Brain organization for emotion — how emotional states are implemented in our brains, and the function of different brain regions in emotion — is one of the topics of this chapter. This chapter describes neural representation of primary reinforcers (taste, pleasant touch, pain). Other stimuli are analysed to the object level before their emotional significance is assessed by stimulus-reinforcement learning; this is because it is generally a property of objects (including people) that they are associated with reward or punishment, not of edges in a scene, tones, etc. The chapter also describes learning about what is rewarding or punishing, stimulus-reinforcement association learning; and amygdala, orbitofrontal cortex, and cingulate cortex. The subgenual cingulate cortex and depression are covered. Output pathways for emotional responses to basal ganglia, including ventral striatum for learned reinforcers are also explained. The chapter also mentions the basal forebrain and hypothalamus, cholinergic pathways, and Alzheimer's disease. The effects of emotion on cognitive processing and backprojections to the cerebral cortex are also topics in this chapter.
The functions of the orbitofrontal cortex, cingulate cortex, amygdala, and other brain regions in emotion and its disorders including depression are described.

The neurology of anxiety
Jeffrey A. Gray and Neil McNaughton

This chapter reviews data from a range of disciplines and, in particular, the comparison of lesion effects with those of anti-anxiety drugs. It presents an essentially two-dimensional picture of the neurology of defense that matches the two ethological dimensions described in Chapter 2. Small defensive distances are dealt with by lower neural levels and large ones by higher neural levels following the hierarchy: periaqueductal gray; hypothalamus; amygdala/hippocampus; cingulate cortex; prefrontal cortex. Different streams within these levels control fear and anxiety, respectively.

Ventrolateral and Medial Frontal Contributions to Decision-Making and Action Selection
Matthew F. S. Rushworth, Paula L. Croxson, Mark J. Buckley, and Mark E. Walton

Recent research on action selection suggests that a useful distinction may be drawn between two systems centered on the ventrolateral prefrontal cortex (PFv) and anterior cingulate cortex (ACC). The PFv is concerned with the selection of actions in response to visual stimuli (stimulus-response mappings) and according to learned arbitrary rules. The ACC is more concerned with reward-guided action selection. This is especially the case when a judgment must be made about whether a reward is worth pursuing, given the probability that the reward will follow the action, or given the effort that will have to be exerted before the reward is obtained. Three lines of evidence supporting this contention are reviewed.
This chapter reviews data that provide critical principals that need to be explained by any theory of the septo-hippocampal system: 1) that it mediates the action of all anti-anxiety drugs; 2) memories depend on synaptic plasticity outside the hippocampus with hippocampal plasticity representing re-programming of a machine not data storage; 3) the prefrontal cortex and hippocampus process goals (where/what combinations) with the distinction between ‘stimulus’ and ‘response’ being inappropriate at their level of the nervous system; 4) the hippocampus has no necessary involvement in any aspect of goal processing but modulates such processing when there is conflict between concurrent goals; 5) frontal cortex, cingulate cortex, hippocampus, and basal ganglia all deal with different aspects of response inhibition; 6) modern theories should account for all types of data on the hippocampus; 7) the hippocampus is phylogenetically old; 8) the hippocampus contains a set of logical gates; 9, 10, 11, and 12) the hippocampus inhibits the formation of incorrect associations rather than forming correct ones by recursive processing and so modulates, but is not part of classical sensory systems; 13) the hippocampus detects mismatch between expected and actual events; 14 and 15) monoamine systems act to alter the signal-to-noise ratio of hippocampal processing, each for a different types of event; and 16) rhythmic ‘theta’ activity is important for hippocampal processing, particularly when optimum performance is required.
This chapter addresses the topic of self-control from the perspective of conflict theory, a well-studied framework for understanding the behavioral and neural adaptation effects seen during the performance of a selective attention task. We begin with an in-depth explanation of conflict theory and a review of recent literature in support of this theory. We explain how the anterior cingulate cortex (ACC) monitors for processing or response conflict and recruits dorsolateral prefrontal cortex (DLPFC) to resolve these conflicts, increasing attention to goal-related stimuli and adaptively improving behavioral performance. Next, we review alternative theories and explanations of cognitive control and compare them to conflict theory. Finally, we focus on the recent application of conflict theory to the understanding of a wide range of mental processes including emotion regulation and appraisal as well as social cognitive phenomena such as moral reasoning and attitudes, social exclusion, and cognitive dissonance. We conclude that conflict theory, a mechanistic framework originally designed to account for cognitive control functions related to attention, also shows promise in its ability to elucidate higher-level emotional and social behaviors and their associated neural activity. We propose that this model should be considered in future studies of processes related to self-control.

Orbitofrontal cortex output pathways: cingulate cortex, basal ganglia, and dopamine
Edmund T. Rolls
in The Orbitofrontal Cortex
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Item type: chapter

The medial orbitofrontal cortex projects reward-related information to the pregenual cingulate cortex, and the lateral orbitofrontal cortex projects punishment and non-reward information to the supracallosal anterior cingulate cortex. These projections provide the reward outcome information needed for action-outcome goal value dependent instrumental learning by the cingulate cortex. The orbitofrontal cortex also projects reward-related information to the striatum for stimulus-response habit learning. Via the striatal route, and further in part via the habenula, the orbitofrontal cortex provides information about rewards and non-rewards that reached the brainstem dopamine neurons, some of which respond to positive reward prediction error, and the serotonin (5HT) neurons. The orbitofrontal cortex is therefore perhaps the key brain region involved in reward processing in the brain. The orbitofrontal
cortex also has projections that can influence autonomic function, in part via the insula.

**Emotion and Decision-making Explained**

Edmund T. Rolls

Published in print: 2013 Published Online: January 2014

Item type: book

What produces emotions? Why do we have emotions? How do we have emotions? Why do emotional states feel like something? What is the relation between emotion, and reward value, and subjective feelings of pleasure? How is the value of a good represented in the brain? Will neuroeconomics replace classical microeconomics? How does the brain implement decision-making? Are gene-defined rewards and emotions in the interests of the genes, and does rational multistep planning enable us to go beyond selfish genes to long-term plans and social contracts in the interests of the individual? This book seeks explanations of emotion and decision-making by considering these questions.

**Motivational Influences on Cognitive Control: A Cognitive Neuroscience Perspective**

Hannah S. Locke and Todd S. Braver

in Self Control in Society, Mind, and Brain

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Item type: chapter

Motivation is an important component of self-regulation that helps set the effort level an organism is willing to expend to achieve a desired goal. However, motivation is an elusive concept in psychological research, with investigations typically targeting either very macro-level (e.g., effects of personality individual differences and experimental manipulations on global behavior) or very micro-level (e.g., physiological interventions targeting specific brain structures) processes. Thus, the current state of knowledge is very poor regarding the particular mechanisms by which motivation influences cognitive and neural systems to drive changes in specific components of behavior. This chapter reviews major perspectives on motivation arising from both the social-personality and neuroscience literatures, and then discuss how a cognitive neuroscience perspective might be fruitfully applied to fill the gaps between them. Specifically, the chapter reviews literature, including
our own recent work, that suggests motivational manipulations impact
brain regions associated with the exertion of specific cognitive control
functions. The chapter concludes by outlining unresolved questions
in motivation, and by suggesting directions for future progress in this
domain.

Cingulate and orbitofrontal contributions to valuing knowns and
unknowns in a changeable world
Mark E. Walton, Peter H. Rudebeck, Timothy E. J. Behrens, and Matthew F. S.
Rushworth

in Decision Making, Affect, and Learning: Attention and Performance XXIII
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Item type: chapter

The world that we and other animals inhabit is frequently stochastic,
uncertain, and changeable and it is imperative that our brains are able
to evaluate and keep track of varying contingencies. While behavioural
ecologists have long researched how animals operate in such natural
environments, investigations into aspects of higher cognition in the
psychology laboratory have tended to focus on controlled, static
situations in which the experimenter determines that some responses
are clearly more correct than others. Over the last few years, there
has been increasing interest in the roles of two parts of the frontal lobe
— the sulcal region of the dorsal anterior cingulate cortex (ACCs) and
orbitofrontal cortex (OFC) — when outcome information indicates a
need for a change in behaviour. This chapter reviews some recent lesion
and functional imaging studies that have compared the contributions
of these regions in guiding beneficial choice behaviour in uncertain,
changeable situations. In particular, it demonstrates that in such task
environments, both regions are not simply important for detecting
mistakes and updating behaviour, but instead play dissociable roles in
the continuous assessment of outcome value in terms of its relationship
with predictors in the world, with different courses of action, and the
usefulness of information to guide subsequent decision making.
This chapter reviews the cycoarchitectonic properties and connectivity profiles of the anterior cingulate cortex (ACC) and the dorsolateral prefrontal cortex (DLPFC) in the hope that it can lead to a greater understanding of control networks and how structures within these networks are interacting. It discusses the degree of correspondence in the anatomy of these areas in the human brain and the monkey brain.

Using the Stroop Task to Study Emotion Regulation

Jason Buhle, Tor Wager, and Ed Smith

The Stroop task is among the most influential experimental paradigms for the study of cognitive control. Recent variants have sought to extend the Stroop task to the study of emotional regulation. To assess these emotional Stroop tasks, it is important to distinguish between those that seek to disrupt performance purely via distraction by emotional stimuli that engage attention, from those that do so by presenting emotional information that specifically conflicts with task-relevant judgments. The emotional stimuli in distraction-based Stroop tasks typically fail to disrupt the performance of healthy adults, and recent work suggests that when inference does occur, it lags behind goal-directed processing, primarily degrading performance on subsequent trials. Although early neuro-imaging research using the emotional distraction Stroop tasks gave rise to the influential hypothesis of distinct emotional and nonemotional processing regions in the anterior cingulate cortex, subsequent research has provided limited support. Other recent evidence suggests that interference in these distraction tasks might reflect a generic transient surprise rather than inherently emotional processes. In contrast to emotional distraction Stroop tasks, studies of emotional conflict have
reported robust congruency effects, but it is unclear that the resolution of stimulus incompatibility is relevant to questions of how one controls one’s emotions. Future research with emotional distraction Stroop tasks should seek to develop variants that evince more robust effects, whereas research on emotional stimulus incompatibility should leverage previous work with nonemotional conflict Stroop variants to explore topics such as the relationship between output modality and dimensional relevancy, and the distinction between categorization and identification task goals.

Decision Making in Frontal Cortex: From Single Units to fMRI
Steven W. Kennerley and Philippe N. Tobler

in Neural Basis of Motivational and Cognitive Control

This chapter presents recent findings from single neuron electrophysiology and functional neuroimaging with respect to the role of the anterior cingulate cortex (ACC), the lateral prefrontal cortex (LPFC), the orbitofrontal cortex (OFC), and the ventromedial prefrontal cortex (VMPFC) in decision making. These findings are based on decision-making frameworks that highlight several cognitive processes such as the representation of internal states, the determination of outcome value, the adaptive coding of outcome value, the determination of action costs, linking value to action, and the integration or specialization of decision variable representations.

Neuroscience of Empathic Responding
Jean Decety

in Moving Beyond Self-Interest: Perspectives from Evolutionary Biology, Neuroscience, and the Social Sciences

Empathy, the capacity to comprehend the affective and emotional states of others in relation to oneself, has evolved with the mammalian brain and plays a critical role in social interaction. This chapter critically examines the contribution of affective neuroscience to the understanding of the mechanisms underlying empathy in humans with a particular emphasis on studies that investigate brain responses to the distress
and pain of others. Both bottom-up sensory information processing and top-down regulation and appraisal mechanisms are involved in the experience of empathy. This accounts for the fact that empathy is not an automatic process and that it can be modulated (amplified or inhibited) by various motivational, dispositional and situational factors.

Anatomical Substrates for Cognitive-Emotional Interactions
Luiz Pessoa

in The Cognitive-Emotional Brain: From Interactions to Integration

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This chapter illustrates how the brain’s architecture exhibits extensive avenues for information interaction and integration, and how its underlying structure provides the substrate for the coordinated flow of information that characterizes complex behaviors. It focuses on architectural features of several brain regions that have been linked to emotion, including two subcortical regions, the hypothalamus and the amygdala. The chapter also discusses features of the basal forebrain, a system historically linked with arousal processes, but suggested to be an important region for cognitive-emotional communication. Finally, it reviews anatomical properties of prefrontal cortex and closely related areas, including medial and lateral prefrontal cortex, orbitofrontal cortex, and the anterior insula.

Cognitive-Emotional Interactions in Prefrontal Cortex
Luiz Pessoa

in The Cognitive-Emotional Brain: From Interactions to Integration

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The chapter reviews key aspects of the current understanding of the neural substrates for cognitive-emotional interactions in prefrontal cortex based on human functional MRI studies. It is shown that cognitive-emotional interactions assume diverse forms and are not limited to mutual suppression. An emerging theme is that lateral prefrontal cortex is a focal point for cognitive-emotional interactions, which have been observed across a wide range of cognitive tasks. Importantly, whether responses in lateral prefrontal cortex (including dorsal-lateral PFC)
increase or decrease in the face of emotional manipulations varies across contexts. As argued, the direction itself (increases vs. decreases) is not diagnostic with respect to the functional nature of the interaction, for example, whether increased activation signifies more or less efficient engagement of prefrontal cortex.

A Role for Posterior Cingulate Cortex in Policy Switching and Cognitive Control

John M. Pearson, Benjamin Y. Hayden, and Michael L. Platt

in Neural Basis of Motivational and Cognitive Control

This chapter describes a model that demonstrates the role of the posterior cingulate cortex (CGp) in policy switching and cognitive control. It begins with the basic anatomy and physiology of CGp. It presents a schematic of the process by which learning, change detection, and policy switching take place. It then reviews recent evidence from single-unit electrophysiology that implicates CGp as an environmental change detector.

Social Pain

Naomi I. Eisenberger

in Social Neuroscience: Toward Understanding the Underpinnings of the Social Mind

This chapter suggests that the need for social connection is a fundamental need and that like other basic needs, a lack of social connection can feel “painful” an experience that has been termed “social pain”. It reviews two studies that utilized functional neuroimaging methodologies to examine whether the dorsal portion of the anterior cingulate cortex (dACC) is sensitive to: (1) the experience of social pain in humans and (2) cues that predict social pain in humans (“disapproving facial expressions”). A third study examined the extent to which sensitivity to one type of pain relates to sensitivity to the other, as well as whether activating one type of pain heightens sensitivity to the other. The chapter then highlights some of the extensions of this work.
by reviewing three studies that examined whether neural responses to social pain relate to and can help us understand real-world social phenomena.

**An Integrative Theory of Anterior Cingulate Cortex Function: Option Selection in Hierarchical Reinforcement Learning**
Clay B. Holroyd and Nick Yeung

in Neural Basis of Motivational and Cognitive Control

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This chapter discusses a new integrative theory of anterior cingulate cortex (ACC) function that proposes that the dorsal ACC supports the selection and execution of coherent behaviors over extended periods. It first presents the current theories of ACC function and its role in four key aspects of behavior: performance monitoring, action, reinforcement learning, and motivation. The chapter then outlines a new theory that proposes that ACC contributes to hierarchical reinforcement learning or high-level, temporally extended behaviors.

**The anterior cingulate cortex: reward-guided action selection and the value of actions**
Matthew F. S. Rushworth and Mark E. Walton

in Sensorimotor Foundations of Higher Cognition

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This chapter examines the contribution of the ventral and medial prefrontal regions of the brain, particularly the anterior cingulate cortex (ACC) and orbitofrontal cortex (OFC), in the optimal evaluation of cost-benefit decisions. The findings suggest that though the ACC may register when actions lead to errors, its function is not error detection per se. The results also indicate that ACC is critical for a representation of the average value of the reward that is based not just on the last trial but on the recent history of reinforcement associated with the action, and for integrating the benefits and effort costs associated with an action.