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Oversimplification in the study of emotional memory

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Abstract

This Short Review critically evaluates three hypotheses about the effects of emotion on memory: First, emotion usually enhances memory. Second, when emotion does not enhance memory, this can be understood by the magnitude of physiological arousal elicited, with arousal benefiting memory to a point but then having a detrimental influence. Third, when emotion facilitates the processing of information, this also facilitates the retention of that same information. For each of these hypotheses, we summarize the evidence consistent with it, present counter-evidence suggesting boundary conditions for the effect, and discuss the implications for future research.

Keywords

affect; episodic memory; limbic system; long-term memory; recall; recognition; stress

"Emotional memory" is a shorthand phrase to refer to a memory for an event that elicits emotional reactions. These events and reactions can vary. The events may be rewarding or aversive; they may vary in intensity and time-course. These features can influence the nature of the emotional reactions. For instance, reactions to a public or personal event that unfolds over minutes or hours may include physiological responses, changes in cognitive processes, the conscious feeling of a change in affective state, and the labeling of that feeling. Reactions to an item that is presented briefly within the context of a laboratory experiment are likely to include fleeting physiological and cognitive responses, but the participant may not be aware of them.

The effects of these emotional reactions on memory are complex, yet they are often distilled to three tenets. First, the experience of emotion enhances memory. Second, when emotion does not enhance memory, this is usually because of the impairing effects of high levels of arousal. Third, when emotion facilitates an early stage of processing, this conveys benefits at a later stage. These views are pervasive because there is evidence, and often a long history, in their support. But as this review highlights, there are boundary conditions whose existence can shed light on the multifaceted nature of the effects of emotion on memory.

Emotional Enhancement of Memory: Underlying Mechanisms and Limitations

It is commonly believed that an emotional event will be remembered better than an event lacking emotion (reviewed by Buchanan, 2007 and Hamann, 2001). William James (1890) described the effect of an emotional event as "a scar upon the cerebral tissues" (p. 670), and the term 'flashbulb memories' was used to describe the purportedly permanent

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representation created for an exceptionally emotional event (Brown & Kulik, 1977). Several studies have shown that emotional public events are remembered better than everyday events with a similar retention interval (e.g., Conway et al., 1994; Paradis, Solomon, Florer, & Thompson, 2004), and laboratory studies have shown emotional enhancement in memory for words (e.g., Kleinsmith & Kaplan, 1963; Sharot & Phelps, 2004), images (e.g., Bradley, Greenwald, Petry, & Lang, 1992), narratives (e.g., Cahill & McGaugh, 1995), and personal events (e.g., D'Argembeau, Comblain, & Van der Linden, 2003).

In explaining flashbulb memory, Brown and Kulik proposed the role of a special emotional memory mechanism based on Robert Livingston's "Now Print" theory (1967). This theory (1967) suggests that when the brain recognizes an event as both novel and significant, the limbic system releases a command that permanently "prints" all recent brain events, leading to facilitated retrieval of all event details at a later time. Select aspects of this theory have been supported. There is increased limbic activity, and a strengthened relation between the amygdala and other medial temporal lobe and cortical regions during emotional relative to neutral event encoding (reviewed by LaBar & Cabeza, 2006). Item-by-item fluctuations in connectivity relate to the durability of an emotional memory (Ritchey, Dolcos, & Cabeza, 2008), with items associated with greater connectivity remembered over longer delays. State-based differences in connectivity also may influence how well emotional events are retained; for instance, functional coupling between the amygdala and medial prefrontal cortex during rest may relate to the ability to retain emotionally positive memories, at least among older adults (Sakaki, Nga, & Mather, in press). Thus, there is evidence that amygdala engagement – through its interactions with other regions – can lead to a strong, long-lasting memory.

Critical aspects of the "Now Print" theory, however, have not been supported. Amygdala activation does not preserve memory for all attended event details, and amygdala engagement during an emotional event does not circumvent the medial temporal lobe processes that typically enable memory consolidation (Kensinger, 2009). Thus, there is no 'special' memory mechanism in the strongest sense (see McCloskey, Wible, & Cohen, 1988; Weaver, 1993). Moreover, even though people retain high confidence in "flashbulb" memories (e.g., Talarico & Rubin, 2003; 2007), their accuracy decreases over time (e.g., Christianson, 1989; 1992; Rubin & Kozin, 1984). This disconnect between accuracy and confidence is consistent with research showing that emotion enhances the sense of recollection experienced during memory retrieval (reviewed by Phelps & Sharot, 2008) and may lead to a shift in participants' response biases: Emotional words (new and old) are more likely to receive an "old" response than neutral words (See Table 1). Although emotion can sometimes enhance the accuracy of a memory representation (e.g., Choi, Kensinger, & Rajaram, 2013; Kensinger, Garoff-Eaton, & Schacter, 2007), or at least the accuracy with which some details of an event are remembered (see next section), emotion may change the qualitative characteristics of how an event is remembered even when it does not affect the likelihood that the event is remembered.

The mixed effects of emotion on memory accuracy may be explained by the frequent presence of two confounds that can exaggerate or mask the enhancing effects of emotion on memory. First, emotional stimuli are often more interrelated than neutral stimuli. This semantic relatedness can have an additive effect with arousal on memory (Buchanan, Etzel, Adolphs, & Tranel, 2006) and in some cases may entirely explain the mnemonic benefit attributed to emotion (e.g., Maratos & Rugg, 2001; Talmi, Luk, McGarry, & Moscovitch, 2007a; Talmi, Schimmack, Paterson, & Moscovitch, 2007b). This interrelatedness can also lead to enhanced conceptual priming and an increased sense of familiarity for both old and new emotional stimuli, leading to increased false memories as well as true memories (see Brainerd, Stein, Silveira, Rohenkohl, & Reyna, 2008). When interrelatedness is controlled, emotion may not enhance false memory (e.g., Choi et al., 2013). Second, the distinctiveness of an emotional stimulus among neutral items has been shown to contribute to the enhanced memory for the emotional items. Emotional stimuli typically benefit from presentation in mixed lists (containing both emotional and neutral items) but not in pure lists (Schmidt, 2012b; Talmi et al., 2007a). Controlling for distinctiveness may eliminate many of the benefits of emotion on memory, although some benefits – such as enhanced memory for taboo words – may remain, suggesting that they benefit from emotion-specific processes (reviewed by Schmidt, 2012a).

The current state of the emotional memory literature suggests that the presence of emotion often contributes to a more durable memory representation. However, this enhancement is not always present, and when it is, it may reflect the contribution of confounding processes not directly linked to the emotionality of the memoranda. By designing studies to directly control for and manipulate these parameters (see Table 2 for examples), researchers can better understand the underlying cognitive and neural mechanisms directly impacted by emotion. Such an understanding may be essential to research examining memory impairments and preservations in special populations. If emotional enhancement is held as a certainty in the memory literature, the field risks disregarding important research that does not show the effect.

Arousal and Memory: Beyond Yerkes-Dodson (1908) and Easterbrook (1959)

A second claim is that when emotion does not enhance memory, this can be understood by the magnitude of physiological arousal elicited. Yerkes and Dodson (1908) proposed that for complex tasks, performance increases with physiological or mental arousal up to a point, at which the effect of arousal becomes detrimental. This has been supported by animal and human studies on the effects of glucocorticoids and/or stress on memory, such that moderate levels during learning enhance subsequent memory, while lower or higher doses either show an impairing effect (e.g., Lupien et al., 1997) or no effect on memory (e.g., Roozendaal, Williams, & McGaugh, 1999).

A closely related explanation for why emotion does not always enhance memory is that increased arousal leads to a restriction of observed cues (Easterbrook, 1959). This narrowing of attention enables memory for salient details to be enhanced, at the cost of memory for less salient details. At high arousal, however, this restriction of cue utilization is thought to preclude processing of information crucial to event memory, such as the physical characteristics of a perpetrator (e.g., Christianson, 1992; Loftus, Loftus, & Messo, 1987).

While these hypotheses have been supported by prior literature, effects may be relevant under narrower circumstances than typically assumed. The Yerkes-Dodson law was based on a study requiring mice to discriminate between two boxes while receiving shocks of various strength, and their claim of a U-shaped curve applied only to *complex* tasks. In their ‘easy’ condition, there was a linear relation between shock strength and learning success. Moreover, in reanalyzing their data, Baumler and Lienert (1993) found that the dependent variable critically matters; although defining the learning criterion as ‘hits’ yields an inverted U-shaped curve for complex tasks, defining the criterion as errors results in a linear arousal-performance relation for complex tasks and no relation for the easy task (Baumler & Lienert, 1993; Hanoch & Vitouch, 2004). Thus, the U-shaped curve may exist only for complex tasks, and only when data are scored in a particular way. Similarly, the Easterbrook (1959) hypothesis was originally based upon tasks investigating drive, motivational concentration, perception, and motor skill, and focused on cue utilization during encoding-stage processes. It has since been applied more broadly to a variety of long-term memory studies and has not been reconciled with evidence that arousal often influences post-encoding processes rather than attention narrowing during encoding (e.g., Riggs, McQuiggan, Farb, Anderson, & Ryan, 2011; Mickley Steinmetz & Kensinger, 2013). Whereas the Yerkes-Dodson law and Easterbrook's attention-narrowing account are valid explanations for arousal-enhanced memory (or the lack thereof) in some cases, the effects of arousal on memory may also depend on other factors.

One such factor is the content of the memoranda: Although stress often enhances emotional memory (e.g., Cahill, Gorski, & Le, 2003) it typically impairs (Payne et al., 2007), or has no effect on (Buchanan & Lovallo, 2001) memory for neutral information. The effects of arousal on memory for neutral stimuli may further depend on their salience (Mather & Sutherland, 2011). Arousal may enhance memory for goal-relevant, salient neutral stimuli while having no effect on, or even impairing, memory for other neutral stimuli (e.g., Sutherland & Mather, 2012).

Even among emotional information, the effects of arousal may differ depending upon the valence of the stimuli (i.e., whether they are positive or negative). For example, free recall of negatively arousing, but not positively arousing words, is enhanced by pre-learning stress (Schwabe, Bohringer, Chatterjee, & Schachinger, 2008). Further evidence for complex interactions between arousal and valence has been shown using fMRI: High (compared to low) arousal is associated with increased amygdala connectivity to the inferior frontal gyrus and middle occipital gyrus while encoding negative stimuli, and decreased amygdala connectivity to these regions while encoding positive stimuli (Mickley Steinmetz, Addis, & Kensinger, 2010).

Another factor is the relation between the arousal experienced and the memory task. Arousal can be relevant to the task, as in the original Yerkes-Dodson experiment, or irrelevant to the task, as often occurs in studies of mood induction. Research has suggested that when the arousal is task-relevant, such as when the content of the to-be-remembered information is arousing, memory for those arousal-inducing, salient details often comes at the cost of memory for other information (the *emotion-induced memory trade-off*; reviewed by Reisberg & Heuer, 2004). When arousal is task-irrelevant, the effects may be more variable. Libkuman and colleagues (1999) found that sustained physiological arousal – induced by stationary running or biking – had little impact on memory for details of scenes. Sutherland and Mather (2012), however, showed that brief presentation of negative arousing sounds increased short-term memory for high-salience letters but had no benefit on memory for low-salience letters.

These studies demonstrate that when arousal does not enhance memory, this could be due not only to dose, but also to task complexity, the way performance is measured, the content of the memoranda, and the relevance of the arousal to the task. Considering only one of these factors often leads to mixed findings (See Table 3), emphasizing the need to assess multiple factors, and their potential interactions.

Facilitated Processing of Emotional Information Does Not Guarantee Memory Accuracy

The third claim we address is that the facilitated processing of emotional information precipitates facilitated retention of that information. There is no doubt that emotional information benefits from prioritized processing. We rapidly orient our attention to emotional stimuli (e.g., Öhman, Flykt, & Esteves, 2001), and we process emotional information faster and more fluently than non-emotional information (Kityama, 1990), even in the absence of full attention (Kensinger & Corkin, 2004; Talmi et al., 2007b; Talmi, Anderson, Riggs, Caplan, & Moscovitch, 2008). This prioritized processing can be related to memory benefits, both because attended stimuli are often well-remembered (reviewed by Chun & Turk-Browne, 2007) and because the amygdala engagement triggered by emotional arousal facilitates both perceptual (e.g., Vuilleumier, Armony, Driver, & Dolan, 2001; Vuilleumier, Richardson, Armony, Driver, & Dolan, 2004) and mnemonic processes (reviewed by LaBar & Cabeza, 2006). However, the assumptions that facilitated processing *always* produces enhanced memory, and that the *cause* of the memory enhancement is facilitated processing, are not always correct.

One demonstration of a disconnect between the effects of emotion on short-term processing and long-term retention comes from studies of working memory. Working memory efficiency can be slowed when emotional stimuli are held in mind (Kensinger & Corkin, 2003), likely because emotional reactions distract from the memory maintenance task. Emotional information may disrupt inter-item binding in working memory (e.g., remembering the relative locations of high and low arousal pictures; Mather et al., 2006) and may also disrupt dorsolateral prefrontal processes related to holding information in mind during delayed-response working memory tasks (e.g., Dolcos & McCarthy, 2006; Dolcos, Diaz-Granados, Wang, & McCarthy, 2008). Yet these same stimuli that impede working memory performance can be remembered well over the long-term (Kensinger & Corkin, 2003), revealing a distinction between the impairing effect of emotion on short-term processing and the beneficial effect on long-term retention. In these instances, the intrusive processing of the emotional content may lead to a more durable memory representation.

Emotion can also have the opposite direction of effect, benefiting short-term processing but impeding long-term retention. For instance, in Murray and Kensinger (2012), participants were faster to form a mental image combining one emotional and one neutral item into a pair, rather than two non-emotional items. However, that facilitated imagery did not lead to facilitated later memory: Individuals remembered the emotional pairs less well than the non-emotional pairs. In this case, the fluent processing of the emotional items may circumvent the effortful, deep, processing that would translate into later memory benefits. The fluent processing may even bias individuals to believe that they have spent enough time learning information, when in fact additional effort would benefit the creation of a durable memory representation. For instance, Zimmerman and Kelley (2010) demonstrated that participants were overconfident when estimating which negative word pairs they would later remember. Likely because of the fluency with which individuals processed the negative pairs, they were misled to believe they had encoded them strongly and would retain them well.

Facilitated processing of emotional cues at retrieval may also mislead individuals, but at this stage of memory, it may cause them to endorse previously unstudied emotional items as "old" (Dougal & Rotello, 2007; Fernandez-Rey & Redondo, 2007; Maratos, Allan, & Rugg, 2000). As discussed earlier, sometimes this bias may result from the increased familiarity that stems from the inherent semantic interrelatedness of emotional items. Other times it may result because emotion facilitates the processing of retrieval cues. People may misattribute that ease-of-processing for a sense of familiarity that the information was previously encountered (e.g., Windmann & Kutas, 2001).

These pieces of counter-evidence emphasize that facilitated processing of emotional information at one stage of processing does not guarantee similar facilitation at another stage. These results highlight the need to avoid the inference that if emotion has not enhanced memory retrieval, it has not facilitated earlier stages of processing. As we have reviewed, retrieval deficits can be indicative of *facilitated* processing at encoding that reduces post-encoding elaboration or time-on-task. More generally, these complexities

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provide an important reminder that memory retrieval provides only a limited window into the set of processes used to form and maintain a memory.

Implications and Applications

Although there is support for these three hypotheses, delineating their limiting parameters is important both for basic and clinical research. First, clinical alterations in the effects of emotion on memory may reflect a re-setting of the boundaries for the effect rather than a generalized change in its presence or absence. For instance, patients with Alzheimer's disease often show little-to-no enhancement of emotional memory within a laboratory setting. Yet when memory for a real-life experience is assessed, the patients often are more likely to remember the occurrence of that event compared to a more mundane event (Waring & Kensinger, 2009). Future research could test how the factors that set the boundary in healthy populations – including semantic relatedness, valence, arousal, and personal involvement – are modified in clinical populations.

Second, a move away from a dose-response (*quantity*-based) explanation for the effects of arousal may enable a focus on the *quality* of the arousal response. "Arousal" can incorporate multiple phenomena – mental feelings of excitation or agitation, short-lived physiological changes, and specific responses of the hypothalamic-pituitary-adrenal system. These facets of arousal may have distinct effects on memory. Thus, when trying to understand how arousal affects memory – either in healthy populations or in individuals with affective disorders – it is critical to operationalize "arousal" and to tease apart the influences of these various aspects of arousal.

Third, by realizing the complex relations between the effects of emotion on different stages of processing, we may come closer to a holistic explanation for the effects of emotion on memory in different populations. For instance, we have shown that, unlike young adults, older adults are not faster at binding emotional pairs than neutral ones. Yet when memory is tested, older adults show a mnemonic advantage for the emotional integrations (Murray & Kensinger, in press). These results can only be explained by realizing that facilitation in one aspect of processing can be disconnected from benefits in another.

As these examples highlight, although there is support for the hypotheses reviewed here, there is danger in accepting them as rules-of-thumb and much to be gained by taking the boundary conditions seriously.

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Table 1

Effect of emotion on discrimination and response bias in tests of memory recognition.

	Hit Rate	**False Alarm Rate**	**Sensitivity**	**Liberal response bias**
Brainerd et al., 2008	Negative > Neutral Neutral > Positive	Negative > Neutral Neutral > Positive		Negative > Neutral Neutral > Positive
Choi, Kensinger, & Rajaram, 2013	Negative > Neutral Positive = Negative Positive = Neutral	Negative = Positive = Neutral	Negative > Neutral Positive > Neutral	Negative > Neutral Negative > Positive
Dougal & Rotello, 2007	Negative > Neutral Negative > Positive	Negative > Neutral Negative > Positive	Negative < Neutral Positive < Neutral	Negative > Neutral Negative > Positive
Fernandez-Rey & Redondo, 2007	Arousing > Neutral	Arousing > Neutral Negative > Positive	Negative < Positive Arousing < Neutral	Negative > Positive Arousal > Neutral (low confidence only)
Johansson, Mecklinger, & Treese, 2004			Emotional = Neutral	Emotional > Neutral Negative > Positive
Maratos, Allan, & Rugg, 2000	Negative > Neutral	Negative > Neutral	Neutral > Negative	Negative > Neutral
Vo et al., 2008	Negative > Positive Positive > Neutral	Negative > Neutral Positive > Neutral	Negative = Positive = Neutral	Negative > Positive Positive > Neutral
Windmann & Kruger, 1998	*Not reported*	*Not reported*	Neutral > Negative (control participants only)	Negative > Neutral
Windmann & Kutas, 2001	Negative > Neutral	Negative > Neutral	Negative = Neutral	Negative > Neutral

Note: Table 1 focuses on standard recognition assessments and does not include studies designed to intentionally elicit false memories. Additionally, only studies that specifically report some measure of response bias are included.

Table 2

Factors to consider when designing a study to assess emotional memory.

Factor	Why consider this factor?	When is it most prevalent?	How to manipulate?	Possible to control for in data analyses?
semantic coherence/relatedness	Stronger semantic clustering of emotional (vs. neutral) stimuli can contribute to emotional enhancement of memory by making stimuli easier to organize. It also can boost false memories because lures are more closely related to studied items.	if not using categorized neutral items if selecting emotional stimuli from a small number of categories (e.g., vicious animals, injured people)	use a design that fully crosses emotional content and semantic relatedness	if standardized database available, use calculated coherence of emotional and neutral stimuli as a covariate in analyses
attention allocation	Emotional stimuli often attract attention. This can enhance memory for the emotional stimuli but can reduce memory for neutral (or low-priority; see Mather & Sutherland, 2011) stimuli competing for processing resources.	if processing demands of task are high (e.g., limited time to process stimuli; multiple stimuli competing for resources)	manipulate task demands (e.g., divided attention and full attention) alter salience of neutral stimuli by manipulating the stimuli or the task	measure eye gaze and use looking time as a covariate (Note: this will only co-vary overt, not covert, attention)
distinctiveness	Many effects of emotion may be due to the incongruent or unexpected nature of the stimulus or event, rather than to an emotional response to that stimulus or event.	if frequency (both within the study session and within an everyday context) is not matched between emotional and neutral stimuli if familiarity and frequency are not matched between emotional and neutral events if mixed lists are used rather than pure lists (this may also affect induced arousal of person; see below)	compare performance in mixed lists to performance in pure lists compare surprising events that elicit different magnitudes of emotional reactions (e.g., garden-path sentences ending in emotional vs. semantic non sequitur)	include ratings of frequency, familiarity, and surprise as covariates
arousal	Arousal can influence memory in a number of ways, depending on whether the arousal refers to the ratings given to a single stimulus within a stream of stimuli, to the state of an individual induced by the presented stimuli or event, or to the natural state of an individual that is unrelated to the stimuli or event.	Stimulus characteristic: if stimuli are not matched for arousal; if an event is surprising; likely to be correlated with the intensity of the emotional response Induced state of person: when emotional stimuli are presented in a block (rather than intermixed with neutral stimuli), or when an event is of relatively long duration (more than a few seconds) Natural state of person: individual variations are always present but may be exaggerated when comparing different patient groups or age groups	Stimulus characteristic: select stimuli to include multiple levels of arousal (e.g., low- and high-arousal negative stimuli) Induced state of person: compare pure to mixed lists of emotional stimuli (although this may also affect stimulus distinctiveness; see above) include intentional mood induction as part of experimental design Natural state of person: direct manipulation likely impossible, but can compare groups selected a priori to differ in baseline state (e.g., high- vs. low-anxiety group)	Stimulus characteristic: include ratings of arousal as a covariate Induced state of person: include change in cortisol or alpha amylase as an estimate of arousal response Natural state of person: include baseline cortisol or alpha-amylase level as an estimate of natural arousal state

Note: This table does not present an exhaustive list. Depending on the goals of the experiment, other factors to consider may include: valence of the stimuli (how positive or negative), discrete emotions elicited by the stimuli, mood of the participant, stimulus complexity, event rehearsal

Table 3

Representative examples of the mixed behavioral patterns revealed by studies examining how stimulus content or features of the arousal response influence the effect of arousal on memory.

Manipulation Category	Specific Manipulation	Study	Key Finding for Effect of Arousal
Content of Memoranda	Emotional vs. neutral	Abercrombie et al., 2003	↑Negative and Neutral
		Buchanan & Lovallo, 2001	↑Positive and Negative; No effect on Neutral
		Cahill, Gorski, & Le, 2003	↑Negative; No effect on Neutral
		Payne et al., 2007	↑Negative; ↓Neutral
		Rimmele et al., 2003	↓Negative; ↑Neutral
		Schwabe & Wolf, 2010	↓Positive, Negative, Neutral
	Positive vs. negative valence	Domes et al., 2004	↓Positive; No effect on Negative
		Schwabe et al., 2008	↑Negative; No effect on Positive
	Memoranda related, or unrelated, to stressor	Smeets et al., 2007	Memory for stressor-related words > Non-stressor-related words
		Smeets et al., 2009	Memory for stressor-related words > Non-stressor-related words
	Memoranda central or peripheral to the elicitor of arousal	Christianson, 1984	↑Central; No effect on Peripheral
		Easterbrook, 1959	Cue-utilization: ↑Central; ↓Peripheral
		Heuer & Reisberg, 1990	↑Central and Peripheral
		Kebeck & Lohaus, 1986	↑Central; ↓Peripheral
		Loftus, Loftus, & Messo, 1987	Weapon focus effect: ↑Central; ↓Peripheral
	Salience of neutral stimuli	Sutherland & Mather, 2012	↑High-salience stimuli; No effect on Low-salience stimuli
Features of Arousal	Level of Arousal	Gold & Van Buskirk, 1975	Inverted-U; moderate (not lower or higher) doses of epinephrine enhance spatial memory
		Lupien et al., 1997	High stress ↓ memory for unrelated pairs of words
		Yerkes & Dodson, 1908	Inverted-U between shock strength and learning success on complex tasks
	Relevance of Arousal to Task: Reason for physiological arousal	Libkuman et al., 1999	Task-relevant arousal ↑ memory for scene details Task-Irrelevant = No effect