "the distinction between 'the emotional brain' and 'the cognitive brain' is blurry and context-dependent…emotion and cognition are deeply interwoven in the fabric of the brain." Pessoa, Moaz & Bar-Haim, and Touroutoglou & Barrett adopt even more hardline positions. Moaz & Bar-Haim, for example, argue that, "a clear cut distinction between cognition and emotion is illusive…most of the relevant processes and conditions involve intricate blends that could be classified as both emotional and cognitive." Adopting a network perspective—where certain cognitive processes (e.g., vigilance for threat) tend to amplify emotional responses and *vice versa* (Borsboom & Cramer, 2013; Grupe & Nitschke, 2013)—they tell us that "cognition and emotion reflect part of a complex network that is not readily decomposable into specific sub-elements, and certainly not into the overly inclusive concepts of cognition and emotion." Likewise, Pessoa emphasizes that, "emotion and cognition interact so strongly that a demarcation between them turns out to be a fruitless enterprise." In short, there seems to be a growing consensus around the position staked out by Davidson in the first edition of the *Nature of Emotion*: "The same basic [brain] structures participate in a myriad of information-processing types. It is therefore unlikely that the neural representation of emotion will be entirely distinct from other types of processing, such as cognition. Indeed the frontal lobes have been identified as a region critically important to both emotion and cognition. This fact…implies that the [conceptual] separation between these forms of processing may be artificial" (Davidson, 1994, p. 242).

THE IMPORTANCE OF UNDERSTANDING THE INTERPLAY OF EMOTION AND COGNITION

Developing a deeper understanding of the ways in which cognition—attention, learning, and memory—and emotion influence one another is both theoretically and practically important. There is a growing recognition that many of the most common psychiatric disorders are marked by prominent disturbances of both cognition and emotion. Moaz & Bar-Haim, for example, remind us that "cognitive and emotional concepts are intertwined in the diagnostic fabric" of posttraumatic stress disorder, that prototypically cognitive and emotional treatments are both effective, and that interventions targeting one domain have positive consequences for the other. Establishing the psychological and neurobiological pathways underlying this recurrent interplay is critically important, not just for clarifying the nature of the emotion, but also for developing more effective and precise treatments for a range of debilitating mental illnesses, including anxiety, depression, and schizophrenia.

ACKNOWLEDGEMENTS

This work was supported by the National Institutes of Health (DA040717, MH107444) and University of Maryland. Authors declare no conflicts of interest.

REFERENCES

Arnsten, A. F. (1998). The biology of being frazzled. *Science, 280*, 1711-1712.

Arnsten, A. F. (2009). Stress signalling pathways that impair prefrontal cortex structure and function. *Nature Reviews. Neuroscience, 10*, 410-422.

Beilock, S. L., & Carr, T. H. (2005). When high-powered people fail: Working memory and 'choking under pressure' in math. *Psychological Science, 16*, 101-105.

Borsboom, D., & Cramer, A. O. (2013). Network analysis: an integrative approach to the structure of psychopathology. *Annu Rev Clin Psychol, 9*, 91-121.

Clore, G.L., Wyer, R.S., Dienes, B., Gasper, K., Gohm, C., & Isbell, L.M. (2001). Affective feelings as feedback: Some cognitive consequences. In L.L. Martin & G.L. Clore (Eds.), *Theories of mood and cognition: A user's guidebook* (pp. 27-62). Mahwah, NJ: Erlbaum.

Davidson, R. J. (1994). Complexities in the search for emotion-specific physiology. In P. Ekman & R. J. Davidson (Eds.), *The nature of emotion. Fundamental questions* (pp. 237-242). New York: Oxford University Press.

Davis, M., & Whalen, P. J. (2001). The amygdala: vigilance and emotion. Molecular Psychiatry, 6, 13-34.

Derakshan, N., & Eysenck, M. W. (2009). Anxiety, processing efficiency, and cognitive performance: New developments from attentional control theory. *European Psychologist, 14*, 168-176.

Desimone, R., & Duncan, J. (1995). Neural mechanisms of selective visual attention. *Annual Review of Neuroscience, 18*, 193-222.

Eysenck, M. W., Derakshan, N., Santos, R., & Calvo, M. G. (2007). Anxiety and cognitive performance: Attentional control theory. *Emotion, 7*, 336-353.

Frijda, N. (1994a). Emotions are functional, most of the time. In P. Ekman & R. J. Davidson (Eds.), *The nature of emotion. Fundamental questions* (pp. 112-122). New York: Oxford University Press.

Frijda, N. (1994b). Universal antecedants exist, and are interesting. In P. Ekman & R. J. Davidson (Eds.), *The nature of emotion. Fundamental questions* (pp. 155-162). New York: Oxford University Press.

Grupe, D. W., & Nitschke, J. B. (2013). Uncertainty and anticipation in anxiety: an integrated neurobiological and psychological perspective. *Nature Reviews. Neuroscience, 14*, 488-501.

Lapate, R. C., Rokers, B., Li, T., & Davidson, R. J. (2014). Non-conscious emotional activation colors first impressions: A regulatory role for conscious awareness. *Psychological Science, 2*, 349 -357.

Lazarus, R. (1994). Universal antecedants of emotion. In P. Ekman & R. J. Davidson (Eds.), *The nature of emotion. Fundamental questions* (pp. 163-171). New York: Oxford University Press.

Miller, E. K., & Cohen, J. D. (2001). An integrative theory of prefrontal cortex function. *Annual Review of Neuroscience, 24*, 167-202.

Moran, T. P. (2016). Anxiety and working memory capacity: A meta-analysis and narrative review. *Psychological Bulletin, 142*, 831-864.

Nettle, D., & Bateson, M. (2012). The evolutionary origins of mood and its disorders. *Current Biology, 22*, R712-721.

Rodebaugh, T. L., Scullin, R. B., Langer, J. K., Dixon, D. J., Huppert, J. D., Bernstein, A., . . . Lenze, E. J. (*in press*). Unreliability as a threat to understanding psychopathology: The cautionary tale of attentional bias. *Journal of Abnormal Psychology*.

Schwarz, N. & Clore, G.L. (2007). In E. T. Higgins & A. Kruglanski (Eds.), *Social Psychology. A Handbook of Basic Principles*. 2nd Ed. (pp. 385-407). New York: Guilford Press.

Yonelinas, A. P., & Ritchey, M. (2015). The slow forgetting of emotional episodic memories: an emotional binding account. *Trends Cogn Sci, 19*, 259-267.