

## CHAPTER 33

# MEMORY AND EMOTION

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Although the concept of memory has existed for thousands of years, its systematic study was launched in the 1880s by the seminal experiments of the German philosopher Hermann Ebbinghaus (1885/1962). Through careful assessments of his own memory, Ebbinghaus forged the way for the field of memory research by demonstrating that humans' ability to retain information over time could be studied scientifically. It is telling that Ebbinghaus's studies involved the intentional memorization of nonsense syllables: He believed that to understand memory processes, one should study retention of information void of meaning or personal importance. Although memory researchers seemed to embrace Ebbinghaus's views on this issue for nearly a century, recent decades have seen increased emphasis on examining memory for personally important experiences and for events that evoke emotional reactions.

Throughout this chapter, we use terms like "emotional stimuli" as a shorthand to denote information in the environment that elicits a rapid change in the internal, affective state of the organism. The focus of this chapter is on how these internal changes influence memory. Affective responses are often described within a two-dimensional space consisting of arousal (the subjective feeling of excitation or the physiological response evoked) and valence (the pleasure or displeasure experienced; see Feldman Barrett & Russell, 1999; Russell, 1980). In this chapter, we focus on episodic memory, or consciously accessible memories of

past events. We first describe how the arousal of a response can affect memory, and we then describe how the valence of an affective response can affect the way the event is remembered.

We consider how each of these aspects of an affective response can influence the likelihood of remembering an event, the vividness with which the event is remembered, and the details retained about the event. In each section, we present the behavioral data and cognitive theories of emotional memory, and we also discuss the relevant neuroimaging and neuropsychological research that has been influential in examining the extent to which memory for emotional experiences is supported by processes distinct from those that support memory for nonemotional events. The neuroimaging studies also have helped to pinpoint the effects of an affective response on the initial creation of a mnemonic representation and on the eventual retrieval of that information. We highlight the general conclusions that have emerged from the research, and note some of the ongoing debates and open questions that remain.

### **The Influence of Emotional Arousal on Episodic Memory**

Not all memories come to mind with equal ease. Moments that elicit arousal often are remembered disproportionately well, with higher recall rates for positive arousing or negative arousing stimuli

than for neutral stimuli (reviewed by Buchanan & Adolphs, 2002; Hamann, 2001). This finding was anticipated by William James (1890) when he stated, “An experience may be so exciting emotionally as almost to leave a scar upon the cerebral tissues” (p. 670), and the propensity to remember arousing experiences has been documented across a variety of experiments, using words, sentences, pictures, narrated slide shows, and autobiographical memories (reviewed by Berntsen & Rubin, 2002; Buchanan, 2007). These benefits can be particularly pronounced when examining a person’s ability to remember information over long delays (Quevedo, Sant’Anna, & Madruga, 2003; Revelle & Loftus, 1992), likely because of the cumulative effects of emotion on both the encoding and also the consolidation phases of memory.

Although the enhancement of memory by arousal is not always seen in the quantity of information retrieved (see Bennion, Ford, Murray, & Kensinger, 2013, for a discussion), in many of these instances there are still other signatures of memory enhancement present, such as an increased feeling of reexperience or memory vividness. In this section, we examine the processes that give rise to memories for arousing experiences, first presenting behavioral evidence that high-arousal information is more likely to be remembered with subjective vividness and with select details, and then describing the encoding and retrieval processes that may convey those benefits.

### **Emotional Arousal Enhances Memory Vividness**

People claim to remember where they were and what they were doing when they learned of the assassination of President Kennedy (Brown & Kulik, 1977; Christianson, 1989; Winograd & Killinger, 1983), the September 11th terrorist attacks (Budson et al., 2004; Hirst et al., 2009; Paradis, Solomon, Florer, & Thompson, 2004; Pezdek, 2003; Smith, Bibi, & Sheard, 2003), or the explosion of the space shuttle *Challenger* or *Columbia* (Bohannon, 1988; Kensinger, Krendl, & Corkin, 2006; Neisser & Harsch, 1992). These details are not always accurate (as we expand upon later in this section), but what remains noteworthy about the memories is that individuals reexperience them with tremendous vividness. Memory for these arousing events is more likely to be associated with the auto-noetic consciousness that defines an episodic memory (Tulving, 1985).

Extremely vivid memories—coined “flashbulb memories” by Brown and Kulik (1977)—form only rarely, yet many studies have confirmed that individuals often remember emotionally arousing stimuli in a more vivid manner than nonarousing stimuli (e.g., Conway, 1990; Kensinger & Corkin, 2003; Rubin & Kozin, 1984; Schaefer & Philippot, 2005). Even for “micro-events” or stimuli presented relatively briefly within a laboratory setting, when individuals are asked not only whether they recognize having seen those micro-events before, but also whether they vividly “remember” their prior occurrence, rates of “remembering” tend to be much higher for arousing pictures or words than for nonemotional ones (Dewhurst & Parry, 2000; Kensinger & Corkin, 2003; Ochsner, 2000; Sharot, Delgado, & Phelps, 2004). This boost in the ability to vividly remember emotional information often occurs even when overall recognition rates are equivalent for emotional and neutral information (e.g., Ochsner, 2000; Sharot et al., 2004).

### **Emotional Arousal Leads to Selective Memory Benefits**

It is important to emphasize that arousal leads to *selective* memory benefits. Although arousing events are typically remembered more vividly than nonarousing events, they are not remembered with complete detail (e.g., Levine & Edelstein, 2009; Mather & Sutherland, 2011; Phelps & Sharot, 2008). Some details are likely “lost” during the initial processing of the event, never becoming part of a memory representation. Even Brown and Kulik (1977) realized that arousal does not lead to a memory that is truly picture-perfect, because some aspects of the event might never be recorded. They stated, “An actual photograph, taken by flashbulb, preserves everything within its scope; it is altogether indiscriminate . . . a flashbulb memory is only somewhat indiscriminate and is very far from complete. In these respects, it is unlike a photograph” (p. 75). Other details appear to be encoded at the time of an event’s occurrence and then later forgotten or distorted. While Brown and Kulik (1977) believed that recollections of surprising and consequential events would be immune to memory distortion or disruption, such that all the information that was encoded would be maintained in memory, numerous studies since have demonstrated that emotional memories are prone to significant forgetting and distortions over time. Individuals often report high confidence in

so-called flashbulb memories despite low consistency in their reports over time, and there often is little or no correlation between how confident individuals are about their memories and how accurate or consistent their memories are (Neisser & Harsch, 1992; Schmidt, 2004; Schmolck, Buffalo, & Squire, 2000; Talarico & Rubin, 2003). Clearly, emotional events do not leave indelible traces.

Some have argued that arousal provides no benefit to memory for detail, enhancing the *feeling* of vividness without elevating the *amount of content* included in the memory trace (e.g., Sharot et al., 2004). As evidence has accumulated, however, a more likely proposal seems to be that arousal provides *selective* memory benefits. It does not enable the formation of a memory that includes all event details; rather, it increases the likelihood that select components of an experience are remembered. Debates still continue about how best to characterize the event features that are most likely to be incorporated into a memory for an arousing event (e.g., Kensinger, 2009; Mather & Sutherland, 2011). As reviewed by Levine and Edelman (2009), these details have been described as those that capture attention; are perceptually, temporally, or conceptually integral to the emotional event; or are goal relevant (see Levine & Edelman, 2009, table 1, p. 13). What is generally agreed upon, however, is that arousal leads to enhanced memory for some select details from the event and not others.

If arousal leads only to selective memory benefits, then the disconnection between an individual's reported confidence or vividness in a memory and the objective assessments of his or her retrieval of detail may stem from two primary factors. First, individuals may ascribe vividness or confidence not only by the number of details remembered but also by the richness or ease with which some details come to mind (see Phelps & Sharot, 2008, for a discussion). Thus, if some details come to mind easily or vividly, an individual may give a high vividness rating to the memory as a whole, or may even give an inflated rating for other event details, assuming that all event details have been retained well. Second, for many events, arousal may play a larger role in the maintenance of internal details, such as the affect experienced at the time of the event, and a lesser role in the maintenance of details that can be objectively measured, such as where, when, and how an event unfolded. Participants may report a vivid memory based on their retention of internal details, yet these internal details may provide little aid in answering questions about the objective details of the event.

### ***The Neural Mechanisms through Which Emotional Arousal Enhances Memory***

When Brown and Kulik (1977) first described "flashbulb memory," they linked these memories to Robert Livingston's (1967) "now print" theory, proposing that there was a special memory mechanism that was induced for these events, permanently "printing" them into an accessible memory trace. Perhaps because of this history, researchers have focused intensively on whether arousal enhances memory via the engagement of special mechanisms, or whether arousal simply intensifies the same processes that allow vivid remembering of nonarousing information. Although parsimony favors the hypothesis that the same processes are recruited to remember arousing and nonarousing information, there is evidence that arousal may trigger a cascade of processes not typically engaged for nonarousing information. Behavioral evidence for such a distinction comes from studies that have asked participants to encode arousing and nonarousing information while performing a secondary task. For example, Kensinger and Corkin (2004) asked participants to study words either with full attention devoted toward the encoding task or with attention divided between the encoding task and a secondary, sound-discrimination task. The addition of the secondary task impaired the likelihood of recognizing nonarousing words and reduced the vividness with which the nonarousing words were remembered, whereas it did not have a large effect on the recognition rates or vividness of memories for the arousing words (see also Bush & Geer, 2001). This finding is consistent with proposals that emotional information is privy to prioritized or relatively automatic processing (reviewed by Dolan & Vuilleumier, 2003) and suggests that arousal can modulate memory even in the absence of the elaborative processes that typically enhance memory.

Lesion studies suggest that many of the effects of arousal are critically tied to the engagement of the amygdala, an almond-shaped region of the medial temporal lobe. Patients with damage to the amygdala do not show a memory boost for arousing information: Although they are not amnesic, they are no more likely to remember arousing events than they are to remember neutral ones. The absence of the memory enhancement for arousing information has been reported in patients with focal amygdala damage (e.g., Adolphs, Cahill, Schul, & Babinsky, 1997; Brierley, Medford, Shaw, & David, 2004; Cahill, Babinsky, Markowitsch, &

McGaugh, 1995; Markowitsch et al., 1994) and in individuals with amygdala atrophy caused by Alzheimer's disease (e.g., Abrisqueta-Gomez, Bueno, Oliveira, & Bertolucci, 2002; Kensinger, Brierley, Medford, Growdon, & Corkin, 2002; Kensinger, Anderson, Growdon, & Corkin, 2004).

The amygdala-mediated effects of emotion on memory seem to be tied to noradrenaline release. Adrenergic agonists enhance memory (Soetens, Casaer, D'Hooge, & Huetting, 1995), adrenergic blockade reduces memory (Cahill, Prins, Weber & McGaugh, 1994; Strange & Dolan, 2004), and individuals with a genetic variant that is thought to increase the availability of noradrenaline show a greater enhancement of emotional memory (de Quervain et al., 2007). The effects of adrenergic modulation on memory are particularly pronounced for emotional information (e.g., Segal & Cahill, 2009)—and in fact, are often absent for neutral information—possibly because amygdala activity in the absence of noradrenaline is insufficient to modulate hippocampal activity (Anderson, Yamaguchi, Grabski, & Laeka, 2006; Onoda, Okamoto, & Yamawaki, 2009; Segal, Stark, Kattan, Stark, & Yassa, 2012).

While these studies have demonstrated the necessary contribution of the combination of adrenergic responses and amygdala engagement to arousal-mediated memory enhancements, neuroimaging methods have provided further clarity with regard to the stages of memory at which arousal yields its effects. Researchers can examine the neural processes engaged at the moment that a subsequently remembered stimulus is processed, or can assess the processes engaged at the moment of retrieval. Neuroimaging studies can also elucidate the extent of overlap between the processes that give rise to memories for arousing stimuli and those that support memories for nonarousing information.

#### **Encoding Processes Contributing to Memory for Arousing Events**

Neuroimaging studies using a subsequent-memory design, sorting neural engagement during encoding on a post hoc basis into subsequently remembered and subsequently forgotten stimuli (e.g., Wagner et al., 1998), have demonstrated that the amygdala plays a fundamental role during the encoding of high-arousal information. Amygdala activity is stronger for arousing items that are subsequently remembered than for items that are subsequently forgotten (reviewed by Hamann,

2001; Phelps, 2004; Kensinger, 2009). Moreover, the individuals who show the greatest amygdala activity during the viewing of arousing items are those who show the greatest emotional memory enhancement (Cahill et al., 1996) and remember arousing stimuli vividly (Kensinger & Corkin, 2004). For nonarousing stimuli, amygdala activity at encoding typically does not relate to memory (e.g., Kensinger & Corkin, 2004), suggesting that the amygdala guides memory only in the presence of an arousal response.

It is important to note that activation of the amygdala leads to *selective* memory benefits. Amygdala activation during encoding does not enable the formation of a memory that includes all event details; rather, it increases the likelihood that select components of an experience are remembered (reviewed by Kensinger, 2009). Amygdala activity tracks with the likelihood of remembering the emotional content from a scene (e.g., a snake) but not with the ability to remember the nonemotional context within that scene (e.g., the forest in which the snake was located; Waring & Kensinger, 2011) or with other contextual details such as the encoding task participants performed while viewing a scene (Dougal, Phelps, & Davachi, 2007; Kensinger & Schacter, 2006a; Kensinger, Addis, & Atapattu, 2011).

Although the amygdala only enhances memory for select event details, its activity at encoding does tend to correlate with a vivid memory upon subsequent retrieval. Amygdala activity during encoding corresponds with the likelihood that people will claim to vividly “remember” an event (Dolcos, LaBar, & Cabeza, 2004; Kensinger & Corkin, 2004; Mickley & Kensinger, 2008), and the greater the amygdala activity during encoding, the greater the vividness that people will later ascribe to an emotional memory (Kensinger et al., 2011).

Arousal does, then, lead to some “special” memory mechanisms, insofar as the relation between the amygdala and memory performance is specific to arousing stimuli. The amygdala, however, does not act in isolation and does not appear to store the memories for arousing information, as evidenced by the fact that amygdala damage does not lead to amnesia (Zola-Morgan, Squire, Alvarez-Royo, & Clower, 1991). Instead, the amygdala appears to exert its influence largely through its modulation of other regions, most of which are implicated in the processing and retention of nonarousing stimuli as well. It has long been proposed that the amygdala interacts with regions of the cortex to modulate memory (Gerard, 1961). The amygdala

is one of the most extensively connected subcortical regions of the brain, with links to numerous cortical and subcortical regions (Amaral, Price, Pitkanen, & Carmichael, 1992; Amaral, 2003). It is, therefore, in an excellent position to modulate functioning throughout many networks. A meta-analysis of emotional memory encoding (Murty, Ritchey, Adcock, & LaBar, 2010) emphasized the role of not only the amygdala, but also other medial temporal lobe regions typically implicated in successful encoding, including the hippocampus and parahippocampal gyrus, as well as the visual, prefrontal, and parietal cortices.

Lesion and neuroimaging evidence have confirmed that the amygdala can modulate the functioning of the sensory cortices. In one study investigating the links between amygdala activity and visual attention, patients with varying amounts of amygdala damage were scanned while they performed a task in which they had to attend to fearful or neutral faces (Vuilleumier, Richardson, Armony, Driver, & Dolan, 2004). Individuals with intact amygdala showed enhanced activity in the fusiform gyrus (a visual processing region) when they attended to fearful faces as compared with neutral faces. Patients with extensive amygdala damage did not show this pattern: They showed equivalent fusiform activity for neutral and fearful faces. Moreover, the amount of amygdala preservation corresponded with the amount of fusiform modulation based on the emotional content of the attended faces. These results suggest that the amygdala can modulate visual processing in humans, increasing the likelihood that an emotional item in the environment is detected and attended.

In addition to these influences on sensory processes, a number of neuroimaging studies have provided evidence for amygdalar modulation of mnemonic processes, suggesting that interactions between the amygdala and the hippocampus serve a critical role in modulating the memory enhancement for emotional information in humans (reviewed by McGaugh, 2013). In healthy individuals, there are strong correlations between the amount of activity in the amygdala and in the hippocampus during the encoding of emotional information (e.g., Dolcos et al., 2004; Hamann, Ely, Grafton, & Kilts, 1999; Kensinger & Corkin, 2004; Kensinger & Schacter, 2005a). Although these correlations cannot speak to the direction of modulation, a neuroimaging study examining encoding-related neural activity in patients with varying amounts of amygdala and hippocampal damage provided evidence for the importance of reciprocal connec-

tions. While in the scanner, patients were asked to encode a series of emotionally aversive and neutral words. Outside of the scanner they performed a recognition task and the encoding trials were sorted on a post hoc basis into those words that were later remembered and those that were later forgotten. The critical finding from the study was that the extent of amygdala atrophy correlated negatively with the magnitude of activity in the hippocampus during the encoding of emotional information, and the amount of hippocampal atrophy also was inversely related to amygdala activity (Richardson, Strange, & Dolan, 2004). Thus, bidirectional connections between the amygdala and the hippocampal system may be important for modulating the encoding of emotional information (see also Kilpatrick & Cahill, 2003).

Ongoing research continues to distinguish the effects triggered by each component of an arousal response, including effects on visual attention and sensory modulation by the amygdala (Dolan & Vuilleumier, 2003; Talmi, Anderson, Riggs, Caplan, & Moscovitch, 2008), and interactions between the amygdala and the hippocampus (reviewed by McGaugh, 2004; Phelps, 2004). The relative contribution of each may also depend on the delay after which memory is being assessed. A long-lasting memory results from a cascade of processes, begun during the initial encoding of the event, and continued as the event is consolidated in memory (Mueller & Pilzecker, 1900). The ultimate effects of arousal on memory, therefore, reflect a culmination of the processes engaged both as the event is initially experienced and in the time that intervenes until retrieval. An active topic of current research is to understand how the effects of arousal on memory unfold over this time course. For instance, Talmi and colleagues (2008) reported that interactions between the amygdala and fusiform gyrus during encoding may explain why emotional information is remembered well after shorter delays, whereas interactions between the amygdala and regions of the hippocampal system may become more important for explaining the enhancement in memory for emotional information after longer delays.

#### *Retrieval Processes Contributing to Memory for Arousing Events*

Arousal continues to affect memory through its influences at the moment of retrieval. Just a decade ago, it was unclear whether the amygdala was activated during the retrieval of arousing events

(see Damasio et al., 2000; Reiman et al., 1997), but since then, evidence has accumulated to implicate the amygdala in the retrieval of arousing experiences (Daselaar et al., 2008; Dolcos, LaBar, & Cabeza, 2005; Fink, Markowitsch, & Reinkemeier, 1996; Kensinger & Schacter, 2005b; Markowitsch et al., 2000; Greenberg et al., 2005). Just as during encoding, enhanced connectivity between the amygdala and the hippocampus may aid in the retrieval of arousing events (Dolcos et al., 2005; Greenberg et al., 2005; Sharot et al., 2004; see also Addis, Moscovitch, Crawley, & McAndrews, 2004).

In an attempt to better pinpoint the nature of the contribution of amygdala engagement to retrieval, some neuroimaging research has used a protracted retrieval trial to distinguish the *search* phase, as a person attempts to retrieve content related to an internal or external cue and to monitor the success of the attempts, from the *elaboration* phase, as a person expands upon the content retrieved. Enhanced amygdala activity appears to aid the recovery of information during the search phase (Daselaar et al., 2008; see also Markowitsch et al., 2000), with amygdala activity occurring early on, even before people retrieve a memory in full. The hippocampus is also more strongly engaged during the search for an emotional event compared with a neutral event (Daselaar et al., 2008; Ford, Morris, & Kensinger, in press); this difference arises even when the retrieval cue is always neutral (Ford et al., in press), suggesting that hippocampal activity is modulated by the emotional content of the information that is associated with a cue, even before that information has been fully recovered.

The role of the amygdala may extend beyond that initial search phase, to enhance the feeling of reexperience (Sharot et al., 2004). Amygdala activity is greater when people are asked to remember the emotional content of an event as compared with other event details (Smith, Stephan, Rugg, & Dolan, 2006). Amygdala activity is also greater in individuals who have stronger emotion associated with a retrieval cue (Sharot et al., 2004), and the amygdala activity correlates with the degree of reported reexperience of the event (Denkova, Dolcos, & Dolcos, 2013). Just as remembering a sound can reactivate auditory cortex (e.g., Buckner & Wheeler, 2001), so might remembering an emotion reactivate the amygdala.

A study that investigated emotional memory in patients with amygdala damage supports the conclusion that the amygdala is involved in both memory search and also in the reexperience of

emotion (Buchanan, Tranel, & Adolphs, 2005). Patients with and without amygdala damage were asked to recall events that occurred prior to their brain damage. Because the medial temporal lobes had been intact at the time of the event and for some period of time thereafter, atypical features of their memory were likely to be connected to the retrieval phase rather than to the encoding or initial consolidation phases (although contributions of long-lasting consolidation processes cannot be ruled out). The patients with amygdala damage were less likely to retrieve memories of unpleasant events, and when they did retrieve those unpleasant events, they rated them as less intense. These findings are consistent with the neuroimaging evidence that the amygdala helps with the search and recovery of arousing memories (such that amygdala damage reduces the likelihood that arousing events will be remembered) and also participates in the reexperience of emotion during retrieval (such that the intensity of reexperienced affect is reduced with amygdala damage).

As during encoding, the amygdala engagement during retrieval is likely to modulate many processes, not only those within the medial temporal lobe. Arousing events are often associated with more retrieval activity within visual cortices (Piefke, Weiss, Zilles, Markowitsch, & Fink, 2003; Van Strien, Langeslag, Strekalova, Gootjes, & Franken, 2009), perhaps reflecting the recovery of sensory information, and within frontal regions, perhaps reflecting the thematic elaboration or online maintenance and reliving of the event (see Daselaar et al., 2008; Greenberg et al., 2005, for more discussion).

### **Summary of Effects of Arousal on Memory**

Arousal often enhances the likelihood of remembering an event and, even when it does not affect this quantitative assessment of memory, it still tends to alter the subjective quality of memory. Memories of high-arousal experiences tend to be more vivid than memories of low-arousal events. These effects of arousal seem critically tied to the combined activation of the adrenergic system and engagement of the amygdala during the initial encoding of an event. This combination enables the modulation of the hippocampal memory system as well as prefrontal and sensory cortices, enhancing the likelihood that a memory is created and that the trace includes some types of details that will enable the recovery of a rich memory trace. The amygdala participates in retrieval as well, and

it appears that the amygdala may again modulate these same systems to aid in the search and recovery of information from memory.

### **The Influence of Emotional Valence on Episodic Memory**

Although some of the research examining the effects of arousal on memory has focused only on negative high-arousal stimuli and has excluded positive information, the general pattern of results discussed in the previous section has been found to hold for all high-arousal stimuli, regardless of their valence. A topic of ongoing investigation is the extent to which the valence of an event (whether it elicits positive or negative affect) influences the memory for that event. To assess the effects of valence, researchers often have contrasted memory for positive and negative stimuli, rated to be equally high in arousal. If different memory patterns are associated with the positive and the negative events, then these differences have been attributed to the valence of the events. In the sections below, we outline what this research has revealed about the effects of valence on the likelihood of remembering an event and on the quality of the memory. We also describe the neural mechanisms that may relate to these effects of valence.

#### **Effects of Valence on the Quantity and Quality of Information Remembered**

When examining the effects of valence on the likelihood of remembering information, virtually every conceivable outcome has been observed. Often, the boost in recall or recognition is comparable for positive and negative stimuli (e.g., Adelman & Estes, 2013; Bradley, Greenwald, Petry, & Lang, 1992; Kensinger et al., 2002). In some studies, particularly those assessing memory for verbal or pictorial stimuli presented within a laboratory setting, negative items are more likely to be recalled than positive ones (e.g., Keightley, Chiew, Anderson, & Grady, 2011). Yet other studies, generally those assessing memory for autobiographical experiences or information encoded in reference to the self, have revealed the opposite pattern: a greater tendency to recall positive events than negative ones (e.g., D'Argembeau, Comblain, & van der Linden, 2005; Linton, 1975; Matt, Vazquez, & Campbell, 1992; White, 2002), sometimes referred to as the *Pollyanna effect* (Matlin & Stang, 1978).

Some of these conflicting findings may be explained by the proposal that memory mechanisms have evolved to facilitate the encoding and retrieval of the affective information that is most relevant to one's goals (Lazarus, 1991; LeDoux, 1996). Remembering a negative experience often may be relevant to survival (see Nairne, Pandeirada, & Thompson, 2008, for evidence that memory is better for survival-relevant information) or well-being, because reexperiencing the event will help a person plan for (or avoid) its future reoccurrence (LeDoux, 1996). In these instances, more attention may be paid to the negative item, thereby enhancing memory for this negative information. However, there likely are instances in which positive events are just as relevant, or more relevant, to one's goals as negative events. Indeed, when positive and negative stimuli are equally related to one's current concerns, they show similar capture of attention (Riemann & McNally, 1995). Furthermore, there is some evidence that individuals (e.g., older adults) who seek positive goal states show enhanced attention toward positive as compared with negative stimuli and also enhanced memory for positive events (reviewed by Mather & Carstensen, 2005).

For autobiographical memories, a related possibility is that there is a memory benefit for the valence of information most likely to be processed in a self-referential fashion. Positive experiences may be more likely to be integrated into a person's conception of themselves (see Matlin & Stang, 1978) and, thus, to be remembered. Negative experiences may be better remembered when individuals are focused instead on other-perception rather than on self-referential processing (e.g., Dreben, Fiske, & Hastie, 1979; Skowronski & Carlston, 1987), or when individuals are depressed and, therefore, have a more negative self-concept (Dalglish & Watts, 1990).

The findings discussed so far suggest that the differential effects of valence may be mediated by effects separate from the affective response. These findings emphasize the need to consider more than just arousal when examining the influence of positive and negative affect on memory. If positive and negative experiences differ in their self-relevance or in their relation to an individual's motivational state or goals, then these differences could underlie effects that would otherwise be attributable to valence. Indeed, recent debates center on whether valence—or other factors often connected to valence—best explain the effects on memory (see

Sakaki, Niki, & Mather, 2012; Levine & Edelstein, 2009).

There is evidence, however, to suggest that the valence of a response may directly influence the way in which an event is processed and remembered. According to the “affect-as-information” framework (e.g., Schwarz & Clore, 1983, 1988, 1996; Clore et al., 2001), the way we feel can alter the way that we process information. Positive affect may promote the reliance on heuristic schemas (see Mandler, 1984; Rumelhart, 1980, for discussion of schemas), on gist-based information, and on broadly activated associative networks (see Fredrickson, 2004, for a related “broaden-and-build” theory of positive affect; and Shenhav, Barret, & Bar, 2013, for a proposal that this relation between positivity and associativity may relate to the role of the medial orbitofrontal cortex in both of these abilities). Thus, when in a good mood, we may notice the global characteristics or “big picture” of an event (e.g., Clore et al., 2001; Fiedler, 2001). Negative affect, by contrast, may elicit a greater focus on the details around us; it may narrow our attention onto those details, at times causing us to lose sight of the “big picture” (Schwarz, 1990; Storbeck, 2013; Wegner & Vallacher, 1986).

These different ways we process information can have downstream impacts on how we remember events that elicited positive or negative affect. While they may not affect the likelihood that we remember the event’s occurrence, they are likely to influence the types of details we retain about the events. Thus, effects of valence may become more apparent when we switch from assessments of the likelihood of remembering an event to assessments of the subjective vividness of an event or the details that are remembered.

A number of studies have suggested that the valence of the response elicited by the event does influence the subjective vividness of the memory. Negative events often are remembered with a greater sense of vividness than positive events (e.g., Ochsner, 2000; Dewhurst & Parry, 2000). Positive stimuli, in contrast, often are remembered with only a feeling of familiarity (e.g., Ochsner, 2000; Bless & Schwarz, 1999). Valence can also influence the likelihood that details are accurately remembered. Although the exact nature of these findings remains debated (see Kensinger, 2009), negative information may be more likely to be remembered with some types of details than positive information, perhaps because attention is focused on some details of the negative experiences.

It has been unclear to what extent these laboratory findings extend to autobiographical events infused with emotional importance. Research on autobiographical memory often has supported the opposite conclusion from laboratory research: that positive memories are more vivid than negative ones (e.g., D’Argembeau, Comblain, & van der Linden, 2003; Schaefer & Philippot, 2005). For example, Schaefer and Philippot (2005) asked participants to recall positive, negative, and neutral events and, for each, to rate the number of sensory, semantic, temporal, and contextual associations retrieved about the memory (using the Memory Characteristics Questionnaire; Johnson, Foley, Suengas, & Raye, 1988). They found that participants’ ratings were higher for positive than for negative memories, indicating greater retrieval of contextual detail for positive events. However, some studies suggest little effect of valence on memory vividness, and instead have found intensity to be the primary predictor of autobiographical memory characteristics (e.g., Talarico, LaBar, & Rubin, 2004).

A difficulty in these studies is finding positive and negative events that are comparable across a range of event dimensions (e.g., duration of event, public or private nature of event, amount of media coverage or rehearsal). Four studies have attempted to circumvent many of these difficulties by examining whether a person’s response to an event outcome (finding it positive or negative) influences what he or she remembers about the event. Levine and Bluck (2004) asked participants to indicate whether particular events had occurred during the verdict decision in the O. J. Simpson trial. Kensinger and Schacter (2006b) examined what Red Sox fans and Yankees fans remembered about the final game of the 2004 playoff series, in which the Red Sox overcame a surprising 0–3 setback in the series to win the championship. Bohn and Berntsen (2007) asked individuals to retrospectively rate their emotions and recall details regarding the fall of the Berlin Wall. Holland and Kensinger (2012) asked participants to remember details about the 2008 presidential election. All four studies found that valence affected some memory characteristics, with negative affect being more likely to enhance memory accuracy or memory for detail. Levine and Bluck (2004) found that individuals who were happy about the verdict were more liberal in accepting that something had occurred and made more memory errors than individuals who were unhappy with the verdict. Simi-

larly, Kensinger and Schacter (2006b) found that Red Sox fans, who found the outcome of the game to be positive, showed more memory inconsistencies over a 6-month period and were more likely to be overconfident in their memories than were Yankees fans, who found the outcome to be negative. In line with the suggestion that negative emotion might be linked to enhanced memory for details, Bohn and Berntsen (2007) found that those individuals who reported feeling negative about the fall of the Berlin Wall had higher memory accuracy than individuals who felt positive about the event. Holland and Kensinger (2012) similarly found that participants who were displeased with the outcome of the 2008 election remembered more details of the election night consistently over the next 6 months than those who were pleased with the outcome.

Studies that have induced participants into positive or negative moods within a laboratory setting generally have corroborated these findings. Participants are more liberal in endorsing items as ones that they have studied when they are in a good mood, and they are more susceptible to false memories when in that pleasant state (Bless et al., 1996; Park & Banaji, 2000; Storbeck & Clore, 2005). Negative mood, by contrast, makes individuals more conservative in endorsing items and reduces the propensity to inaccurately endorse items that are related (but not identical) to studied items (Storbeck & Clore, 2005; Storbeck, 2013).

The effects of valence on memory, however, may depend on the delay after which memory is assessed. Breslin and Safer (2011) tested the memories of Yankees and Red Sox fans for the 2003 and 2004 American League Championship Series, which the Yankees and Red Sox won, respectively. They tested the memories 4–5 years later and found that fans showed the most accuracy for the game that their team had won. Although the requisite longitudinal study has not yet been conducted, the contrast of the results of Breslin and Safer (2011) with those of Kensinger and Schacter (2006b), who assessed fans' memories after an approximately 6-month delay, suggests that the effects of valence on memory may change over time. Breslin and Safer (2011) attribute the different effects of valence to the rehearsal that may occur in the time between an event's occurrence and the moment of retrieval. This finding may also reflect the tendency for negative affect to fade more rapidly than positive affect (see Walker & Skowronski, 2009, for a review). Over long enough

time frames, preferential retention of positive information may also relate to age-related changes in affective focus, with an increased prioritization of positive affect (Mather & Carstensen, 2005).

The tendency for negative affect to fade more rapidly over time than positive affect is also relevant to the results of a recent study by Szpunar, Addis, and Shacter. (2012) that examined memory for simulations of future events. Participants were initially instructed to imagine positive, neutral, or negative future scenarios, each comprising a familiar person, object, and location. After delays of either 20 minutes or 24 hours, participants completed a cued recall test that provided two elements of the simulated event (e.g., person, object), and participants tried to recall the third element (e.g., location). At the short delay, participants recalled more positive and negative than neutral simulations, and there were no memory differences between the positive and negative simulations. By contrast, at the long delay, participants recalled more positive and neutral than negative simulations. In other words, there was a significant delay  $\times$  valence interaction, such that negative simulations were forgotten more quickly over time than either positive or neutral simulations. In line with research on the fading affect bias (Walker & Skowronski, 2009), Szpunar et al. (2012) suggested that the affect that serves to bind together the elements of a simulated event may dissipate more quickly for negative than positive events. Consistent with this idea, Gallo, Korthauer, McDonough, Teshale, and Johnson (2011) reported evidence for a positivity bias in memory for simulated future scenarios following a 24-hour retention interval. In light of other evidence that future simulations exhibit a general positivity bias (see Schacter, 2012; Schacter et al., 2012; Sharot, 2011, for a review and discussion) it remains to be determined whether reduced retention of negative simulations after long delays is specifically characteristic of imagined *future* events or whether it occurs more broadly for imagined events in general.

### **Neural Mechanisms Underlying the Effects of Valence on Memory**

Neuroimaging evidence has corroborated the “affect-as-information” perspective, finding evidence that the effects of valence on memory may be connected to differences in how the information is processed initially. It was noted in the section “The Influence of Emotional Arousal on Episodic

Memory” that emotion seems to increase activity in a large number of regions: not only the amygdala and other medial temporal lobe regions, but also regions in the prefrontal, parietal, and sensory cortices as well. The particular modulation of these regions may vary depending on the valence of an event. Across a few studies, the frontal and parietal regions have been more active during the encoding of positive events, while the sensory regions have been more active during the encoding of negative events (Mickley & Kensinger, 2008; Mickley Steinmetz & Kensinger, 2009). These findings are consistent with the proposal that positive affect is associated with distributed attention and a focus on the conceptual aspects of an event, while negative affect heightens the processing of sensory details.

There is some evidence that this distinction may continue during the retrieval phase, with more prefrontal engagement during the retrieval of positive autobiographical memories and more posterior, sensory activation during retrieval of negative events (Piefke et al., 2003; Markowitsch, Vandekerckhove, Lanfermann, & Russ, 2003). Recent research also suggests that regions within the hippocampal system may be differently recruited during the retrieval of positive and negative events (Denkova et al., 2013; Ford et al., 2014). A difficulty with the interpretation of many of the retrieval studies is that differences between positive and negative memories could stem from a multitude of factors, including differences in the types of content retrieved or in the effort elicited to retrieve them, in the details that become elaborated, or in the reencoding of the event. Parsing apart these effects will be a worthwhile focus of future research.

### **Summary of Effects of Valence on Memory**

There is no clear answer to whether valence affects the likelihood of retrieving an event. The answer likely depends on a number of other factors, including the relevance of the information to the person or the person’s goals. There is a clearer effect of valence on the ability to remember information vividly and with at least some detail, with negative information generally being remembered with more vividness and with at least some additional detail. These differences may relate to the different types of processing engaged while experiencing negative and positive affect, with negative affect leading to a greater processing of

sensory details and positive affect encouraging a broader scope of attention. The effects of valence on memory may also change over time, emphasizing that processes that unfold over time are likely to interact with those implemented during the initial occurrence of an event.

### **Conclusions**

In this chapter, we have reviewed the effects of arousal and valence on memory. We have described how these features of an affective response can influence the likelihood that an event is remembered, the subjective vividness with which it is remembered, and the likelihood that particular types of details are retrieved. We have emphasized the importance of considering the selective enhancements conveyed by these responses. Arousal leads to good memory for some details but not others, and valence shifts the focus from a detail-oriented processing of negative information to a more general processing of positive information. Thus, the effect of the affective response on memory will depend on the way memory is assessed and the types of information people are asked to retrieve.

We have reviewed neuroimaging and neuropsychological studies, demonstrating that the effects of arousal are connected to engagement of the amygdala and to its modulatory influence on other medial temporal lobe regions and on distributed cortical networks, including the prefrontal, parietal, and sensory regions. The effects of valence may be related to the divergent recruitment of these networks, with positive affect disproportionately recruiting the prefrontal and parietal regions, and negative affect recruiting the sensory cortices. Thus, at least in part, emotional information is remembered better than nonemotional information not because of the engagement of processes unique to memory for emotional information, but rather because of limbic modulation of the same processes that are typically recruited to remember nonemotional information.

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