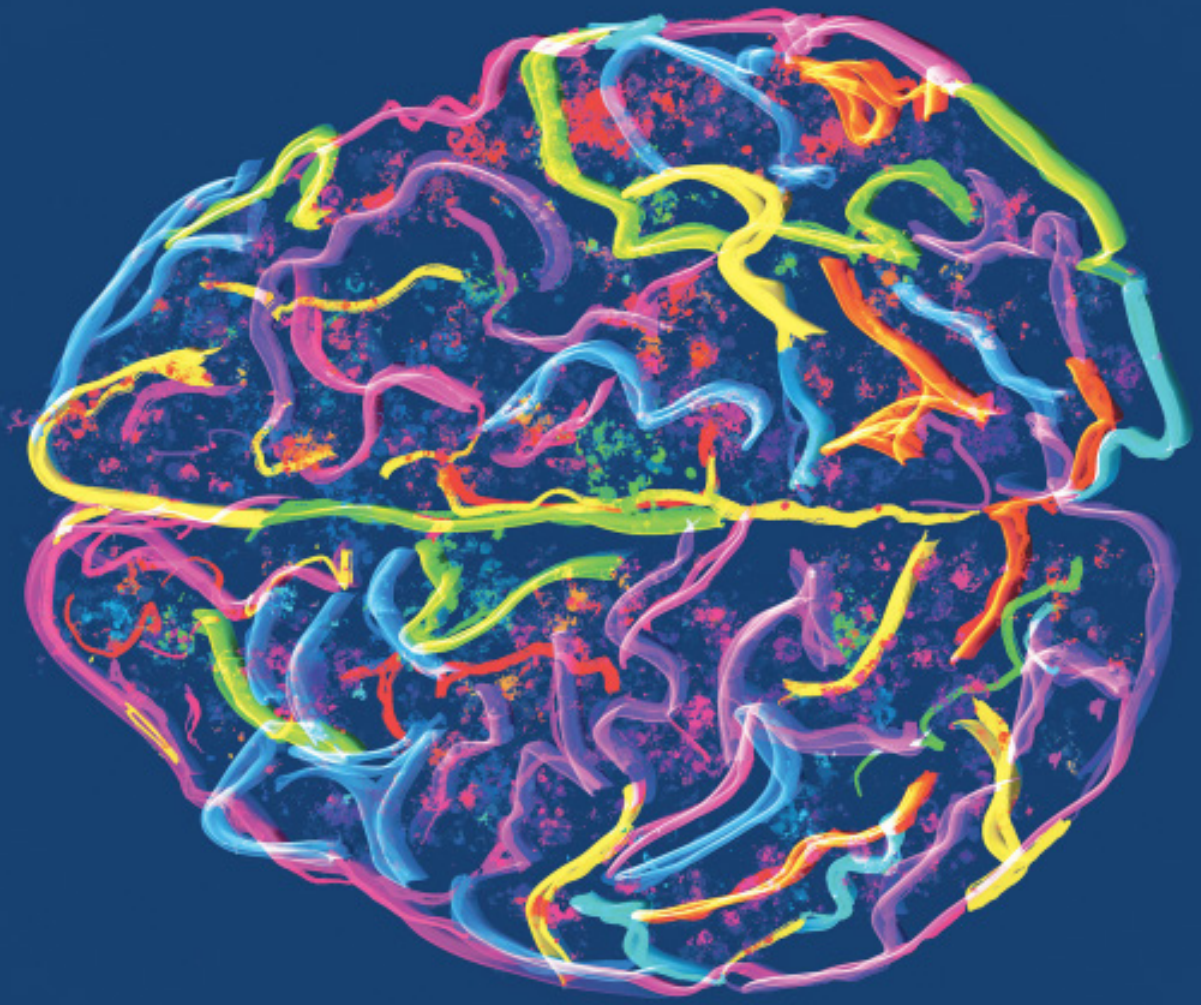
COGNITIVE NEUROSCIENCE

Fifth Edition



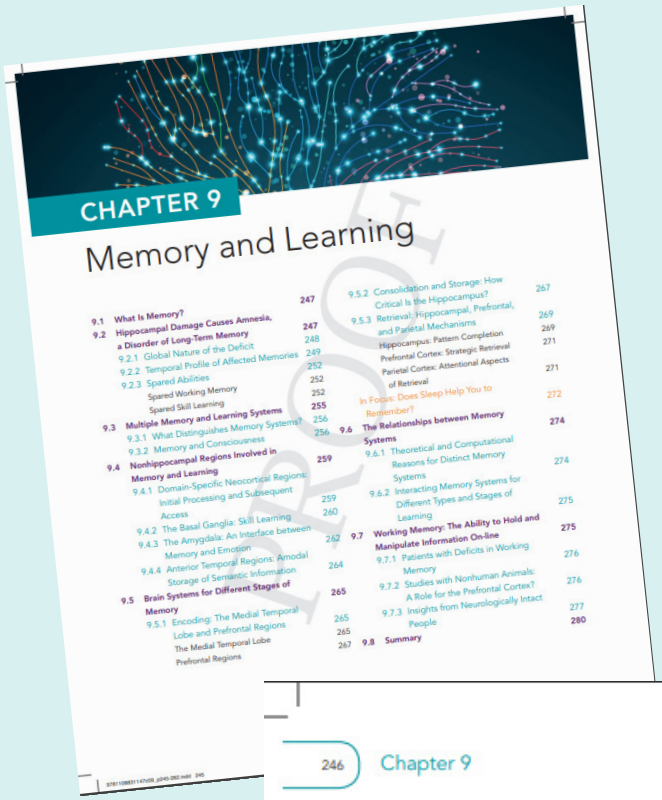
Marie T. Banich and Rebecca J. Compton

All chapters have been updated and streamlined

BRIEF CONTENTS

The chapter text has been reduced by ten percent compared with the previous edition and updated to integrate findings from new approaches, including transcranial magnetic stimulation, diffusion tensor imaging, multi-voxel pattern analyis, studies examining functional connectivity, and meta-analytic methods.

Chapters open with an outline to provide a clear conceptual structure of the contents.



CHAPTER 9

Memory and Learning

In response to a seizure disorder that could not be controlled effectively by anticonvulsant medications, in 1953 a young man underwent an experimental surgical procedure that removed portions of his medial temporal lobe that we now know are critical to memory. Although the surgery was successful in reducing his seizures, it resulted in a profound deficit in memory. From that point onward, he was unable to remember the events of his life or the people he met after the surgery, such as his physicians and other caregivers, or to learn new facts about the changing world around him. After the surgery he could not tell his age, the current date, or any aspect of his recent history, such as where he was living and how long he had lived there. His memory was no better for people in the public eye or the public events in which they figured. Such deficits persisted until his death in 2008 at the age of 82.

Nevertheless, throughout his life, he still expressed a wide range of memory abilities. He could reason and solve problems, recognize objects, and perform voluntary and reflexive motor acts appropriate to all manner of objects and situations. These abilities, along with his full range of linguistic skills, demonstrated that he could access the considerable store of knowledge that he had acquired early in life before the surgery. His ability to remember the remote past prior to his surgery seemed largely intact, as was his ability to hold information in memory temporarily while working with it, as long as he was not interrupted.

Remarkably, he was able to acquire and express a variety of new skills, such as mirror drawing or reading words presented backward. He did so despite being unable to remember that he had ever been asked to perform such tasks! Like neurologically normal people, he improved gradually with practice and his ability generalized to items he had not seen previously, such as novel backward words.

Because of the mixture of memory loss and memory retention, his life had some surreal qualities. For example, he enjoyed solving crossword puzzles and could happily do the same crossword puzzle over and over again, because he didn't notice the repetition. Although he also enjoyed watching television shows, they were difficult for him to understand because the commercials caused him to forget the story line. He could also hold a perfectly reasonable conversation, except that his conversation was devoid of current content; he could not tell you about recent weather conditions or the books that he had most recently read. If you avoided such topics, you would be hard-pressed to notice any memory deficit at all. However, if you left even for only a few minutes, upon returning he could not remember what you had been conversing about, and, most likely, could not remember having ever met you!

The patient in the opening vignette of this chapter is known in the scientific literature by his initials, H.M. After realizing the unintended effects of the operation, his surgeon, Dr. Henry Scoville, contacted Brenda Milner and her colleagues at McGill University in Montreal to unravel the mystery of his memory loss. Professor Milner discovered the divide in H.M.'s memory that we just discussed: the paradox that while certain aspects of memory were lost after removal of his medial temporal lobe, others were retained (Scoville and Milner, 1957). This work was critical in demonstrating the existence of at least two separable systems that support our ability to remember. As noted by Eric Kandel, who won the Nobel Prize in Physiology and Medicine in 2000 for his work on the molecular mechanisms of memory formation, "[t]he study of H.M. by Brenda Milner stands as one of the great milestones in the history of modern neuroscience. It opened the way for the study of the two memory systems in the brain, and provided the bases for everything that came later."

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Opening case histories pique student interest and make connections to everyday life and real people and events.

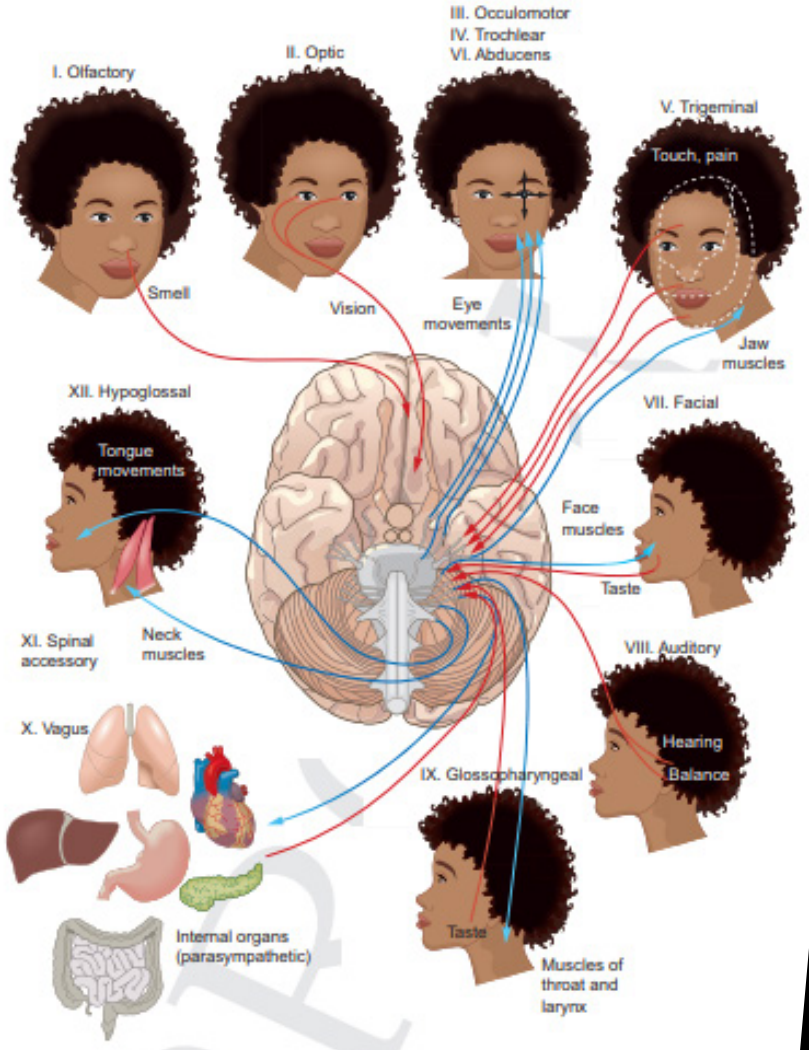

FIGURE 1.9 Locations at which the 12 cranial nerves enter (sensory) or exit (motor) the brain, and each nerve's A ventral (bottom) surface view of the brain is shown in the middle. The majority of cranial nerves enter at the medu The magenta lines represent sensory functions; the purple lines show motor functions. Some cranial nerves are sens motor only, and some are mixed.

1.4.3 Cerebellum: Fluid Movement

Located posterior to the medulla (see Figure 1.6) is the **cerebellum**, a brain region important for the regulation of muscle tone and guidance of motor activity. The cerebellum allows a pianist to play a piece of music seamlessly or a pitcher to throw a ball fluidly. Damage to the cerebellum does not result in paralysis, but instead interferes with precision of movement and disrupts balance and equilibrium. The classic test used to detect cerebellar damage is one in which the doctor asks a person to alternate between touching their own nose, and then the doctor's outstretched finger. Although a person with cerebellar damage can follow this command, the path taken by the hand from their nose to the doctor's finger will be imprecise a amd also contributes to lack of ot manifestation of temporary punch-drunk syndrome, in w ance and coordination after sustain

Although the cerebellum is traditiona structure, a specific region of the cerebe bellum, may also be linked to certain a cessing, allowing for fluidity and precisi (Stoodley, 2012). The lateral cerebellum the timing of discrete temporal interva brain's internal clocks (Breska and Ivry,

Over 250 beautiful full-colour images with robust captions help students visualize and retain key concepts, enhancing multi-modal learning.

NOTE: Pages in this sample skip between chapters to give you insight into the book's features.

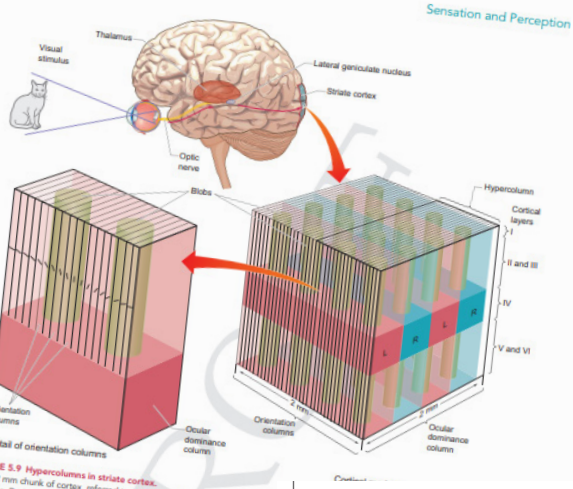

FIGURE 5.9 Hypercolumns in striate cortex.
A 2 x 2 mm chunk of cortex, referred to as a hypercolumn, contains subcolumns. Each subcolumn contains cells that are especially responsive to line right eye. Running through these columns are also "blobs," which are cluster

information from the two eyes? Another way of asking this question is to ask why we even have two eyes in the first place. The main reason for having two eyes is to enable depth perception. To reach for a cup, you need to know how far away it is so that you know how far to stick out your arm. However, the retina only records the spatial location of light patterns in two dimensions. Depth must be computed by the brain, because it is not directly coded by the retina.

One of the most important cues for depth computation is binocular disparity. **Binocular disparity** refers to the fact that the image that falls on each retina is slightly different, because the eyes are positioned in different locations. The images on the two retinas are more discrepant when objects are close to the viewer and less discrepant when they are further away. You can

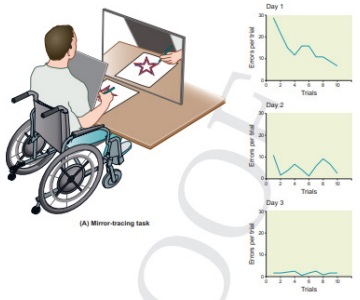

FIGURE 9.9 The mirror-drawing task, which first provided evidence for new learning in the amnesic, H.M.
(A) In this task, the person must trace between the lines of a star while looking in the mirror. (B) As shown here, the number of errors (going outside of the lines) exhibited by H.M. decreased with practice. His performance improved at about the same rate as observed in typical control participants.

general). To examine this question, they used a **mirror-reading task** (Cohen and Squire, 1980). For this task, word tricles

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neuronal spiking or activation (Masse et al., 2020)? This question of how information is maintained in working memory, and whether there may be different states or kinds of maintenance, is likely to be an area of intense research in the coming years.

However, we are still left with another question. If indeed information is accessed in working memory by reactivation of representations in the posterior cortex, then what role does the prefrontal cortex play in working memory? To solve this mystery, we need to turn back to psychological models of working memory. Beginning principally with Baddeley (Baddeley and Hitch, 1974; Repov and Baddeley, 2006), some researchers have strongly advocated distinguishing between the storage or maintenance properties of working memory and the control or executive processes of working memory. In Baddeley's model of working memory, specialized subsystems mediate the storage process, and a distinct **central executive** performs the mental work of controlling these subordinate subsystems and forming strategies for using the information they contain.

The distinction between the maintenance and manipulation portions of working memory helps to make clear at least one of the reasons that the term working memory is preferred to the term short-term memory. Working memory involves the important addition of mental "work" that is performed by the central executive above and beyond the more passive retention capability of a short-term store. Sometimes all that is demanded of working memory is the maintenance portion, such as when we have to recall verbatim the dance steps that our instructor just called out (two steps left, one step forward, one step back, two steps right). More often, though, working memory is required to do more, such as when we are preparing an ambitious meal or doing mental arithmetic.

Understanding that there is an executive, or information-manipulation, component of working memory helps to make sense

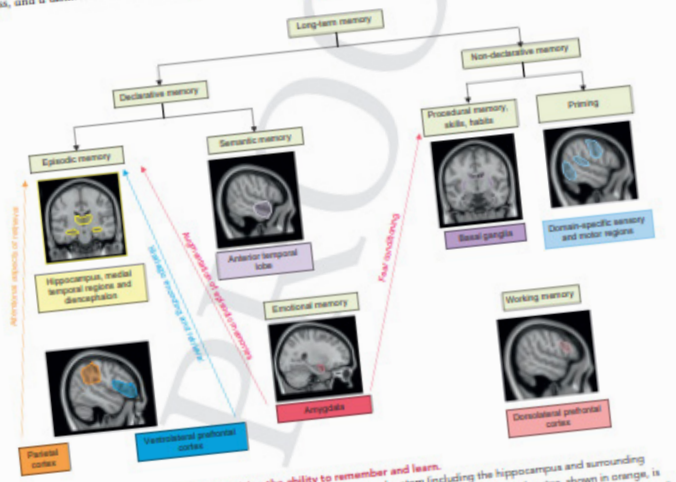

FIGURE 9.24 Network of structures underlying the ability to remember and learn.
Shown here are the major structures involved in memory. The hippocampal system (including the hippocampus and surrounding entorhinal cortex), shown in yellow, plays a critical role in declarative and episodic memory. The parietal cortex, shown in orange, is important for attentional aspects of retrieval, while the ventrolateral prefrontal cortex, shown in blue, is important for strategic encoding and retrieval of episodic memories. Anterior temporal regions, shown in light purple, are important for amodal aspects of semantic memory. The basal ganglia, shown in dark purple, has been implicated in procedural/implicit memory. Domain-specific sensory and motor regions, shown in light blue, are important for priming and domain-specific memory storage. The amygdala, shown in red, is important for emotional memory, affecting the encoding of episodic memory as well as fear conditioning. Finally, regions of the dorsolateral prefrontal cortex, shown in pink, are involved in organizing, manipulating and controlling the contents of working memory.

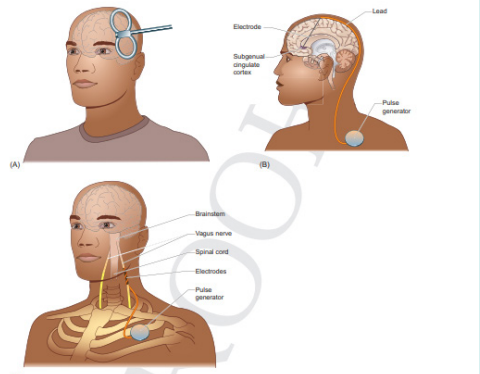

FIGURE 14.13 Some novel treatments for depression.
(A) Repetitive transcranial magnetic stimulation for depression is a noninvasive procedure that involves placing a magnetic coil over the left dorsolateral prefrontal cortex to alter activity of the brain below the coil. (B) In contrast, deep brain stimulation is an invasive procedure in which the subgenual anterior cingulate cortex is stimulated by electrodes placed within the brain. (C) Vagus nerve stimulation is a procedure in which a device placed inside the chest cavity stimulates the vagus nerve as it enters the brain.

subcallosal cingulate gyri and related structures, suggesting that the structural integrity of these regions influenced treatment response (Sankar et al., 2020).

Needless to say, implanting electrodes inside the brain is a risky procedure. Risks include complications from the surgery itself and the potential for seizures induced by the electrical current. For these reasons, it is likely that DBS will remain a treatment of last resort for patients with severe depression who have already exhausted other options, particularly as knowledge of the effectiveness of the procedure is still preliminary (Lozano et al., 2019).

VAGUS NERVE STIMULATION. Like DBS, **vagus nerve stimulation (VNS)** involves stimulation of the nervous system, but in this case the stimulated structure is the vagus nerve. This nerve carries sensory information from the internal organs – stomach, intestines, heart – into the brain, as well as carrying motor information from the brain to these organs. Just as DBS was adapted from treatments used for Parkinson's disease, VNS was adapted from treatments used for epilepsy. In the VNS procedure, a device containing stimulating electrodes is implanted in the upper chest, near the collarbone, where it can stimulate the vagus nerve before it enters the brain (Figure 14.13C). This

but not performance on a task of matching the identity of objects (Sliwinska and Pitcher, 2018).

While much research has focused on interpreting and producing facial expressions of emotion, we are also able to perceive and express emotion using other parts of the body (de Gelder and Solanas, 2021). For example, you can easily perceive the difference between someone standing in a dejected stance versus a threatening stance. As we reviewed in Chapter 6, some ventral-stream regions of the visual system, such as the extrastriate body area, appear to be specialized for processing visual information about bodies. Activity in these areas is modulated by the emotionality of the bodily expression, in conjunction with amygdala activity (Peelen et al., 2007). Moreover, perceiving bodily expressions of emotion appears to involve a wide network of regions, including motor regions involved in action observation, regions implicated in understanding the mental states of others (which we will address in more detail in the next chapter), as well as regions more traditionally associated with emotion, such as the amygdala (Buchman et al., 2018).

The studies just discussed have focused on perceiving expressions; but what about the ability to convey emotion, such as through a facial expression? Several muscles in the face seem to have evolved for the sole purpose of forming emotional expressions (Figure 12.17). Facial muscles move when they receive input from cranial nerves that are controlled by the brain's various motor systems (see Chapter 4). There are at least two systems for control of facial expressions: a system centered in the basal ganglia that controls spontaneous or automatic facial expressions, and a system centered in the motor cortex that controls voluntary facial expressions. Thus, a patient with damage to the basal ganglia (such as a patient with Parkinson's disease) may not make any facial expressions in spontaneous conversation, contributing to a mask-like appearance, but he or she may make posed facial expressions if explicitly instructed to do so or with voluntary effort.

Interestingly, the brain's right hemisphere appears to play a more important role than the left hemisphere in both perceiving and producing facial expressions. High-speed videography approaches have quantified asymmetries in the initiation of facial expressions, finding that spontaneous expressions tend to start on the left side of the face, implying right-hemisphere dominance (Ross and Pulusu, 2013). The left side of the human face also tends to express more intense emotion in static photos (Figures 12.18 and 12.19). Nonhuman primates, such as macaque monkeys and chimpanzees, also exhibit more dramatic expressions on the left side of the face (e.g., Wallez and

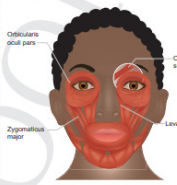

FIGURE 12.17 Muscles of the face that are used to make facial expressions.
The corrugator muscle is used to furrow the brow, as in anger or fear; the orbicularis and zygomaticus muscles are used in smiling, and the levator labii muscles are used to wrinkle the nose in disgust (Niedenthal, 2007).

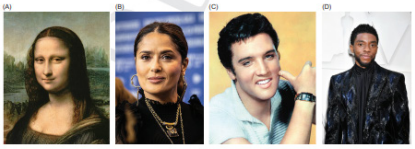

FIGURE 12.18 Striking asymmetries in facial expression of emotion.
Although we think of people's faces as symmetrical, asymmetries can be seen. Note the asymmetrical expressions on some well-known faces: (A) the *Mona Lisa*, (B) Salma Hayek, (C) Elvis Presley, and (D) Chadwick Boseman.

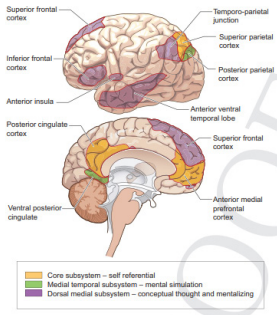

FIGURE 10.13 The main regions involved in the so-called "default network" and its division into three subsystems.
This network is involved when attention and processing are directed internally, rather than to the external world. It has been proposed to have three subsystems: a core region (shown in yellow) that allows for the processing of self-referential information; a medial temporal subsystem (shown in green) that is involved in constructive mental simulation; and a dorsal medial subsystem (shown in purple) that is involved in the process of inferring or reflecting upon the mental states of others (from Andrews-Hanna et al., 2014).

thought may be disrupted in certain populations, such as those who have mental illness. Understanding the functions of the default network, therefore, is likely to be an important topic of research in the coming years.

? **Key Question:** What are some of the network models of attentional control? How do they conceptualize the relationship between the brain regions involved?

? **Key Question:** What role in attentional control is played by the default network?

10.7 Hemineglect: Clinical Aspects

We spend most of the rest of this chapter investigating hemineglect, the syndrome described in its opening vignette. Hemineglect, sometimes referred to as unilateral neglect, is one of the syndromes in which attentional dysfunction most prominently and commonly occurs. First, we describe the clinical aspects of neglect and then we discuss how this syndrome has increased our understanding of the cognitive neuroscience of attention (Adair and Barrett, 2008; Milner and McIntosh, 2005).

10.7.1 Clinical Features

In this section we discuss the clinical features of neglect, first by describing the typical way in which this disorder is manifested. We then examine the features in a bit more detail to illustrate that the disorder cannot be explained merely as a consequence of sensory deficits, but rather reflects a disruption in attention.

Typical Manifestation

As mentioned previously, hemineglect is a syndrome in which people ignore, or do not pay attention to, the side of space contralateral to their lesion. The side of space ignored is usually defined with reference to the body midline, but neglect may occur with regard to other spatial reference frames as well (e.g., information to the left of the head's midline when the head is turned from body midline). This inattention is manifested regardless of the modality in which information is presented. Depending on the nature of the hemineglect syndrome experienced by a patient, they might fail to notice items on the left side of the world (i.e., spatial neglect), draw the left side of objects (i.e., allocentric neglect), or use the left side of

Each chapter includes an 'In Focus' box that expores in depth a specific applied issue in cognitive neuroscience, helping students see the implications of research for real life.

Key terms are introduced in **boldface** and defined in a glossary at the back of the book.

activity in this region increases in response to more abstract rewards, such as money.

The cell bodies of the third dopaminergic subsystem, the **mesocortical system**, are also located in the ventral tegmental area. The axons of these cells project to much of the cortex, especially the motor and pr ex, as well as prefrontal cortex, where they influence mental functions. These include working memory, w to keep information and executive func- including planning hine but not of other icit in these cognitive als that have had this oldman-Rakic, 1991).

As you c different regi nitive and er neurotransm actually hig noradrenalin disorder, the they are bot and choliner of new long- fusely to ma noradrenergic systems influence attention and memory. Gi these areas of overlap, some current research is desig to h understand how these various neurotransmitter syste

IN FOCUS: Can Herbs Really Improve Your Memory, Attention, and Mood?

Balm is sovereign for the brain, strengthening the memory and powerfully chasing away the melancholy.
(John Evelyn, 1699)

Although we may think that the use of herbal supplements and therapies is a new and trendy approach to treating a variety of disorders, it is actually a time-honored practice, as attested to by this quotation. Long used in traditional Chinese medicine and the Ayurvedic practices of India, herbal supplements are now being used increasingly as an alternative to standard pharmaceutical products in Europe and to a lesser degree in the United States. For example, memory problems are treated by herbalists and aromatherapists in the United Kingdom with rosemary, lemon balm (a member of the mint family), and sage, while ginkgo, derived from the leaf of the *Ginkgo biloba* tree, a plant native to China, is used there as well as in Europe, especially in France and Germany to treat dementia. St. John's wort, an aromatic perennial that is native to Europe, whose effects were known by ancient Greek and Roman physicians such as Hippocrates and Galen, is frequently used in Germany and other European countries to treat mild-to-moderate depression. Kava, derived from a shrub native to Polynesia and the Pacific Islands and traditionally taken as a beverage mixed with water and coconut milk, is used to reduce anxiety and induce calm. Do these herbs have the claimed effect on thinking and mood, and, if so, how do they work?

Much controversy surrounds the answer to this question. One source of controversy is the fact that in the United States such substances are not regulated by the Food and Drug Administration, so dosages and purity are not monitored. In at least one case, however, local use of a plant in Eastern Europe, the Caucasian snowdrop (see Box Figure 1.1), for memory problems led to a new drug to treat Alzheimer's disease. Researchers there synthetically produced its active ingredient to create galantamine, now used in European countries and the United States, which has shown to be effective in slowing the decline associated with Alzheimer's disease (Tricco et al., 2018).

BOX FIGURE 1.1 A plant, the Caucasian snowdrop, an extract from which is used to treat Alzheimer's disease. The Alzheimer's drug, galantamine, is derived from an extract from this plant, which is a member of the daffodil family. It is thought to inhibit the breakdown of acetylcholine, thereby increasing the amount of acetylcholine in the synaptic cleft. This drug is an example of ethnobotany drug discovery, in which the local use of the plant in Eastern Europe led to investigations of its actions and then synthetic production of its active compound. Credit: rsester/Getty Images.

There is evidence of efficacy for at least some herbs, especially in treating dementia and depression. It was initially reported about 25 years ago in the Western scientific literature that ginkgo special extract EGb 761 slows the mental decline of people with Alzheimer's disease (LeBars et al., 1997). Since that time a variety of meta-analyses have documented its effectiveness at doses of about 240 mg in slowing the disease in people with mild-to-moderate Alzheimer's over the course of about half a year as compared

Key Questions are placed at the end of each section to reinforce the most important concepts. Bigger-picture Thought Questions at the end of each chapter are designed to expand students' thinking to broader issues beyond the chapter content. These questions could serve as the basis for small-group discussions or could be used to elicit written responses from students.

positive emotional state can be either hig
elation) or low-arousal (calmness, conter
is a complex concept, including aspects
nomic arousal, and subjective feelings of
sity, which collectively appear to engage
systems including brainstem nuclei, str
autonomic system, and cortical regions
and default mode networks (Satpute et
arousal is clearly a key aspect of emotio
not be easily localized.

Some researchers have pursued the id
tions may have "signatures" that are bro
than tied to a single brain region or system. Studies taking this approach have used multivariate pattern analysis (see Chapter 3) in an attempt to identify patterns of brain activity that correspond with specific emotions (e.g., Kragel et al., 2016; Saarimaki et al., 2016; Touroutoglou et al., 2015). Although researchers still disagree about the best way to interpret the results of these studies (Clark-Polner et al., 2017), the results generally indicate that different emotional states are associated with unique yet highly overlapping patterns of activation. That is, different emotional states can be distinguished statistically based on their distributed patterns of brain activation, but they also share regions in common as well. For example, many emotional states are
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are integrally
processing and

comprehensive understanding of emotional experience
take into account how all these aspects of emotion are
grated within the brain.

? **Key Question:** What aspects of emotion processing appear to involve cortical rather than only subcortical regions?

? **Key Question:** What key regions do you think should be included in a summary of "the emotional brain"?

? **Thought Question:** Some people argue that emotions are harder to study than other aspects of cognition because emotions are subjective. Do you agree or disagree? Why?

? **Thought Question:** We often hear the distinction made between emotional thought versus rational thought. Is there a clear dividing line between emotion and reason? How does that distinction relate to the aspects of emotional processing covered in this chapter?

Chapter summaries allow students to review the material learned or preview what is to be discussed.

12.3 SUMMARY

Subcortical Contributions to Emotion

- The hypothalamus mediates some of the physiological phenomena associated with emotional states, such as changes in the autonomic nervous system and endocrine function that are associated with fleeing or fighting.
- The amygdala is involved in learning the emotional significance of information and in producing a quick, instinctive, emotional response. The amygdala can also influence how attention is directed to emotionally significant events.
- The ventral striatum, or nucleus accumbens, is important in reward-seeking behavior. It is especially responsive to unpredicted rewards and becomes active when a person is anticipating a reward.

Cortical Contributions to Emotion

- The insula is involved in representing internal body states that are relevant to emotion. It is also important for the coding for unpleasant tastes, and also plays a role in the experience and perception of disgust.

Now in its fifth edition, this accessible yet thorough text highlights the most important theoretical, conceptual, and methodological issues in cognitive neuroscience. Written by two experienced researchers who excel at teaching, the consistent narrative ensures that concepts are linked across chapters, and the careful selection of topics enables readers to grasp the big picture without getting distracted by details.

- Introduces the fascinating intersection of brain and cognition, and explores how the brain supports mental functions such as perception, memory, language, attention, emotion, and social cognition
- Relates the material to real-world concerns through use of examples within the text, focus on clinical applications – such as developmental disorders, brain injuries and dementias – as well as opening case studies and 'In Focus' boxes
- Develops the critical thinking skills needed to evaluate future developments in a fast-moving field
- Summaries at ends of chapters consolidate knowledge of key points

New to this edition

- All chapters have been updated and streamlined so that readers can quickly grasp key concepts
- 'Key Questions' are interspersed throughout each chapter to identify and review concepts, and 'Thought Questions' are provided at the ends of chapters to broaden critical thinking
- The illustration program has been updated to improve the consistency of visual motifs, and now includes more conceptual diagrams and figures to highlight major ideas
- The online resources have been expanded, with further reading and video links for every chapter

"I highly recommend this book! It is wonderfully engaging, with case studies, logical progression of topics, effective questions and summaries, and complex, yet accessible, material."

BJ Casey, *Barnard College, Columbia University*

"Banich and Compton captivate their audience with interesting case studies, compelling examples, and beautiful figures. A 'must-read' to learn more about mind and brain!"

Jessica Andrews-Hanna, *University of Arizona*

"The revised and updated version of this textbook nicely presents a comprehensive treatment of key topics in an easy-to-read and thought-provoking approach."

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