items, there is an important distinction between constructing familiar versus novel sequences; the operation of the PFC is sensitive to this distinction, as indicated by the fact that frontal-damage patients are far more impaired on generating a novel sequence than a familiar one.

Think Critically
- When might it be advantageous to code for order by using the relative familiarity of the items?
- What is the difference between sequencing and coding order?

6. What is involved in monitoring our performance “on-line”?
Work on monitoring as an executive process has followed two lines of research. One focuses on monitoring the contents of working memory; the PFC is clearly involved. The other focuses on monitoring for errors, a process that has been well studied in behavioral experiments. In addition, ERP and fMRI studies suggest that such monitoring is extremely rapid, occurring within 100 milliseconds of the response, and that the process is mediated by the anterior cingulate.

Think Critically
- Is there any difference between monitoring the contents of working memory and attending to the contents of working memory?
- What are some of the advantages of being able to monitor for errors on line?
In September 11, 2001, two planes crashed into the two buildings of the World Trade Center in New York. You watched television that day as the images were played over and over, and you clearly remember seeing both buildings hit. But you didn’t see that there was a video available of the first plane until the next day. Emotion interacts with memory.

You’re driving on a highway. All of a sudden there are brake lights ahead of you as far as you can see and traffic has slowed to a creep. A wrecker passes on the shoulder, and you realize there’s been an accident. You’re scornful of the rubbernecks who are causing the delay by their ghoulish curiosity. After half an hour, you’re at the crash site. Although the road is clear, you, too, pause to stare before driving on. Emotion interacts with attention.
You know that the odds favor the house, but the thrill and the excitement of the possibility of a big payoff overcome common sense. You bet the ranch. Emotion interacts with decision making.

These common scenarios emphasize the importance of emotion in understanding a range of cognitive processes. In this chapter we discuss what is known about the interaction of emotion with cognition. We specifically address five questions:

1. How have researchers defined emotion to allow scientific investigations of the interaction of emotion and cognition?
2. What techniques are typically used to manipulate and measure emotion in the laboratory?
3. What are the means by which stimuli can acquire emotional properties and how is this emotional learning expressed?
4. How does emotion alter our ability to remember?
5. How does emotion change attention and perception?

1. THE CONNECTION

In spite of the intimate relationship between emotion and cognitive processes, which we often experience consciously—"I was so furious," we say, "that I couldn't think straight"—emotion was not considered an appropriate domain of inquiry within the study of cognition until very recently. Why has it taken so long for the study of cognition to include the exploration of emotion?

The idea, no longer tenable, that emotion and cognition are distinct and separable mental activities can be traced back to early philosophical thought. Plato, for example, believed that human beings have three "souls," corresponding to three aspects of human nature: the intellect, the will, and the emotions. The influence of this early philosophical thought laid the groundwork for debates over the centuries about cognition and its relation to emotion.

In modern times, the study of cognition has been greatly influenced by the development of the computer—so much so that we speak of the "cognitive revolution" to describe the new way of thinking about cognitive processes that was based on the model of the computer (as discussed in Chapter 1). The computer provides a useful tool, but it is obvious that studying human information processing solely by analogy to a technological device leaves little role for emotion. Thus, both historically and in contemporary work, the prevailing models have left little room for the investigation of the connection between emotion and cognition. Nonetheless, the link between emotion and cognition is undeniable, and some psychologists have sought to explore this nature. One of the more recent debates (in the 1980s), which opened the door for further investigation of the interaction of emotion and cognition, involved the question of whether or not an emotion could be experienced without cognitive appraisal (an interpretation of the reason for your feeling). On one side was research showing that emotional stimuli presented subliminally, without the participants' awareness,
nonetheless influenced the way participants evaluated subsequent neutral stimuli (Zajonc, 1980, 1984). From this the investigator, Robert Zajonc, argued that affective ("affect" is a general term that includes emotions and preferences) judgments, such as how much you like a particular painting, occur before, and independently of, cognition. The other position, championed by Richard Lazarus (1981, 1984), held that emotion could not occur without cognitive appraisal. Sweating and an increased heart rate, both signs of arousal, may occur when you watch a horror movie, talk to someone you find attractive, or work out at the gym; but in each case your appraisal of your emotional response would very likely be different. Thus, your emotional response—disgust, say, or joy—depends on the reason you experience arousal, and this determination is part of cognition (Schacter & Singer, 1962). Zajonc, then, argued that emotion can occur independently of cognition, and Lazarus believed that emotion depended on a subset of cognitive processes; their writings helped to draw researchers' attention to the interaction between emotion and cognition.

But the single most influential factor in this new focus is our growing understanding of the neural systems underlying emotion. It now appears, from neuroimaging and other brain-based studies, that some brain structures are more or less specialized for processing emotional stimuli. One of these is the amygdala, a small, almond-shaped structure in the medial temporal lobe just anterior to the hippocampus (LeDoux, 1996) (Figure 8-1). This research is consistent with the idea that there are separate systems for emotion. However, these neural structures specialized for

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**FIGURE 8-1** The amygdala

The amygdala is centrally involved in the processing of emotional stimuli. Although the ancient Greeks and Hebrews (as well as the Elizabethans) believed the liver to be the seat of the emotions, the modern view is different.
emotion both influence, and are influenced by, neural systems known to be important for cognitive behaviors (Dolan, 2002; Ochsner et al., 2002); the inference is that emotion and cognition are interdependent.

It is no longer considered ideal to study emotion without considering cognition and vice versa. The neural systems, and behavioral expression, of emotion and of cognition are interdependent in many circumstances. The understanding of cognition is incomplete without exploration of the role of emotion.

Comprehension Check:

1. In what sense is the relationship between emotion and cognition a very old question? In what sense is it new?
2. What is the key difference between Lazarus’s and Zajonc’s positions?

2. DEFINING EMOTION

Many have argued that the essential appeal of the arts is the subtlety and power with which emotion can be expressed by the artist and evoked in the spectator—it is the essence of Aristotle’s conception of tragedy. Shakespeare certainly knew the intrigue of complex emotional lives; his aim, in his words, was “to hold, as ’twere, the mirror up to nature,” and he portrayed those emotions in his plays. A great opera combines dramatic scenarios and sublime music to heighten the emotional experience of the audience. And a great rock song does more than get your feet tapping—it also tugs at your emotions. All of us, not just our artists, have a rich vocabulary for describing our emotional lives: joy, elated, contented, delighted, cheerful, pleased, jovial, exultant, glad, blissful all describe subjective variations of the experience of “happiness.” Art and language emphasize the complexity and subtlety of emotion. But how can we define emotion in a way that captures the range of emotional experience, yet is objective and therefore can allow scientific investigation?

Researchers and philosophers have struggled with this problem. Although no one has found a way to measure the individual experiences, a single definition of emotion is elusive (Russell, 2003). Thus the term emotion has been used to refer to mental and physical processes that include aspects of subjective experience, evaluation, and appraisal, motivation, and bodily responses such as arousal and facial expression. For the purposes of this chapter (adapted from Scherer, 2000), we will use the term emotion when referring to a relatively brief episode of synchronized responses (which can include bodily responses, facial expression, and subjective evaluation) that indicate the evaluation of an internal or external event as significant. Emotion refers to a range of reactions to events that are limited in time, such as experiencing joy, fear, or sadness in response to hearing some news. Mood, on the other hand, is used to refer to a diffuse affective state that is most pronounced as a change in subjective feeling. Moods are generally affective states of low intensity but relatively long duration.
sometimes without any apparent cause, such as a spontaneous feeling of gloom or cheerfulness. Two related concepts are attitudes and motivation. Attitudes are relatively enduring, affectively colored beliefs, preferences, and predispositions toward objects or persons, such as like, love, hate, or desire for a person or object. Finally, motivation refers to the propensity to action that is a component of some affective responses. When you watch a horror movie, at fearful moments you may hide your eyes to escape the image on the screen. A primary function of emotion is to motivate action (if the image on the screen had been real, your action in response might have been of larger scale, and you might have survived to see another day).

In an effort to establish a scientific framework for the investigation of emotion, researchers have focused on various aspects of affective experience (facial expressions, feelings of arousal, motivation), attempting to capture a range of emotion responses such as sadness, fear, and happiness. The two main current approaches classifying the range of emotional states are the attempt to define basic emotions and the attempt to explore their dimensions. Each approach is more or less useful, depending on the question being asked.

2.1. Basic Emotions

In his groundbreaking work “On the Origin of Species” (1859), Charles Darwin was one of the first to propose that there are a limited number of basic and universal human emotions. He derived this idea in part from colleagues who had studied different cultures around the world. When Darwin asked them about the emotional lives of people far removed from Western culture, they all reported similar emotional facial expressions. Darwin suggested that this universality of emotional expression implies a common emotional experience.

Nearly a hundred years later Paul Ekman and his colleagues studied the facial expression of emotion and suggested that there are six basic expressions of emotion, corresponding to anger, disgust, fear, happiness, sadness, and surprise (Ekman & Friesen, 1971) (Figure 8-2). Each of these expressions is characterized by a unique subset of facial muscle movements, and the ability to convey them appears to be innate. Infants display these facial expressions, as do people who have been blind since birth and so never had the opportunity to mirror them. These facial expressions appear to be universal and similar in range, appearance, and interpretation whether you are from Papua, New Guinea, or Buffalo, New York. More recently, researchers interested in the detection of deception have taken advantage of this detailed knowledge of characteristic muscle movements corresponding to genuine facial expressions to help determine when someone is lying (Gladwell, 2002).

Using these social, emotional facial expressions as stimuli in experiments, researchers have started to study the neural systems underlying the perception of basic emotional expressions. It has been shown that certain neural systems seem to be specialized for the perception of specific emotional expressions. For example, there are reports of patients with bilateral damage to the amygdala who have a specific deficit in the perception of expressions of fear (Adolphs et al., 1999). More recently,
other neural structures—the insula and basal ganglia—have been shown to underlie the perception of disgust (Calder et al., 2001), and a neurotransmitter system (activated by dopamine) and a neural structure (the ventral striatum) are important for the perception of expressions of anger (Calder et al., 2003; Lawrence et al., 2009). Although there is not yet a complete understanding of the specific neural representations that underlie the perception of each of the six basic emotion expressions defined by Ekman, this research supports the idea that there are in fact distinct basic emotions, emotional reactions that are universal across cultures. However, it is important to acknowledge that Ekman’s six basic emotions do not capture the range of human emotional experience. Several more complex emotions, among them guilt and love, are less clearly linked to specific facial displays.
2.2. Dimensional Approaches

Dimensional approaches to the exploration of emotion seek to classify the range of emotional states on certain specific scales. Our emotions are not "on" or "off," but are experienced on a continuum. The two primary dimensional approaches used by researchers emphasize, and attempt to measure, different aspects of emotional experience.

2.2.1. The Circumplex Model

Arousal is the overall term for the bodily changes that occur in emotion, such as changes in heart rate, sweating, and the release of stress hormones in response to a stimulus—the changes in your physical self when you're watching a horror movie or asking for a date. The intensity of the emotional reaction may be assessed by the strength of these responses. Valence, on the other hand, is the subjective quality, positive or negative, of the emotional response to a specific object or event. Both these dimensions can be put on scales: you can be asleep, relaxed, or highly excited, you can be极大地 pleased, indifferent, or highly turned off—and anything in between.

The circumplex model of emotion puts "arousal" on one axis and "valence" on the other (Barrett & Russell, 1999; Russell, 1980). "Arousal" refers to both the strength of the response to a stimulus and to activation, that is, the mobilization of resources. "Valence" (or "evaluation") reflects the degree to which the experience is pleasant or unpleasant. Using these two dimensions of emotional experience, the circumplex model creates a graphic framework in which a range of emotional states can be positioned. For example, "sadness," "fear," "excitation," and "nervousness" are considered discrete emotional states. These could be understood as varying along the dimensions of arousal and valence. "Sadness" and "fear" are both unpleasant, but "sadness" is not as arousing or activating as "fear." "Excitement" and "nervousness" are both arousing states, but "excitement" is relatively positive and "nervousness" is relatively negative. As more emotional responses are plotted, the reason for the name of the model becomes clear: the data fall in a circular pattern (Figure 8-3).

The dimensions of arousal and valence may have distinct representations in the human brain. For instance, one study examined brain activation patterns that result from the presentation of olfactory stimuli (A. K. Anderson et al., 2003). The amygdala responded primarily to the intensity of the smell whether it was pleasant or unpleasant to the participant, whereas different subregions within the orbitofrontal cortex (OFC) responded when the smell was either pleasant (medial OFC response) or unpleasant (lateral OFC response), regardless of the stimulus intensity. These results suggest that the amygdala, which also is important in our perception of expressions of fear in others, may code several different aspects of emotional experience.

2.2.2. The Approach–Withdrawal Distinction

Emotions may be classified along the dimension of motivation, which can be conceptualized as the propensity to action that is a component of some emotional
FIGURE 8.3 The circumplex model of emotion
This graph, on which arousal is plotted on the vertical axis and valence on the horizontal, permits the depiction of a range of emotional status. The basic emotions are noted in boxes.

responses. Different emotions lead to different goals for action. Some, such as happiness, surprise, and anger, are referred to as “approach emotions” in that they evoke the desire to approach the stimulus object or situation. In contrast, others—sadness, disgust, and fear—are referred to as “withdrawal emotions” in that they evoke the desire to withdraw from objects or situations linked to these emotions. The approach–withdrawal model characterizes the component of an emotional response that is the propensity to action—that is, motivation—as either a tendency to approach the object, event, or situation or to withdraw from it. Davidson et al. (2000) have provided evidence that there is a cerebral asymmetry in the neural representation of approach and withdrawal tendencies. Using EEGs, these investigators found that participants varied in the relative level of activity of the anterior left and right cerebral hemispheres when at rest, and linked this asymmetry to their various
Participants with greater activity in the left anterior frontal region at rest (measured by EEG) rated themselves higher on "approach" traits such as enthusiasm, pride, and attentiveness. Those with greater activity in the right anterior frontal region rated themselves higher on "withdrawal" traits such as irritability, guilt, and fear. The rating scale is the Positive and Negative Affect Scale (PANAS); whether approach (positive affect) or withdrawal (negative affect) traits are being rated is shown on the horizontal axis.


dispositions. Participants who rated themselves higher on a series of positive affective traits such as enthusiasm, pride, and attentiveness ("approach" traits) showed relatively greater EEG activity over the left anterior frontal region at rest, whereas those who rated themselves higher on negative affective traits such as irritability, guilt, and fear ("withdrawal" traits) showed relatively greater EEG activity over the right anterior frontal region (Figure 8–4).

This asymmetry also reflects emotional responses. In an intriguing study with infants, researchers found that infants with more dominant right-hemisphere EEG activity at rest were more likely to cry and fuss when separated from their mothers in comparison to infants with more dominant left-hemisphere EEG activity (Davidson et al., 2000). Although all healthy people are capable of both approach and withdrawal dispositions and emotional responses, the relative frequency and intensity of these emotional reactions in a given person may be related to the relative baseline asymmetry in the activity of the anterior right and left cerebral hemispheres.

**Comprehension Check:**

1. What evidence is used to support the idea that there are basic emotions that are universal across cultures? What are these basic emotions?
2. Describe an emotional reaction that would result in an approach response and another that would be linked to a withdrawal response.
3. MANIPULATING AND MEASURING EMOTION

As social animals, we often try to manipulate and measure the emotions, moods, and attitudes of those around us—that is what we are doing when we try to comfort a grieving friend or reassure a frightened child. But although manipulating and measuring affect is a part of human experience, it is a challenge to do so in a manner that can be assessed objectively and reliably. Researchers interested in emotion have met the challenge by using a number of techniques.

3.1. Manipulation by Mood Induction

As mentioned earlier, mood is a more stable and diffuse affective state than emotion, longer lasting and not necessarily linked to a specific event or object. In research, one method that has been used to manipulate affective experience is to change the participant’s mood. This technique, called mood induction, focuses on changing the baseline state reported by the participants on arriving at the laboratory. Typical means of changing a participant’s mood are to show the participant affective film clips (hilariously funny or grim and despairing, depending on the change sought by the experimenter), to play music (again, upbeat or solemn), or to ask the participant to focus on affective situations, real or imagined, that result in either positive or negative mood states. Mood induction is considered successful if the participants report a shift of mood in the predicted direction.

3.2. Manipulation by Evocative Stimuli

The most common laboratory technique used to manipulate emotion (as opposed to mood) is the presentation of emotionally evocative stimuli. Typical stimuli used to elicit emotional responses in participants are pictures of faces with different emotional expressions; pictures of emotional scenes such as an appealing baby or a very unappealing muzzle of a revolver (Figure 8–5); words that vary in valence, arousal; money; loud noise; and mild shock. By presenting participants with stimuli that evoke emotional experiences, investigators can explore the impact this emotional experience has on mental and physical behaviors and neural responses.

3.3. Measuring Emotion Directly

How would you know whether you were being successful in your attempt to comfort a sad friend? You might simply ask: “How are you doing now?” Or you might look for an emotional reaction, such as a smile or the end of tears. Probably the most common technique used to assess affective states or responses, both inside and outside the laboratory, is self-report. If we want to know how someone feels, we ask. This is a form of direct assessment, in that participants explicitly report their emotional reaction, mood, or attitude. Although this is an often-used method for assessing affective states, it relies on introspection and is affected by cultural conventions.
Therefore, it is important to have a way to measure an affective reaction by *indirect assessment*, that is, by means independent of subjective report and language.

### 3.4. Measuring Emotion Indirectly

One way of making an *indirect assessment* is to ask the participant to choose among different options on the assumption that an emotional assessment of the options partly determines the choice. A second indirect measure of emotional assessment is the inhibition or facilitation of a behavior, such as response time or eye movements. The pleasure of seeing a joyful reunion between friends in the yard outside your classroom may cause you to linger your gaze and be slow to respond to a question. Emotion can influence our actions and the ease with which we respond by both inhibiting and facilitating behaviors.

A third technique of indirect assessment makes use of psychophysiology, the study of the relationship between mental states and physiological responses. One of the primary ways that emotion differs from other mental processes is that emotion typically results in substantial changes in our physical state. As described in Chapter 1, the autonomic nervous system, part of the peripheral nervous system, is concerned with maintaining the body's internal environment. Its sympathetic branch, which prepares the body for action in the face of, say, a threatening event, may become more activated and initiate a number of physiological responses, including pupil dilation, sweating, and increased heart rate and blood pressure. Correspondingly,
the parasympathetic branch is dominant when the threat is past, and the body is at rest; its functions, which essentially conserve energy, such as by slowing heart rate, can also be measured (Figure 8–6). An underlying emotion may also be reflected in reflex responses and facial muscle movements. All these bodily responses can be assessed with psychophysiology.

Two important psychophysiological responses assessed by researchers interested in emotion are the skin conductance response and the potentiated eyeblink startle.

The skin conductance response (SCR) is an indication of autonomic nervous system arousal. Even a subtle emotional stimulus can produce a response from the sweat glands (controlled by the autonomic nervous system). The increased sweating creates

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**FIGURE 8–6 The autonomic nervous system**

The sympathetic branch prepares the body for action: the parasympathetic branch counteracts this sympathetic branch and maintains the body equilibrium at rest.

a change in the electrical conductivity of the skin. The SCR is assessed by placing electrodes on the participant’s fingers; the electrodes pass a small electrical current through the skin. Changes in resistance to the current, which occur with subtle changes in the sweating, are measured. You may already be familiar with the SCR because it is typically used as a component of the lie detector. Because it is often assumed that there is an emotional reaction related to guilt or anxiety when telling a lie, answers to questions that are known to be true (for example, your name or address) should yield less of an SCR than answers that are not true.

The strength of the startle reflex, the response that follows a sudden and surprising stimulus such as a sudden loud noise, can be measured. If you are walking down a relatively quiet street at midday and suddenly hear a car backfire, you might be startled. If you hear the same sound late at night on a deserted street when you’re already feeling a little anxious, you might startle even more. Startle is a reflex that is potentiated, or enhanced, when we are in a negative emotional state. The degree of potentiation can be measured in the laboratory by examining the strength of the eyelink response, a component of the startle reflex. The strength of this response is measured by electrodes placed on the skin over the eye muscles. The amount of muscle contraction reflects the strength of the startle reflex. We blink harder when startled more, which is called a potentiated eyelink startle. A researcher interested in a participant’s emotional responses to different scenes might present the scenes one at a time and unexpectedly present a loud click or popping noise. The difference in the strength of the potentiated eyelink startle to the sound provides information about the emotional state evoked by the different scenes. Scenes that are more negative elicit a stronger startle reflex response than scenes that are neutral or more positive (Lang et al., 1990).

One of the interesting distinctions between SCR and potentiated startle measures is that the SCR reflects arousal that can occur in response to both negative and positive stimuli, whereas the startle reflex is modulated by valence—that is, it increases when the participant is in a negative emotional state and decreases when the participant is in a positive emotional state. Both measures provide an indirect, physiological assessment of an emotion, but they differ in the type of emotional information they register.

Comprehension Check:

1. Describe a technique that can be used to manipulate emotion in the laboratory.
2. Give an example of a direct assessment of an emotional response and an example of an indirect assessment of an emotional response.

4. EMOOTIONAL LEARNING: ACQUIRING EVALUATIONS

Why do you like some movie genres and not others? Some brands of soap and not others? Some kinds of people and not others? In this discussion, the supposedly rational answer—in the case of movies, “because I enjoy the special effects”—does
not suffice. What underlies these preferences? Here's another instance: have you ever felt uneasy, for no good reason, around someone you barely knew—and then realized that the person reminded you of someone who had once done you harm? What underlies this emotional reaction?

All these instances involve emotional learning—learning, one way or another (and not always on the basis of fact), that people, places, and things are not all neutral but often acquire some kind of value. Some people, places, or things are better or worse, comforting or scary, or simply good or bad. This value determines, in part, our emotional reaction to the person, place, or thing.

Some emotionally evocative stimuli are inherently positive or negative; there is no need to learn their value. A mild shock is aversive to all animals, from family pets to Nobel laureates. These types of stimuli are called primary reinforcers because their motivational properties occur naturally and do not need to be learned. Other stimuli are motivating only because we have learned that they represent positive or negative consequences. A bathtub full of hundred-dollar bills will not keep you warm (or at least not very warm), taste good, or provide safety—nonetheless, a bathtub full of hundred-dollar bills would be very nice to have. Money has value because we have learned to associate it with stimuli that are inherently motivating; with money we can buy things that keep us warm, taste good, and provide safety. Money is a classic example of a secondary reinforcer, a stimulus whose motivational properties are acquired through learning.

Understanding how stimuli acquire affective value is of interest to a wide range of professions, advertising and animal training among them. For psychologists, understanding how a stimulus becomes associated with an emotion is a central challenge in the investigation of the interaction of emotion and cognition. There are several means by which a stimulus can acquire emotional significance.

4.1. Classical Conditioning

The name most often associated with classical conditioning is that of Ivan Pavlov (1849–1936), the great Russian physiologist who discovered the principles of such conditioning. Pavlov was interested in digestion and intended to examine salivation in dogs in response to food. His studies became complicated when the dogs started to salivate before the food was presented; the salivation response was occurring when a researcher opened the door to the dogs' quarters. The dogs were salivating in response to an event associated with the presentation of food. Pavlov realized that reflexes such as salivation can be evoked not only by the appropriate stimulus (in this case, food), but also by events associated with these reflex-inducing stimuli. Further research has demonstrated that all sorts of reflexes and responses, including emotional responses, can be elicited by conditioning.

In the study of emotion, it has become clear that stimuli that are linked with positive or negative events themselves take on affective qualities and elicit affective reactions. For example, if you have been in a car accident, it would not be surprising if you were to feel uneasy the next time you found yourself at the intersection where the accident happened. The association between the previously neutral location and the
negative accident results in a conditioned arousal response and a feeling of nervousness linked to that location. It is not uncommon for us to feel anxious or aroused around people, places, or things that have previously been connected with unpleasant experiences. This is the result of emotional classical conditioning, the learned association between a neutral event and an emotional event.

Emotional classical conditioning can be expressed in different ways. As autonomic conditioning, it can be expressed through bodily responses, such as an arousal response. As evaluative conditioning, it can be expressed through a preference or attitude: a stimulus that predicts a negative emotional event may be rated more negatively. Most studies of emotional classical conditioning examine either autonomic responses or subjective reports of evaluation, although these two types of conditioned responses are often acquired simultaneously.

One of the more widely studied forms of autonomic conditioning is aversive, or fear conditioning. Fear conditioning occurs when a neutral stimulus paired with an aversive or fearful event comes to elicit a fear response when the stimulus is presented alone. That is what is happening when the acquired arousal response is made to the site of the car accident. The experience is a familiar one: most of us could find examples in our lives to substitute for “car accident” and “intersection.” Learning by aversive conditioning has been considered a model for fear learning in general, and it has been suggested that it may be specifically related to phobias (Ohman & Mineka, 2001).

Aversive conditioning has been studied extensively in both humans and nonhumans. Across species, it has been shown that the amygdala is a critical brain structure in the acquisition and expression of aversive conditioning (LeDoux, 1996). Humans with damage to the amygdala do not acquire conditioned fear responses (Bechara et al., 1995; LaBar et al., 1995), but they show a normal ability to report that the neutral stimulus predicts the aversive or fearful event. For example, a patient known as S.P., who had sustained bilateral damage to the amygdala, and normal control participants were given several pairings of a blue square and a mild shock to the wrist (Figure 8–7). After a few trials, the normal participants showed a skin conductance response to the blue square presented alone, indicating autonomic conditioning. S.P., however, showed no evidence of arousal to the blue square alone, even though her arousal response to the shock was normal. When S.P. was shown her own data and asked what she thought about the results, she answered:

I knew that there was an anticipation that the blue square, at some particular point in time, would bring on one of the volt shocks. But even though I knew that, and I knew that from the very beginning, except for the very first one where I was surprised, that was my response. I knew it was going to happen. I expected that it was going to happen. So I learned from the very beginning that it was going to happen: blue and shock. And it happened. I turned out to be right, it happened! (Phelps, 2002)

It is clear that S.P. understood fear conditioning and had episodic memory of the events of the study. The ability to acquire and report this explicit representation depends on medial temporal structures, the so-called hippocampal complex, that are close to the amygdala (see Chapter 5). Patients with damage to the hippocampus, who have an intact amygdala, show the opposite pattern of results; that is, they
show normal autonomic conditioning, as measured by SCR, but they are unable to report that the blue square predicts the shock (Bechara et al., 1995).

This double dissociation between direct (explicit report) and indirect (SCR) measures of emotional learning indicates that there are at least two kinds of learning systems that are operating independently: one (which relies on the hippocampus) mediates learning accompanied by awareness, namely, the declarative memory system described in detail in Chapter 5; the other (which relies on the amygdala) is necessary...
for conditioned autonomic responses. Additional support for the notion that awareness is not necessary for aversive conditioning comes from studies in which the stimulus linked with the aversive event is presented subliminally, so that the participant is unaware that it has been presented; this procedure can result in the expression of autonomic conditioning, as measured by SCR (Ohman & Soares, 1998).

Studies of autonomic conditioning have revealed the importance of learned physiological responses. Studies of evaluative conditioning, on the other hand, are more concerned with learned preferences or attitudes, the subjective, emotional responses that are acquired through classical conditioning. Evaluative conditioning is the goal of many (most) forms of advertising. Why do advertisers assume that pairing new products with attractive stimuli, such as popular athletes or celebrities, will alter our attitudes and, specifically, our purchasing decisions? We don’t really think that using products endorsed by stars will confer stardom on us. Nonetheless, advertising works. It works because evaluative conditioning works. If we experience positive affect (for example, admiration of a celebrity endorser or amusement at clever ad copy) in the presence of a neutral stimulus (a deodorant, say) we may eventually come to prefer that stimulus. Evaluative conditioning manifests itself via a subsequent change in valence, that is, the degree to which the stimulus is regarded as pleasant (or unpleasant).

Like aversive conditioning, evaluative conditioning can occur without awareness (as can be the case with advertising). In other words, a preference is acquired and expressed, but we may be unaware of how this preference came to be. For example, in one study researchers paired a series of neutral pictures with either positive, negative, or other neutral pictures (Baeyens et al., 1990). Some participants were told to search for a relationship between the members of a pair; others were told simply to look at the pictures. Participants’ awareness of the relationships between the neutral and emotional pictures was then assessed. Participants were considered “aware” if they correctly indicated which emotional picture was paired with a target neutral picture; if they indicated a different emotional picture of the same valence as the one actually paired with the target neutral picture; or if, although unable to indicate a particular picture, they correctly expressed the valence of the picture paired with the target neutral picture. Regardless of a participant’s level of awareness of the relationship, similar levels of evaluative conditioning were observed.

Specifically, when participants were asked to rate how much they liked the neutral pictures, those who had been unable to report any knowledge of the relationship between the target neutral pictures and their respective pairs showed levels of acquired preferences similar to those of participants who were completely aware of the relationship between pictures. This attitude formation can occur independently of awareness. In addition, results consistent with this idea were obtained in two studies conducted with amnesic participants, who have deficits in declarative memory. Preference formation was demonstrated even though these patients were unable to report any memory for the conditioning procedures (Johnson et al., 1985; Lieberman et al., 2001).

It is likely that both types of emotional classical conditioning—autonomic conditioning and evaluative conditioning—occur simultaneously. For instance, a typical
aversive conditioning study might pair an abstract pattern with a mild electric shock. After several presentations of such pairings the abstract pattern may come to elicit an arousal response when presented alone. This is an indication of autonomic conditioning. At the same time, if participants are asked to rate how much they like the abstract pattern compared to a similar pattern that was never paired with shock, they might rate the pattern paired with shock more negatively, thus indicating evaluative conditioning.

Even though autonomic and evaluative conditioning can occur simultaneously, there is some evidence that these two types of emotional classical conditioning can be dissociated. This evidence comes from studies of extinction. Extinction is the decrease in a learned emotional response that occurs when a stimulus is presented enough times without the occurrence of the emotional event that the participant learns that this conditioned neutral stimulus no longer predicts the occurrence of the emotional event. Your unfortunate car accident again: the first time after the accident you drive through the intersection where it occurred, you may feel nervous—this is a conditioned autonomic response to that particular location. Several months later, however, after you have driven through this intersection a number of times with no further mishap, your nervousness may fade; it has been extinguished. This is an example of the extinction of a conditioned autonomic response.

With autonomic conditioning procedures, extinction typically is rapid. After a few extinction trials in which the neutral event occurs without the aversive one, the conditioned autonomic response may no longer be expressed (e.g., LaBar et al. 1995; Ohman & Soares, 1998). Evaluative conditioning, on the other hand, is very hard to extinguish. Once a preference or attitude is acquired, this preference does not seem to diminish, even when there are twice as many presentations of the previously neutral stimulus without the occurrence of the emotional event and the participant is fully aware that the presentation of this stimulus no longer predicts the emotional event (De Houwer et al., 2001). Even if you extinguish your autonomic response when you pass the intersection where you had the accident, it is likely you will still dislike this intersection. This resistance to extinction for evaluative conditioning differentiates conditioned preferences from other types of classical conditioning.

### 4.2. Instrumental Conditioning: Learning by Reward or Punishment

Emotional learning can occur when certain actions and stimuli are paired with reward or punishment. Take, for example, gambling. For a gambler who bets on horses, actions such as going to the racetrack and placing the bet, and stimuli such as the racing pages and the morning line of probable odds, are paired with rewards if the player wins. Although the bettor may lose (punishment), part of the reason gambling is so appealing to some people is that the thrill and excitement of an occasional large win is often more powerful than the many smaller losses that may occur. Thus, liking to gamble may arise from instrumental conditioning. The principle underlying instrumental conditioning (which is also known as operant conditioning) is that a behavior or response will increase or decrease in frequency depending on the...
outcome of that behavior—on whether it yields a reward or a punishment. If we do something that leads to a good result (reward), we are more likely to repeat that behavior, and if we do something that leads to a bad result (punishment), that behavior is less likely to be repeated. Instrumental conditioning depends on our taking an action that can be rewarded.

In an effort to understand the nature of reward, researchers have explored the neural systems of reward learning and, to a lesser degree, of punishment learning (e.g., Bornhovd et al., 2002; Delgado et al., 2000). The neural system for reward is described in terms of both a neurotransmitter, dopamine, that is linked to reward and a neuroanatomical region, the striatum. The "mesolimbic dopamine pathway" links the ventral tegmental area of the medial forebrain bundle in the midbrain to the striatum, in the forebrain. It is this pathway that is activated in expectation of reward (Figure 8–8). If the ventral tegmental area is stimulated, activation of this pathway results in the release of dopamine to the striatum (Wise & Rompre, 1989). Neuroimaging studies have consistently shown activation of the striatum in response to a reward the participant perceives as such (e.g., Delgado et al., 2000; Knutson et al., 2001), and drugs that block the action of dopamine have been shown to lead to impairments in performance of rewarded learning tasks (Stellar & Stellar, 1984).

**FIGURE 8–8** The mesolimbic dopamine pathway—the reward circuitry of the brain.

Ventral tegmental area is stimulated, activation of this pathway results in the release of dopamine to the striatum and other regions, such as the frontal cortex. This sequence occurs in the presence of a reward.

One of the most interesting findings to emerge from research on the neural basis of reward learning is that the neural system involved responds to all types of reward, whether it is a drug given to an addict (Breiter et al., 1997), a primary reinforcer such as food (Rolls et al., 1980), or a secondary reinforcer such as money (Delgado et al., 2000; Knutson et al., 2001). The fact that a common neural pathway mediates both primary and secondary reinforcers suggests that this system is important for coding perceived reward value. However, what is rewarding to one person may not be rewarding to another—and may be neither healthy, necessary, nor inherently valuable.

Instrumental conditioning requires action that can be reinforced. It is this action, and the stimulus prompting it, that acquires affective value. However, along with the action and stimulus, the affective value of a range of other, associated stimuli may be altered as well. An addict learns to associate taking the drug with reward. Drug taking is also linked to a number of other stimuli: the location where it usually takes place, the paraphernalia used, other people who use the drug with the addict, the dealer who sells the drug. All these stimuli, simply by their association with the action of drug taking, can acquire affective value by classical conditioning. Instrumental and classical conditioning can go hand in hand in an intimate relationship that makes changing behaviors such as taking drugs so challenging.

4.3. Instructional and Observational Learning

Both classical and instrumental conditioning depend on emotional experience for learning to occur—you must receive a stimulus that you perceive as positive, rewarding or negative—punishing. There are other means of emotional learning that do not require direct emotional experience, but depend instead on instruction by observation. Why, for instance, are some people afraid of germs and why do most people try to avoid them? Outside a research facility or academic setting—and for English majors not even then—most people have never seen a germ. And as far as our unassisted perceptual systems are concerned, germs are an imaginary concept. However, we have been told about the negative value of germs (and admonished from childhood, and in signs in restrooms, to wash our hands to avoid them). This is an example of instructional learning. (If the instruction is threatening enough and not modulated by experience, the healthy avoidance of germs can become an unhealthy phobia.)

Unlike other species, we can learn about the emotional significance of events and stimuli through symbolic means such as language. We do not have to experience directly negative or positive consequences to know whether a stimulus is good or bad. Learning through instruction is a common means of emotional learning in humans, and it is highly effective. Learning emotional responses to neutral stimuli that are directly linked to aversive consequences (conditioning) is similar to learning through verbal communication (instruction) (Hugdahl & Ohman, 1977).

In fact, learning to fear through instruction and through classical conditioning activate some of the same neural pathways. In particular, the amygdala is not only
important in aversive conditioning, but also plays a role in the physiological expression of instructed fear learning. This finding resulted from a study designed to be as similar as possible to the fear conditioning study described earlier in which patient S.P. participated. The difference is that shock was paired with the blue square only through verbal instruction. Patients with right or left amygdala damage as well as normal participants were told that they might receive a mild shock to the wrist when a blue square is presented (“threat”), but they would never receive a shock when a yellow square was presented (“safe”). Even though none of the participants in fact received a shock, the normal participants and those with right amygdala damage showed a potentiated startle response during presentations of the blue square, indicating a negative emotional response to the blue square—threat stimulus. The participants with left amygdala damage, however, did not demonstrate potentiated startle to the blue square (Funayama et al., 2001), indicating that the left amygdala is involved in instructed learning to fear. Although only the left amygdala plays a role in the expression of instructed fear, perhaps because of the verbal nature of instructed learning, these results suggest that the amygdala plays a role in the expression of fears that are imagined and anticipated, but never actually experienced. A related study using fMRI data from normal participants was reported by Phelps et al. (2001). Both these studies are examined in the accompanying A Closer Look.

Like instructional learning, *observational learning* does not rely on direct experience with positive or negative consequences. If we observe someone being rewarded or punished for a behavior, or enjoying or avoiding an event, we may learn something about the value of that behavior or event. A teacher who “makes an example” of a disruptive pupil and administers a reprimand in front of the entire class is hoping that the other pupils will engage in some observational learning.

Some nonhuman animals also learn by observation. For example, monkeys raised in a laboratory free of snakes can learn to fear them by observing monkeys raised in the wild who have an intense fear of snakes (Mineka et al., 1984) (Figure 8–9). The neural systems for learning through observation may involve “mirror neurons.” Mirror neurons, discovered in monkeys, are neurons that respond both when an action is observed and when that action is performed (see Chapter 11). Mirror neurons in the premotor cortex of a monkey fire when that animal performs a motor response and also when it observes another monkey performing that response. In humans, it typically is not possible to study responses in single neurons, but by the use of neuroimaging techniques, mirror responses have been reported similar to those observed in the monkey (Gallese & Goldman, 1998; Rizzolatti et al., 1996). Moreover, researchers have discovered mirror responses for emotion. Watching someone else experience pain results in activation of parts of the pain circuitry in the observer (Singer et al., 2004). In an effort to extend this finding to observational learning, participants were told to watch a film clip of a confederate of the investigator undergoing classical conditioning in which a blue square is paired with a mild shock to the wrist. The participants were then presented with blue squares, but never actually received a shock. The amygdala, which we know
ACLOSER LOOK
Expressing Imaginary Fears


Introduction
Do symbolically communicated and imaginary fears rely on the same neural mechanisms as fears acquired through direct, aversive experience, as in fear conditioning? This question was addressed in two studies (Funayama et al., 2001; Phelps et al., 2001).

Both groups of investigators were interested in how verbally communicated fears are represented in the brain and whether expressing this type of emotional learning depends on the amygdala, which has been shown to be critical in fear conditioning.

Method
Two techniques were used to assess human brain function: functional magnetic resonance imaging (fMRI) in normal participants (Phelps et al., 2001) and physiological responses of patients with amygdala lesions (Funayama et al., 2001). In each of the studies, participants were told that the presentation of a colored (for example, blue) square would indicate the possibility that a mild shock to the wrist would be delivered; this was called the “Threat” stimulus. Participants were also shown a square of another color (for example, yellow) and were told that this stimulus indicated that no shock would be delivered; this was called the “Safe” stimulus. In the fMRI study, normal participants were presented with the Threat and Safe stimuli while responses in the amygdala were assessed. Skin conductance responses were also measured to obtain a physiological indication of a fear response. In the patient study, normal controls as well as patients with left, right, and bilateral amygdala damage participated in an experiment of similar design in which eye-blink startle to the Threat and Safe stimuli was assessed as a measure of fear learning. In both the fMRI and patient study, none of the participants actually received a shock to the wrist.

Results
In both the fMRI and patient studies, normal control participants exhibited a physiological response consistent with fear in reaction to the presentation of the Threat (relative to Safe) stimulus. In autonomic measures taken during the fMRI study, the participants showed increased SCR to Threat versus Safe. In the patient study, the normal control participants showed a potentiated startle reflex response to Threat versus Safe. These results suggest that simply instructing someone about the potential aversive properties of a stimulus can elicit a fear response. Both the fMRI and patient studies also found that the left amygdala is important for this expression of instructed fear. In the fMRI study, activation of the left amygdala was observed in response to the Threat versus Safe stimulus, and the magnitude of this activation was correlated with the magnitude of the SCR response. In the patient study, patients whose damage included the left amygdala failed to show potentiated startle to the Threat stimulus.

Discussion
These results suggest that the left amygdala responds to verbally instructed fears and plays a critical role in their expression. The left amygdala may be particularly important because these fears require linguistic interpretation, which is known to rely on the left hemisphere in most people. Animal models of the neural mechanisms of fear learning have relied on fear conditioning, in which learning occurs through direct aversive experience. These results suggest that similar neural mechanisms may underlie fears that are unique to human—that is, fears that are linguistically communicated and are imagined but never actually experienced.
Figure 8-9: An example of observational learning

Two sets of monkeys were required to reach past a snake to get food. Monkeys raised in the laboratory showed no fear of the snake and would reach for food—until they saw another monkey, raised in the wild, that refused to reach for the food and displayed fear of the snake. The laboratory-raised monkeys then also demonstrated a fear response to the snake and refused to reach for food.

(Courtesy of Susan Mineka, Northwestern University.)

It is important for fear conditioning and instructed fear, also responded when participants observed the confederate respond to the shock paired with the blue square. The magnitude of amygdala activation during observation was the same as when the participants were presented with the blue square and were anticipating the shock themselves (Olsson et al., 2004).

4.4. Mere Exposure

All the types of emotional learning described thus far rely on linking a stimulus or action to something that is “good” or “bad.” When a preference or attitude is acquired through mere exposure, no linkage is required; just the simple repetition of a stimulus can make it likable. The mere exposure effect is based on familiarity, and so only the (repeated) presentation of the stimulus is necessary. In a typical mere exposure study, participants are shown neutral stimuli, such as abstract patterns. Some patterns are presented perhaps 10 times, others 5 times or once, and some patterns are not shown at all. After the exposure procedure, participants are asked to rate how much they like these abstract patterns. They are more likely to give high ratings to the patterns that they have been exposed to more frequently than to those they have been exposed to less frequently or not at all. Mere exposure effects have been observed with a range of stimuli, including Chinese ideographs, musical tunes, and nonsense syllables (Zajonc, 1980).
Although the mere exposure effect results from familiarity, it does not require recollection of previous experience with the stimulus. A study examining preferences for novel musical tunes found that the mere exposure effect was equally strong for tunes the participant could and could not identify as having been previously presented (Wilson, 1979). Similar effects have been observed for other types of stimuli. The factor that predicted the formation of a preference for the tunes and other stimuli was the amount of previous exposure, not awareness of that exposure (Zajonc, 1980). The notion that mere exposure effects can be obtained independent of awareness receives further support from studies demonstrating the mere exposure effect for stimuli presented subliminally (Bornstein, 1992). The next time you find yourself humming along with a song on the radio, remember: the more you hear it, the more you'll probably like it.

**Comprehension Check:**

1. Describe an emotional learning situation in which there is evidence for both evaluative conditioning and autonomic conditioning.

2. In what ways can you learn to like or dislike something even when no conditioning occurs?

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### 5. EMOTION AND DECLARATIVE MEMORY

Day to day, we tend to use our memory to answer questions such as “Where did I leave the keys?” But on the scale of a life, your lasting memories are not of the pocket in which you left your keys. Memories for events that are emotional and important seem to have a persistence and vividness that other memories lack. Memory for emotional public events, such as the destruction of the World Trade Center, will persist, although imperfectly. Memories for emotional private events, such as the birth of a baby, also are imbued with special qualities. How, exactly, does emotion influence memory?

As discussed in Chapter 5, one of the primary advances in memory research during the past 40 years has been the growing recognition that memory is not a unitary concept: different forms of memory, conscious and unconscious, relate to different neural systems. Declarative memory is long-term memory that can be consciously recollected and described to other people. It includes episodic memory, the “first-hand” memory of our own individual past histories, and semantic memory, knowledge about objects and events in the world. Both forms of memory can be influenced by various aspects of emotion in several possible ways.

#### 5.1. Arousal and Memory

Regrettably for our peace of mind, memories for embarrassing situations may not fade. It would be nice to forget those occasions when our ignorance or social awkwardness was on full display. But we don’t forget these events, and sometimes other people...
don't either. Why are these moments when you'd like to sink through the floor selected to last (and last vividly) and others are not? One reason is that embarrassment, an emotional reaction, leads to arousal, and arousal enhances our ability to store memories.

It is well known that emotional arousal can enhance recollection. This has been shown for a number of different types of stimuli and a range of memory tasks, both in and out of the laboratory (Christianson, 1992). In a classic study, Hueur and Reisberg (1992) showed each of two groups of participants a different slide show with a corresponding narrative. Both shows depicted a mother and son going to visit the father at work. The slides and narrative at the beginning and end of each show were the same and represented neutral events, such as the mother and son leaving the house and the mother making a phone call. In one of the slide shows, the emotion condition, the middle section of the story showed the father, identified as a doctor, responding to a gruesome accident. In the other slide show, the neutral condition, the father was a car mechanic. After seeing the slide show, participants were asked to recognize details of the slides and narrative. For both groups, there was no difference in the ability to remember details of the early and late portions of the show, which depicted neutral events. Participants in the emotion condition, however, were much better at remembering details from the middle, emotional portion of the slide show they saw compared to participants in the neutral condition, who saw a middle part that carried no emotional weight.

It is a well-documented finding that there is better declarative memory for arousing, emotional stimuli. How does this happen? To understand how this works, we can look at the neural mechanism underlying the influence of emotional arousal on memory.

A number of studies have shown that the amygdala, which is critical for the acquisition and expression of aversive conditioning, also has a secondary role in memory. Patients with damage to the amygdala do not show arousal-enhanced memory (Cahill et al., 1995; LaBar & Phelps, 1998). Neuroimaging studies reveal a correlation between the strength of the amygdala response to an emotional stimulus at encoding and the likelihood of successful recollection of that stimulus at a later time (Cahill et al., 1996; Hamman et al., 1999). These results suggest the amygdala can influence declarative memory for emotional events. But it is neighboring medial temporal lobe structures, in and around the hippocampus, that underlie the acquisition of declarative memory: the amygdala has its influence by interacting with the hippocampus.

Hippocampal consolidation is a slow process by which memories become more or less stable over time. A series of studies has demonstrated how the amygdala, through arousal, can influence hippocampal processing, modulating the consolidation of hippocampal-dependent memories (McGaugh, 2000). By enhancing hippocampal consolidation with arousal, the amygdala alters the storage of new information in memory (McGaugh et al., 1992).

To demonstrate that the amygdala modulates storage, investigators have disrupted or enhanced amygdala processing in rats after memory encoding. In one study, rats were given a maze-learning task, which depends on the hippocampus for normal learning. Immediately after learning, some of the rats were given a pharmacological agent that induced an excitation response in the amygdala; the other rats
were given a (nonactive) saline injection. Those rats whose amygdalas were artificially excited after learning showed better memory for the maze than the rats that received saline (Packard & Teather, 1998). The mechanism by which the amygdala modulates consolidation relies on activation of the β-adrenergic system in the amygdala. Beta-blockers (drugs that block the action of the β-adrenergic system by blocking β-adrenergic receptors) also block the effect of arousal on declarative memory (Cahill et al., 1994; McGaugh et al., 1992). It has been suggested that one of the adaptive functions of having a long consolidation process for the storage of declarative memories is to allow time for the arousal response to enhance the retention of events linked to emotional consequences.

If arousal, via the amygdala, modulates the storage of declarative memories, there should be different forgetting curves for arousing and nonarousing stimuli. This has been demonstrated in a number of studies. In an early experiment, participants were presented with word-digit pairs (Kleinsmith & Kaplan, 1963). Half the words were emotional and arousing, half were neutral. Participants were then presented with the word alone and asked to recall the paired digit. Some participants were given this memory task immediately after encoding, others a day later. Participants who were asked to recall the digits immediately showed somewhat better memory for the digits paired with neutral words, although this difference was not significant. Participants who were tested 24 hours later showed significantly better memory for the digits paired with high-arousal words. Comparing across the groups, there was evidence of forgetting over time for the neutral word-digit pairs, whereas memory for the arousing word-digit pairs did not diminish over time (Figure 8–10). Consistent with the idea that the amygdala enhances consolidation or storage processes, patients with damage to the amygdala show similar patterns of forgetting for arousing and neutral words (LaBar & Phelps, 1998).

![Figure 8–10: Memory and arousal](image)

Memory for digits paired with high- and low-arousing words was assessed both immediately after encoding and 24 hours later. Digits paired with low-arousing words were forgotten over time; digits paired with high-arousal words were not forgotten.

5.2. Stress and Memory

The effect of arousal on memory storage can help to explain why those events that are most exciting, embarrassing, or nerve wracking may receive preferential treatment in memory. However, prolonged stress and extreme arousal can have the opposite effect, impairing memory performance. The effect of arousal and stress on declarative memory can be characterized by an inverted U-shaped curve (Figure 8-11). Mild to moderate arousal enhances memory performance, but if the arousal response is prolonged or extreme, memory performance suffers.

The mechanism underlying this stress-induced memory impairment is related to hormonal changes that occur with long-term stress. Glucocorticoids, a group of stress hormones released by the adrenal gland, are the primary culprit. In studies with rats, researchers have shown that extended exposure to stress leads to increased levels of glucocorticoids that can reduce the firing rate of hippocampal neurons, impair memory performance, and, if exposure is long enough, lead to hippocampal atrophy (McEwen & Sapolsky, 1995). The hippocampus has two types of glucocorticoid receptors, which are affected by different levels of glucocorticoid exposure. The existence of these two types of receptors may help to explain why different levels of exposure to arousal and stress hormones lead to either an enhancement or an impairment of memory.

The research examining the effect of stress on human memory is limited; the ethics of psychological investigation preclude inducing in humans the levels of stress necessary to impair memory performance. However, there is some evidence that patients who suffer from stress-inducing disorders, such as depression or post-traumatic stress disorder, have impaired memory, and that patients who suffer from these
disorders for a number of years show signs of hippocampal atrophy (Bremner, 2002; Nasrallah et al., 1989).

Although it is difficult to test the effects of stress on human memory in a controlled laboratory study, it has been possible to demonstrate in humans the glucocorticoid influence observed in rats. For instance, in one study participants were daily either administered a drug that artificially increases the level of glucocorticoids or given a placebo. After four days, participants who had taken the drug and who had elevated glucocorticoid levels showed impaired memory performance relative to participants who took the placebo (Newcomer et al., 1994). These results support the conclusion that stress hormones can impair memory if exposure is prolonged.

5.3. Mood and Memory

Mood reflects a lasting and diffuse affective state that is not necessarily linked to any specific event. Have you ever noticed that when you are in a bad mood, you are more likely to recall negative and unfortunate events, whereas when you’re in a good mood, happy occurrences come to mind more readily? This common experience reflects an influence of mood on memory known as the mood-congruent memory effect (Bower, 1981).

Mood induction—the deliberate attempt to change a participant’s mood—is used to assess the mood-congruent memory effect. In a typical study, participants are first asked to fill in a mood questionnaire that asks them to rate how happy, sad, positive, or negative they are feeling at that moment. A mood-induction procedure follows: for example, participants may be shown a movie and told to try to feel whatever mood the movie seems designed to elicit. A second questionnaire is administered to determine whether mood induction was successful. Following successful mood induction, participants are given stimuli to remember, such as positive words (for example, *happiness*), neutral words (for example, *cloth*), or negative words (for example, *failure*). Memory for the words is then assessed, typically by free recall (i.e., participants are not given specific cues but simply instructed to recollect as many of the words as possible). The mood questionnaire is administered a third time, to ensure that the induced mood was in place at the time of test. If in fact it was, participants will show better recall for words whose valence is congruent with the mood state (for instance, they will remember more positive words when in a positive mood) than words whose valence is incongruent with the mood state (for instance, they will remember fewer negative words when in a positive mood).

Mood-congruent memory effects are not always found. For example, tested recognition memory ("Did you see this word before?") are less likely than tested recall ("What was the word you just saw?") to elicit mood-congruent memory effects (Bower & Cohen, 1982). In addition, although mood-congruent memory effects have been found for both positive and negative moods, they are stronger for positive moods. This may reflect a tendency toward more creativity and generative activity with positive moods (Fiedler et al., 2001).

Mood-congruent memory effects can be observed when memory encoding occurs before or after mood induction. Therefore, the mood-congruent memory effect is the result of altering the retrieval, rather than the encoding or storage, of
memory. Two hypotheses have been proposed to explain the influence of mood on memory retrieval. The first suggests that mood creates a bias in responding: the memory representations for the mood-congruent and mood-incongruent stimuli are equally accessible, but participants are biased to respond to the mood-congruent stimuli (Schwarz & Clore, 1988). The second hypothesis suggests that mood actually changes the accessibility of the memory representation during retrieval, so that given mood leads to greater activation of memories for stimuli whose valence is consistent with that mood. For this reason, memories of mood-consistent stimuli are more easily retrieved (Bower, 1981). With most memory tests using free recall, it is difficult to distinguish a tendency or bias to respond with mood-congruent stimuli from a change in the accessibility of these stimuli to retrieval. However, in a cleverly designed recognition memory test, investigators were able to demonstrate that the primary mechanism by which mood alters memory is the greater accessibility of mood-congruent memories (Field & et al., 2001). In other words, mood can actually determine which memories are most available for explicit retrieval at any given time.

4. Memory for Emotional Public Events

There is only so much that can be done to manipulate emotion in a controlled and naturally responsible fashion. Because emotional reactions studied in the laboratory are therefore mild and constrained, some researchers have chosen to study emotion and memory in “natural experiments.” An area that has been invested in this way for its psychological, historical, and cultural importance is memory for emotional public events. Although these studies cannot be nearly as controlled or detailed as laboratory research, they nevertheless provide a window through which we can have another view of the link between human memory and emotion.

One of the first emotional public events studied by psychologists was the assassination of John F. Kennedy in 1963. This event shocked the nation, and reactions to it are highly emotional. Two psychologists, Roger Brown and James Kulik (1977), studied the qualitative aspects of memory for this event, asking people to recall incident details of their experience of the event, such as where they were and whom they were with when they heard about it. Many respondents had detailed recollections and believed their memory to be extremely accurate, almost like a photograph. They recorded every aspect of the scene. Brown and Kulik introduced the term flashbulb memory to describe memory for surprising and consequential events; the case reflects the vivid and detailed nature of the recollections reported. Brown and Kulik suggested that there are special mechanisms for the formation of memories for emotionally charged events and that they elicit a “print now” response from the memory system, which ensures that the memory remains accurate and not forgotten.

This groundbreaking study highlighted the qualitative nature of memory for emotional public events and seemed to imply that such memory is different and more detailed than other kinds of declarative memory. But the study was not particularly concerned with assessing the accuracy of these flashbulb memories and...
such a study was not conducted until more than a decade after the assassination. Despite respondents' confidence, the accuracy of flashbulb memories has been called into question. Since this initial study, there have been investigations of memory for a number of emotional public events in various parts of the world, including the 1981 assassination attempt on Ronald Reagan (Pillemer, 1984), the Challenger space shuttle catastrophe (Neisser & Harsch, 1992), the assassination of the Swedish prime minister, Olaf Palme (Christianson, 1989), the Loma Prieta earthquake in California (Neisser et al., 1996), the Hillsborough, England, soccer disaster (Wright, 1993), the resignation of the British prime minister, Margaret Thatcher (Conway et al., 1994), and the death of King Baudouin of Belgium (Finkenauer et al., 1998). Studies examining memory for the attack on the World Trade Center in New York in 2001 have also been reported (Begley, 2002; Talarico & Rubin, 2003). Taken together, these studies suggest that even though memory for emotional public events may be more accurate than most ordinary memories, they do not have the type of photograph-like accuracy implied by the term flashbulb memory—despite the confidence of respondents.

One of the first studies to demonstrate significant errors and distortions in memories for emotional public events examined memory for the Challenger explosion in 1986 (Neisser et al., 1992). Within a few days of the event, students were asked to recollect what they knew and how they heard about it. Three years later, they were again asked to recall this event. When comparing the early and later recollections, the investigators found significant differences between them. For example, a few days after the explosion, most respondents reported hearing the news from someone before seeing the television reports. After a few years, however, most respondents stated that they had been watching the Challenger flight on television and saw the explosion as it occurred. But despite the distortions of most of the second reports, all respondents were extremely confident in the accuracy of their memories. Similar results have recently been reported for memories of the 9/11 terrorist attack (Talarico & Rubin, 2003). It seemed as if the powerful nature of these events overrode any doubt.

In a study designed to discover factors that may be related to accuracy and confidence for memory of emotional public events, researchers examined memory for the O. J. Simpson murder trial verdict in 1995, a "hot-button" political and social event for many people (Smolock et al., 2000). A little more than a year after the verdict, respondents were still fairly accurate in their recollections of the personal details surrounding the event (where they were, who was with them). After three years, however, many showed significant distortions in their memories. As in the Challenger study, all respondents, including those whose memory was faulty, gave detailed accounts of their experience and were confident of their accuracy. In the Simpson verdict study, the only factor that emerged as predicting better accuracy later three years was the level of emotional involvement of the respondent at the time of the verdict. Those who reported higher levels of emotional arousal to the verdict had more accurate memories for the event when questioned three years later. These results are consistent with the idea that higher levels of arousal (at least up to a point) may help guard against some distortions of memory.
Although memory for emotional public events is often inaccurate in detail, it is nonetheless long lasting and compelling. The respondents in the Challenger study remembered that the event had occurred; their inaccuracies concerned their own connection to it. Similarly, although many people are confident that on September 11, 2001, they saw television pictures of two planes striking the World Trade Center (Pedzek, 2003), they couldn't have: no video of the first plane was available until the following day. (A moment's thought will suggest why: no television station, network or otherwise, was photographing the buildings that morning before the first attack—they had no reason to. Video of the first plane came from another source, and it took a certain amount of time before it was available.) Again, people obviously remember what occurred, but have forgotten details about their connection to it. Nevertheless, iconic images of emotional public events—John Kennedy smiling in an open car moments before the shots, the heartbreaking arc of the damaged Challenger against the blue sky—the image of billowing smoke from the World Trade Center (Figure 8-12) have left a lasting impression.

**Figure 8-12** An emotional public event


(Photograph by Chris Collins. Courtesy of Corbis/Stock Market.)
Some large-scale studies are under way examining memory for the World Trade Center disaster (Begley, 2002). These studies should help clarify whether, as Brown and Kulik (1977) proposed, special mechanisms exist for the formation of memories for emotional public events or, as the results from the Simpson verdict suggest, these memories are the result of ordinary memory mechanisms, likely interacting with arousal. It is clear that the recent advances in our understanding of the influence of emotion on memory will help us interpret results from these studies in light of both cognitive and neural mechanisms.

**Comprehension Check:**

1. What does the inverted U-shaped curve describe, when referring to the impact of emotion on memory?
2. What evidence supports the idea that mood can influence memory?

## 6. EMOTION, ATTENTION, AND PERCEPTION

Emotional events are distracting—despite your opinion, only moments before, about the drivers in front of you who slowed traffic to look at the accident, the car crash seized your attention, compelling you to pause and look before you returned your concentration to the road ahead. In some circumstances an emotional stimulus may break through to awareness. You may be reasonably successful at tuning out the conversations around you at a party—until someone mentions an emotionally evocative topic or word.

Emotion can influence attention and perceptual processing by different means. Most of the studies that have examined the influence of emotion on attention or perception have reported effects for negative, arousing, or threat-related stimuli—often in combination. It is proposed that these stimuli, because of their potential importance for survival, may receive priority in attention and perception (LeDoux, 1995; Ohman et al., 2001a; Whalen, 1998).

### 6.1. Emotion and the Capture of Attention

Emotion captures our attention and makes it hard to respond to nonemotional stimuli. This was demonstrated in an emotional version of the Stroop test, a classic measure of attention (see Chapter 7). As in the original version, participants were presented with words printed in different ink colors and asked to report the color of the ink and ignore the words. However, in this modified version the words were not color names but either emotional words (for example, rape, cancer) or neutral words (for example, chair, keep). When the words are emotional, participants find it more difficult to ignore the words and name the color of the ink (Pratto & John, 1997). This effect can be exaggerated for stimuli that are specifically relevant.
given person, such as the word *snake* for someone with a phobia for snakes (Williams et al., 1996).

In an effort to determine the precise mechanism underlying the capture of attention by emotion, researchers (Fox et al., 2001) employed the exogenous cueing technique developed by Posner (1980; see Chapter 3). The investigators suggested that emotion could capture attention by one of two mechanisms: it could either *draw* attention or *hold* attention. Participants were asked to respond as quickly as possible when a dot appeared either to the right or left of fixation and indicate by pressing a button on which side of the screen the dot appeared. The location of this dot probe was cued by a stimulus that was presented in the same location 150 milliseconds before the dot appeared. Most of the time, the cue predicted the correct location of the dot, but sometimes it predicted an incorrect location. As cues, the investigators used emotional and neutral words and faces to differentiate two components of attention (Figure 8-13).

The researchers reasoned that if emotion can enhance the automatic orienting or shifting of attention to the cue location, then the participants should be faster for valid emotion cues than for valid neutral ones. This pattern of performance would support the interpretation that emotion *draws* attention. However, if emotion makes it difficult to withdraw or disengage attention from an inappropriate cue, then the participants should perform similarly for the valid emotion and neutral cues, but should respond more slowly for invalid emotional than for invalid neutral cues. In other words, it should take the same amount of time for participants to shift attention to both emotional and neutral cues, but longer to stop looking at an emotional cue and shift attention to another location in order to respond on the invalid cue trials. This pattern would be consistent with the idea that emotion *holds* attention and makes it difficult to disengage from an emotional stimulus. The findings supported the idea that emotion holds attention: the primary effect of the emotion cue was to make it more difficult to respond when the cue was invalid. These results suggest that the capture of attention by emotion makes it hard to disengage in order to focus on nonemotional aspects of the task at hand.

![Figure 8-13 Emotion holds attention](image)

*When, as here, a cue is invalid—i.e., does not predict the location of the target—the participants take longer to respond if that cue is emotional (here, an angry face) than if it is neutral. Attention is being emotion.*

6.2. Facilitation of Attention and Perception

Emotion can capture attention and impair performance on a task; and, as we see in this section, it can also facilitate attentional processing. How is it that emotion can both impair (or "capture") and enhance (or "facilitate") attention? The effect of emotion on attention depends on the specific demands of the task. In the studies considered so far, successful completion of the task required the participants to focus on and process the nonemotional aspects of the task; in the emotional Stroop task, for instance, participants are told to ignore the content of the words and to process the color. The attention tasks that demonstrate facilitation due to emotion usually require the participants to respond to or process the emotional stimuli directly or to respond to or process a stimulus that is cued by emotion.

"Finding the face in the crowd" is an example of a task in which performance is enhanced by emotion (Hansen & Hansen, 1988; Ohman et al., 2001b). This is a visual search task in which participants must locate a target among distractors as quickly as possible. In this variation, the targets are either neutral faces or faces with emotional expressions, such as angry or happy. When the target faces are angry, participants take less time to find the target than when the target faces are neutral or happy. Similar results have been observed for other negative stimuli, such as pictures of spiders and snakes among other natural stimuli (Ohman et al., 2001a). This is a "valence-asymmetric" effect; facilitation is apparent for negative stimuli, but not for positive ones.

In addition, a series of studies has demonstrated that the time needed to detect negative stimuli is not influenced by factors such as the number of distractor items (Ohman et al., 2001a, 2001b). These results are reminiscent of other findings on attentional search tasks in which certain visual features "pop out" so that identifying these target stimuli among distractor items is relatively easy and does not require that each stimulus in the display be examined (see Chapter 2). It has been suggested that visual features that pop out during search tasks are more elementary and may be processed more easily without attention (Treisman & Souther, 1983). On this basis, it is proposed that negative faces (and other natural emotional stimuli) receive priority in processing and their enhanced detection on the visual search task is due to a mechanism that operates without requiring attention (Ohman et al., 2001a).

The face-in-the-crowd effect is thought to result from enhanced early processing of the emotional faces (Ohman et al., 2001a). Neuroimaging studies have suggested that the amygdala plays a role in this initial processing of emotional faces. Research has demonstrated that the amygdala shows robust activation to fearful, relative to neutral, facial expressions, and that this occurs even when the faces are presented so quickly that participants are unaware of their presentation (Whalen et al., 1998). In addition, a number of studies have found that manipulating attention does not influence the amygdala's response to "fear faces" (expressions of fear in others) (Northoff et al. 2003; Vuilleumier et al., 2002; Williams et al., 2004). In most cases, the amygdala shows a similar response to fear expressions whether or not they are consciously detected or the focus of attention (see the accompanying Debate box for a further discussion of this topic). These results are consistent with the idea that the emotional content of faces is processed before attention is deployed.
Is the Detection of Threat Automatic?

The affective primacy hypothesis, originally proposed by Wundt (1897) and reintroduced by Zajonc (1984), suggests that the processing of emotional stimuli does not depend on limited cognitive resources. Zajonc argued that detecting emotional salience occurs prior to, and independent of, awareness and appraisal. Stimuli that can be processed irrespective of attentional resources and in an obligatory manner—that is, the processing cannot be "turned off"—are said to meet the criteria for automaticity (see Chapter 7). Automaticity is characteristic of many perceptual functions: we can’t help detecting the edges, objects, and scenes that we see. Reading is a skill that becomes automatic: once you are adept at reading, it is not possible to see a string of letters and not perceive the word they spell.

Evidence from neuroscience indicates that specialized brain systems may ensure that some emotional stimuli, specifically those indicating threat, are processed automatically. The evolutionary reasons for this are clear: even if the alarm is false, it is certainly better to be safe than sorry if the potential consequence is physical harm or death. Evidence that there may be special neural mechanisms for detecting a threat is derived in part from research on classical fear conditioning in rats. This research shows that there are two pathways by which information about the emotional significance of a conditioned stimulus can reach the amygdala (LeDoux, 1986). The cortical pathway allows the stimulus to go through all stages of normal perception before reaching the amygdala; the subcortical pathway skips some perceptual stages and allows the amygdala to make a fast and crude assessment of the emotional significance of a stimulus. It is suggested that this subcortical pathway provides an early warning system in the presence of potential danger (LeDoux, 1996).

There are clear differences in the complexity and range of affective experience across species; however, for fear in particular there appears to be significant overlap across species between basic “fight or flight” responses and their corresponding neural circuitry (Davis & Whalen, 2001; LeDoux, 1996). A number of neuroimaging studies in humans have shown that the amygdala’s processing of faces showing fear meets the principles of automaticity: the processing is irrespective of attentional focus (A. K. Anderson et al., 2003; Vuilleumier et al., 2004) and awareness (Whalen et al., 1998), and it appears to be obligatory in the presence of fear stimuli (A. K. Anderson et al., 2003; Williams et al., 2004). Although these findings do not necessarily implicate a subcortical pathway for perception, neuroimaging studies have attempted to demonstrate that a subcortical pathway for the detection of threat stimuli by the amygdala underlies its automatic response to fear faces in humans.

Specifically, fMRI studies have reported a lack of activation in visual cortex when fear faces are presented without awareness (Pascual et al., 2004; Williams et al., 2004). The amygdala seems to respond preferentially to a fear face, even if the visual cortex does not. In addition, Vuilleumier and colleagues (2003) took advantage of the fact that a visual subcortical pathway should respond preferentially to crude, less detailed visual information, whereas the visual cortex should respond preferentially to highly detailed visual information. They found that the amygdala, pulvinar, and superior colliculus (components of a proposed subcortical pathway) show a greater response to less detailed versions of fear faces relative to neutral ones, whereas the visual cortex showed a greater response to fine details of these fear faces. Finally, two studies have reported amygdala activation to fear in patients whose visual cortices are damaged, resulting in an inability consciously to identify stimuli (Morris et al., 2001b; Pegna et al., 2005). The amygdala’s enhanced response to fear faces in the absence of awareness, highly detailed information, or an intact visual cortex supports the existence of a subcortical pathway for the detection of threat stimuli by the amygdala.
However, another study (Pessoa et al., 2002) arrives at a different conclusion. Using a demanding attention task in which participants are asked to attend to the orientation of lines in the periphery while a fear or neutral face is presented in the center of the screen, these investigators did not observe amygdala activation in response to fear faces in the absence of attention. In this situation, the amygdala’s response to fear faces is not automatic. Pessoa et al. argue that the presence of a subcortical pathway for detection of threat by the amygdala should result in an obligatory response to a fear face, regardless of how demanding the attentional task. In other words, the amygdala’s response should never be dependent on attention. In addition, there is not yet any anatomical evidence in primates verifying the existence of a subcortical pathway for the detection of visual information by the amygdala (Pessoa & Ungerleider, 2004). The evidence to date for such a pathway has been limited to rats (LeDoux, 1998; Romanski & LeDoux, 1992).

The finding that attention can modulate the amygdala’s response to a fear face clearly demonstrates that activation of the amygdala can depend on attention in some circumstances and is not completely automatic. Although these results indicate limitations on the automaticity of the amygdala’s response to fear faces, they do not rule out the possibility of a subcortical pathway. A limitation in interpreting fMRI results in humans is that the signal observed is not an absolute measure of neural function, but rather a relative measure indicating the degree of difference between conditions (for example, fear versus neutral faces). It is not possible to conclude that there is no amygdala response, but only that there is no significant difference in observed activation. Of course, fMRI results used to argue in favor of a subcortical pathway by pointing to the lack of activation in visual regions in normal participants suffer from the same limitation (Pasley et al., 2004; Williams et al., 2004). It is unclear whether fMRI, when used without other techniques, can provide sufficient evidence that a subcortical pathway for the detection of visual threat stimuli by the human amygdala does, or does not, exist. (More generally negative evidence from neuroimaging—no significant difference in activation—is not as diagnostic as positive evidence.)

Whether or not a subcortical pathway for the detection of threat stimuli by the amygdala exists in humans is still a matter of debate. However, whether or not the amygdala receives input about the emotional significance of a stimulus via a cortical or subcortical pathway, amygdala activation to fear faces meets most of the principles of automaticity—that is, it is independent of attention and it is obligatory—with certain limitations for highly demanding attention tasks (Pessoa et al., 2002). Future research will need to determine the characteristics and range of these limitations. To date, most, but not all, of the available research supports the affective primary hypothesis, at least for the processing of threat stimuli. In most situations, the amygdala enables preferential processing of stimuli that are emotional and potentially threatening, thus ensuring that information of importance to the organism is more likely to influence behavior.

Another study seeking to determine whether the amygdala modulates the facilitation of attention with emotion made use of the phenomenon known as the **attentional blink** (discussed in Chapter 3). The attentional blink is a brief loss of attention that occurs when a second visual stimulus appears very quickly, perhaps a few hundred milliseconds, after the first one (Chun & Potter, 1995). (Proofreaders must guard against attentional blink, or they will miss a second error that falls soon after an earlier one.) An attentional blink test might employ a string of 15 words as stimuli that are presented very quickly, about one every 100 milliseconds. If the experimenter tells participants that they only have to attend to and report the second of two target words, which are printed in a different color of ink from the rest of the words, participants are generally successful—unless the second target word is presented soon after the first target word. It is almost as if noticing and encoding the first target word creates a temporary refractory period during which it is difficult to notice and report the second target word. It is as if attention blinked.
To investigate the role of the amygdala in the facilitation of attention, the emotional salience of the second target word was altered. When the second target word was an emotional, arousing word, participants were more likely to report it (Anderson et al., 2005). In other words, emotion facilitated processing and decreased the attentional blink. Consistent with the “face in the crowd” studies reported earlier, this result suggests that when attentional resources are limited, emotional stimuli reach awareness more readily than non-emotional stimuli. This study was also conducted with patients who had suffered damage to the amygdala (A. K. Anderson & Phelps, 2001). These patients showed no difference in the attentional blink effect for emotional words versus neutral ones, which offers further evidence that the amygdala is modulating this enhanced awareness for emotional stimuli.

The idea that specific neural systems give rise to the enhanced attentional and perceptual processing of emotional stimuli is consistent with a psychological model suggested in the early years of the twentieth century (Wundt, 1907). This is the affective primacy hypothesis, which proposes that emotional stimuli are processed relatively automatically, making fewer demands on limited cognitive resources than do other types of stimuli. The findings from the attentional blink study, as well as recent research demonstrating enhanced detection of emotional stimuli in the neglected field of patients with attentional neglect (Vuilleumier & Schwartz, 2001; see Chapter 3), provide support for this early psychological theory.

Although the amygdala appears to be involved in the facilitation of attention by emotion, it must interact with brain systems underlying attention and perception to accomplish this. Two mechanisms have been proposed to explain the amygdala’s influence on attentional and perceptual processes. The first suggests that through learning the actual cortical representation of emotional stimuli is altered to allow for enhanced perception of emotional events (Weinberger, 1995). Evidence for this effect has been demonstrated with fear conditioning in rats by showing that the processing of neurons that have receptive fields for different tone frequencies is altered to enhance perception of the frequency used as the conditioned fear stimulus. In humans, neuroimaging studies have reported enhanced auditory cortex activation for a tone used as a conditioned stimulus during fear conditioning (Morris et al., 2001a). In addition, words that have an emotional meaning elicit greater activation in the lingual gyrus (A. K. Anderson, 2004), a region thought to be involved in the representation of words (Booth et al., 2002). Although these neuroimaging studies in humans do not prove that emotion, via the amygdala, plays a causal role in creating lasting changes in the cortical representation of stimuli, they are consistent with the studies of rats observing this effect (Weinberger, 1995).

The other proposed mechanism for the facilitation of attention by emotion is a faster, more transient modulation of perceptual processing. There are connections from the amygdala and sensory cortical processing regions, such as the visual cortex (Amaral et al., 1992) (Figure 8-14). It is hypothesized that the amygdala, which receives input about the emotional significance of a stimulus early in processing, provides rapid feedback to sensory cortical areas of the brain, thus enhancing other perceptual and attentional processes. Consistent with this model, several neuroimaging studies have demonstrated enhanced activation in visual cortex for
emotional stimuli (e.g., Kosslyn et al., 1996; Morris et al., 1998). The strength of this activation response in the visual cortex is correlated with the strength of amygdala activation to these same stimuli (Morris et al., 1998). Researchers have attempted to determine whether the enhanced response in the amygdala for fear faces is causally related to the enhanced response in the visual cortex. Neuroimaging techniques demonstrated that damage to the amygdala eliminates the enhanced visual cortex response normally observed for fear faces (Vuilleumier et al., 2004). By combining neuroimaging and studies of patients with brain damage, researchers have provided strong support for the conclusion that the amygdala’s transient modulation of visual processing regions underlies some of the effects of emotion on attention and perception.

Through these two mechanisms—a lasting change in the cortical representation for stimuli linked to emotion and a transient enhancement of sensory cortical processing—the amygdala can alter the processing of incoming information to produce increased vigilance in the presence of threat (Whalen, 1998). Both these mechanisms highlight emotion’s influence on perceptual regions, such as visual and auditory cortex, as opposed to other brain regions that are thought to underlie the allocation of attention (Corbetta & Shulman, 2002). A growing body of evidence suggests that many observed effects of attention are linked to enhanced perception (Carrasco, 2004) and enhanced processing in perceptual brain regions that occur with attention (Polonsky et al., 2000). Consistent with the notion that emotion enhances activation in visual processing regions, thus facilitating awareness and identification of emotional stimuli, a recent study found enhanced contrast sensitivity for stimuli paired with a fear face (Phelps et al., in press). Contrast sensitivity—the ability to detect subtle gradations of gray—is known to arise from the functioning of the primary visual area (Carrasco, 2004). These results suggest that emotion can actually enhance how well we see.

The studies showing that emotion can facilitate attention demonstrate that the line between attention and perception can be fuzzy. The facilitation of attention...
emotion apparently is the result of mechanisms by which emotional stimuli receive priority in perception. Models of the neural mechanisms underlying emotion, attention, and perception support this interpretation.

**Comprehension Check:**

1. What are two ways in which emotion can influence attention?
2. Describe how the amygdala may play a role in the modulation of attention or perception by emotion.

**Revisit and Reflect**

1. **How have researchers defined emotion to allow scientific investigations of the interactions of emotion and cognition?**
   Although we all have an intuitive sense of what emotion is, finding a precise definition of emotion is challenging. Emotion is often described as the range of relatively brief reactions (including facial expression, bodily responses, and subjective evaluation) that occur in response to a significant internal or external event. In this way, emotion has been differentiated from mood, attitudes, and motivation—all of which involve affective responses and can influence cognition. Researchers interested in studying the impact of emotion on cognition have generally considered either basic emotions or the dimensions of emotion. Basic emotions are reflected in distinctive in facial expressions, in happiness, sadness, disgust, fear, anger, and surprise. Dimensional accounts reflect either specific qualities of the emotion response (valence and arousal) or the motivational state (approach versus withdrawal) elicited by an event.

**Think Critically**

- Can either the “basic emotions” or the dimensional approach to emotion capture the complexity of emotion you experience in your life?
- How would you know whether an animal or insect is experiencing an emotion? What kind of behavioral cues would lead to your conclusion?

2. **What techniques are typically used to manipulate and measure emotion in the laboratory?**

Researchers have used a range of different techniques to invoke and assess emotion. The most common way to manipulate emotion is to present emotionally evocative stimuli. Techniques to measure emotion include both direct and indirect assessments. An affective response can be assessed directly by simply asking the participants to indicate their subjective experience. Two common indirect, physiological measures of emotion are the skin conductance response, which measures mild sweating that occurs with autonomic nervous system arousal, and potentiating startle, which reflects a reflex response that is modulated by emotion. In the brain, these different assessments of emotion have been shown
to reflect distinct neural pathways. Although direct and indirect measures of an emotional reaction may be similar, they reflect (at least partly), distinct components of emotion.

Think Critically

- Reflecting on your experience in the past week, how have you tried to manipulate or assess emotion in a social situation? What did you do?
- To what extent do you think your body’s response to an emotional event is consistent or inconsistent with your subjective emotional experience? Why do you think this is so?

3. **What are the means by which stimuli can acquire emotional properties and how is this emotional learning expressed?**

Although there are some stimuli in the environment that naturally elicit an emotional reaction, such as an electric shock, most stimuli and events that elicit an emotional reaction have acquired their emotional properties through learning. These secondary reinforcers are neutral stimuli that acquire emotional properties by being associated with an emotion event (money is a classic example of a secondary reinforcer). This association can occur through a number of means. Directly pairing neutral and emotional events, without any action by the participant, is classical conditioning. Instrumental conditioning occurs when a neutral stimulus signals an action that will lead to reward or punishment. We can also learn about the emotional properties of an event without actually experiencing positive or negative outcomes through social means, by verbal instruction or by observation of another’s experience. Emotional learning can be expressed directly, through the subjective evaluation of stimuli paired with emotional events (for example, how much do you like this person?), or indirectly, through autonomic reactions to these stimuli (for example, does your heart race when you see this person?). Studies of both normal people and patients with brain damage suggest that direct and indirect measures may reflect partially independent emotional learning mechanisms.

Think Critically

- If you were to run into someone with whom your relationship ended badly, what range of emotional reactions might you expect to have? How might you expect these different reactions to change if you ran into this person every day for a week?
- What are some cultural symbols (money is one) that have come to acquire emotional properties? How did these symbols become emotional?

4. **How does emotion alter our ability to remember?**

It has long been known that emotion can influence memory; recently, researchers have helped to specify exactly how this occurs. Probably the most widely investigated effect of emotion on memory is arousal’s influence on memory accuracy. Through the amygdala’s modulation of memory consolidation in the hippocampus, an arousal response helps ensure that emotional events are likely to be
remembered. However, if this arousal response becomes prolonged (extreme stress), emotion can have the opposite effect; that is, it can impair memory performance through changes in the hippocampus.

In addition, researchers have found that mood during memory retrieval can alter which information is likely to be retrieved. And research on memory for emotional public events suggests that emotion can have an independent effect on the subjective sense of remembering. Emotional events are often recollected with a high sense of confidence and detail, even when these recollections are not completely accurate. These studies suggest that our sense of how accurate our memories are for emotional events may not reflect actual accuracy to the same degree as do our memories for neutral events.

**Think Critically**

- What were you doing on a specific day of high significance, public or private? How confident are you in the accuracy of your memory? If you can, check the details of your memory with someone also involved. Do both of you have the same memories of the events of that day?
- The last time you were sad, what kind of things did you remember? Are they different from memories that came to mind when you were in a better mood? How so?

5. **How does emotion change attention and perception?**

Emotion can influence attention in two different but related ways. Emotional events in the environment are more likely to enter awareness than are neutral events. The evolutionary reasons for this are clear: emotional events may signal threat, and so we should be especially attuned to these events. However, when something emotional is in the environment, this stimulus might capture attention and make it harder to focus on nonemotional aspects of the situation. In this way, emotion can sometimes impair performance on attention tasks, specifically when the task requires attention to nonemotional aspects of the stimulus.

The brain mechanisms underlying the influence of emotion on attention highlight the role of the amygdala in modulating processing in the visual cortex. This modulation of processing in perceptual areas of the brain may result in enhanced perception for emotional stimuli.

**Think Critically**

- Mr. Spock in the *Star Trek* television series was supposed to be half human and half Vulcan—and his Vulcan side, governed solely by reason and logic, dominated. He was uninfluenced by emotion. How did his interactions with the environment differ from yours? In an emergency situation how might Spock perform better than you? How might his reactions suffer?
- If emotion influences perception and attention, how would you expect other cognitive functions, such as memory and reasoning, to be altered as a consequence?