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SOCIAL COGNITION (J BEADLE, SECTION EDITOR)

Examining Memory in the Context of Emotion and Motivation

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Abstract

Purpose of the Review In this review, I summarize the limited literature that includes manipulations of both emotion and motivation within the same experiment to examine their interactive and distinct effects on episodic memory. I position this work within the context of theories according to which emotion and motivation are inseparable, as well as other theories that view these constructs as dissociable.

Recent Findings Memory studies that manipulate emotion and motivation within the same trial provide support for theories that view them as separate constructs. Although separate constructs, studies that compare emotion and motivation, indicate they have similar effects on memory, but the extent of this similarity may depend on affective valence, task-relevance, and retention interval.

Summary Investigating the behavioral effects of emotion and motivation on memory can inform our theoretical understanding of these constructs, with value for practical and clinical applications ranging from academic performance to psychopathology.

Keywords Memory · Emotion · Motivation · Reward · Valence

Introduction

A quote attributed to novelist Salman Rushdie states, "memory is a way of telling you what's important to you" [1]. From a scientific perspective, Rushdie has it backwards. Rather than memory telling you what's important, researchers have discovered that what is important, and carries affective and motivational significance, is more likely to be encoded and stored in memory. Emotion and motivation are the two most studied types of affective significance in the memory literature, but these lines of research rarely inform each other (see Fig. 1, top panel). A recent review paper [2••] has considered the effects of reward and emotion as related constructs within the broader context of motivated cognition. The goal of this review is to focus on the limited literature intentionally manipulating both emotion and motivation, within the same paradigm, to connect and compare their effects on episodic memory—defined as memory for events that can be recollected within a temporal and spatial context. In this paper, I conceive of emotion as positive or negative affect that is induced by an external stimulus in the environment, and motivation as the urge to engage in goal-directed behavior to obtain a reward or avoid punishment. Both emotion-modulated and motivation-modulated memories are considered to be adaptive. For example, stimuli that evoke feelings of fear like a dangerous animal, or information that must be studied to achieve a certain grade, will be better remembered than neutral or unimportant information because these memories contribute to survival, current and future goals, and well-being. I will discuss general theories of emotion and motivation to argue that studying their separate and combined effects on memory may advance our general understanding of these constructs. I will also discuss some future directions and applications of this research.

Emotion- and Motivation-Modulated Memory

Several reviews have outlined emotion-modulated memory [3–8] and motivation-modulated memory [9–11], with one recent review detailing these literatures in parallel [12•]. Decades of memory research indicate that valence [6, 8]—the affective quality of the emotion, ranging from negative to positive—and arousal [4, 7]—the intensity of

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the emotion, ranging from low to high—play an important role. This modulation occurs at multiple stages: emotional information is prioritized at encoding [13], focused on postencoding [4], consolidated [14], recapitulated [6, 15–18], and remembered with enhanced recollection and richness [19–21], even if remembered details are not accurate [22]. Emotion processing involves a large network of brain regions, including the limbic system [23, 24] and the prefrontal cortex [25]. The amygdala, one of the most frequently studied brain regions, is thought to mediate aspects of emotional learning and facilitate memory operations in other memory-related regions including the hippocampus and prefrontal cortex [26–29].

Investigations into motivation[1]-modulated memory have characterized how reward (and punishment) anticipation [30–40], and reward feedback [41, 42••] influence memory formation. Research on reward processing has implicated regions in the dopaminergic midbrain, including the ventral tegmental area and substantia nigra (often dubbed the "reward network") [43], as well as medial frontal cortex [44]. Specifically, reward anticipation is associated with increased activation in the orbitofrontal cortex, amygdala, dorsal and ventral striatum [31, 37, 45–49], and insula [50]. Reward feedback has been shown to activate the ventromedial prefrontal cortex [44, 51], but there have been mixed findings on the role of the nucleus accumbens [44, 52]. Dopaminergic neurons also become active during reward predicting cues, novel stimuli, and punishment [53]. Interactions between regions in the midbrain and hippocampus are thought to modulate memory encoding of stimuli proximal to reward cues [31, 53, 54]. Figure 2 depicts neuroimaging evidence signifying that emotion and reward processing have both overlapping and distinct neural correlates.

Are Emotion and Motivation the Same Construct?

The literatures reviewed above indicate emotion and reward motivation can modulate memory processes and have overlapping neural correlates, but does this indicate that they are the same construct? There has been debate about whether emotion and motivation are in fact separable. Many experimental paradigms conflate the two constructs, making it difficult to separate their influences on cognition and behavior [55]. Some researchers take the stance that the two constructs are one and the same and thus can never be separated [56] making it impossible to study their unique and interactive effects on cognition [57]. The authors of a recent review argue that emotion and motivation are integrated and eventually merge into a single process with overlapping neural correlates [58•]. Indeed, there can be activation in reward circuitry during an "emotional" experience: for example, when participants are in a positive mood [59] or recalling positive autobiographical memories [60]. As pointed out by Goschke and Bolte [61], it may not be particularly surprising that positive emotions, like those elicited by recalling positive memories, would be rewarding, and that earning rewards, such as winning money at a slot machine, would evoke positive emotions. It may also seem reasonable that given this overlap, emotion and motivation would have similar effects on memory. If emotion and motivation are one construct that cannot be separated because they engage the same cognitive and neural mechanisms, it would follow that experimental combinations of emotional and motivational manipulations should produce no interactive effects on memory performance.

Few studies have examined this issue directly to date. Wittmann et al. [62] used a paradigm in which reward motivation and emotion were manipulated orthogonally (see Fig. 1, middle panel). Reward was not explicitly tied to successful memory for emotional pictorial stimuli, but was presented in close temporal and contextual proximity. The researchers found an additive effect of positive emotion and reward anticipation on successful incidental memory encoding. Mather and Schoeke [41], using a similar paradigm, also reported that incidental memory encoding was enhanced for positive pictures that were associated with reward anticipation. A more recent study, however, did not find that reward enhanced memory for positive images [63••]. Yan and colleagues [63••] reported main effects of both emotion and reward motivation on memory, but no additive or interactive effects of the two factors. Moreover, memory for negative episodic information has not been observed to be sensitive to reward. Based on findings that negative stimuli tend to be better remembered than neutral or positive stimuli, Shigemune and colleagues [34] hypothesized that rewards would boost memory for negative stimuli, compared to rewarded neutral stimuli or unrewarded negative stimuli, in an intentional encoding paradigm. In line with the findings by Yan et al. [63••], reward and emotion enhanced memory performance separately, but negative rewarded images were not better remembered than negative unrewarded images.

Both emotion and motivation can enhance memory, and under some experimental conditions, when positive images are encoded in close temporal/contextual proximity to a reward cue, this can have an additive effect, such that incidental memory is better when these two

[1] The terms motivation, reward motivation, and reward are used interchangeably in the current review. Most studies in the human literature have used monetary rewards to evoke a motivational response.

Research Question	Common Experimental Paradigms
Does emotion modulate memory? Does motivation modulate memory?	**emotion and motivation are manipulated with different stimuli in separate lines of research**
Are emotion and motivation the same construct? Do they they have additive or interactive effects on memory?	**emotion and motivation are manipulated orthogonally in the same experimental encoding trial**
Are emotion and motivation dissociable? Do they have different effects on memory processes?	**emotion and motivation are compared in separate blocks of the same experiment**

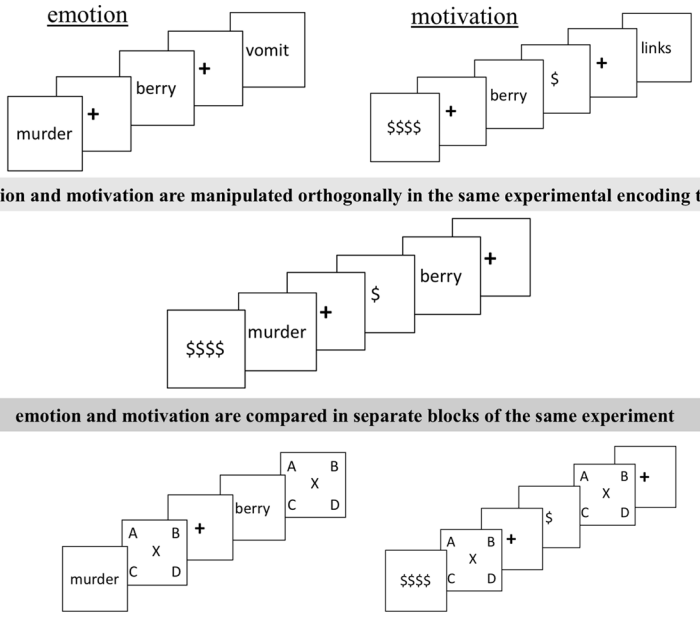

Fig. 1 Common experimental paradigms used to answer various research questions about emotion and reward effects on memory. Note. Depiction of the three research questions detailed in the paper with corresponding experimental paradigms that are commonly employed in the literature. Top Panel: The figure illustrates how questions about emotion and motivation effects on memory have been tested in separate lines of research. The figure depicts (incidental or intentional) encoding trials where emotion is induced with valent words* (e.g., murder, vomit) compared to neutral words (e.g., berry), and motivation is induced with cues at the beginning of each trial indicating a high ($$$$) compared to low ($) reward value for task performance. Memory for the words would be tested on a subsequent memory task (not depicted). Middle Panel: to examine whether emotion and motivation are the same construct, emotion and motivation are induced orthogonally, but within the same experimental trial. The figure depicts (incidental or intentional) encoding trials where emotion is induced with valent words* (e.g., murder) compared to neutral words (e.g., berry), and motivation is induced with cues at the beginning of each trial indicating a high ($$$$) compared to low ($) reward value for task performance. The interactive or additive effects of emotion and motivation on memory for the words would be tested on a subsequent memory task (not depicted). Bottom Panel**:** to examine whether emotion and motivation are dissociable, their effects on memory are compared in separate trials or blocks of the same experimental task. The figures depict (incidental or intentional) encoding trials where emotion is induced at the beginning of each trial with valent words (e.g., murder) or neutral words (e.g., berry), and motivation is induced with cues at the beginning of each trial indicating a high ($$$$) compared to low ($) reward value for task performance. Following the emotion or motivation induction, a stimulus would be flashed in one of the five locations on the screen (e.g., A, B, C, D, or X) and subsequent memory for this stimulus would be tested on a memory task (not depicted). *In this figure, emotion is induced using negative and neutral words, but as described in the current paper, emotional images quite commonly serve as stimuli in the literature, as do emotionally positive stimuli

types of affect are jointly present in the trial. This gives some support to emotion and motivation being distinct and separable processes. If emotion and motivation were relying on the same mechanisms to support successful encoding and episodic memory formation, there would be no advantage to including both in the same trial, but

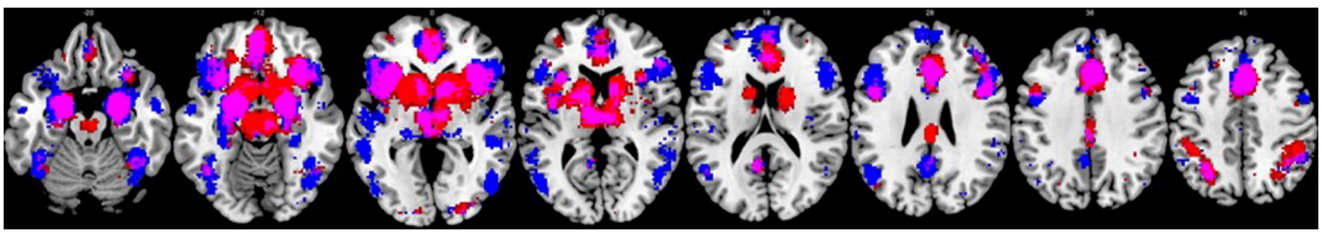

Fig. 2 Neural correlates of "Emotion", "Reward", and their overlap. Note. A search of the Neurosynth [105] (https://neurosynth.org/) database with the terms "emotion" (in blue) and "reward" (in red) suggest separate and overlapping (in purple) neural correlates of these constructs

the boundary conditions on this effect are not sufficiently clear.

How and When Are Emotion and Motivation Dissociable?

The studies detailed in the previous section manipulated emotion and motivation orthogonally within the same trial to examine additive and interactive effects on memory. Despite some claims that emotion and motivation are confounded [55–57], this and other evidence indicates they are dissociable. If emotion and motivation engaged identical neural networks (see Fig. 2), impairment in one domain should be associated with impairment in the other, but this is not always the case. Dysfunctional emotion processing due to amygdala damage is not always linked to reward processing dysfunction [64], and lesions in dopaminergic brain regions in rats can impair motivation to seek out sweet foods, but leave intact positive affect associated with sweetness [65•]. Berridge and colleagues [65•, 66•, 67•, 68•] have reported neurobiological evidence that the circuitry supporting incentive motivation is different from that involved in hedonic (i.e., emotional) experiences: this distinction has been characterized as "wanting" versus "liking", respectively. This distinction lead to the development of incentive-sensitization theory [69] which has been influential for understanding drug addiction and disordered eating, as the theory posits that one can have increased or disordered "wanting" without parallel increases in "liking".

In a thought-provoking review, Chiew and Braver [70] argue that characterizing common and distinct effects of positive emotion and reward motivation is necessary for advancing theories of affect and cognitive control. Indeed, many researchers have done this in the cognitive control domain which have been detailed in a recent review [71•], but similar work in the episodic memory domain is scarce. The few studies that have attempted this have focused on comparing emotion and motivation effects on attentional scope (see Fig. 1, bottom panel). Substantial evidence indicates that emotional valence can modulate the scope of attention, such that positive emotions widen and negative emotions narrow our field of view [72–74]. Valence-driven differences in attentional scope may therefore have downstream effects on episodic memory for central versus peripheral information [75, 76]. To test this hypothesis, Gable and Harmon-Jones [77] compared effects of reward anticipation induced via monetary gains (i.e., "wanting") to positive emotion induced via appetitive images (i.e., "liking"), on incidental memory for neutral words presented in various locations on the screen. Reward motivation and positive emotion had similar effects on attentional scope and incidental memory: both "wanting" and "liking" manipulations at the beginning of each trial narrowed attention, leading to preferential encoding of centrally presented information. A more recent recognition study included a comparison of positive and negative emotion to reward and punishment motivation. Similar to the effects reported by Gable and Harmon-Jones, words associated with a positive emotion or reward motivation led to better memory, but only at a short retention interval. Negative or punishment motivation led to better recognition at a longer retention interval [78]. These finding suggests that despite observed differences in neural circuitry, emotion, and motivation may ultimately have a similar behavioral influence on memory, but valence and retention interval may play a significant role in the conclusions.

Another dimension on which researchers have defined the distinction between emotion and motivation is in terms of agency or control [42••, 79, 80]. Motivational states are goal-directed and may depend on the perception that deliberate steps or behaviors can help achieve the goal. Emotions, on the other hand, are often associated with lack of control [79]. Emotions are often triggered by an external stimulus[2] and can drive automatic, spontaneous, and impulsive behaviors [81]. Bowen and Spaniol [42••] compared performance on an incidental memory task in which neutral words were presented in central and peripheral locations on the screen during states of motivation or emotion. During motivation blocks, participants earned or avoided losing money depending on task performance. In emotion blocks, monetary gains and losses were random, akin to the outcomes of playing a slot machine. Similar to the findings by Gable and Harmon-Jones [77], positive valence, whether induced via motivation or emotion, led to similar effects on memory for words presented after the monetary cue, but motivation and emotion effects on memory differed after loss feedback. During motivation blocks, when the participant was in control, but ultimately unsuccessful on the task, memory was better than emotion blocks when the loss was out of the participant's control. Reward motivation narrowed attentional focus and improved memory for central items, perhaps in the service of gaining information to help avoid a controllable loss in the future. This same level of focus did not occur in unsuccessful loss-evoked emotion blocks. Comparisons between emotional and motivational states and influences on cognition are difficult because they are induced and manipulated very differently. Emotion, via pictures or words that evoke negative or positive responses, and motivation, via gain or loss of monetary rewards or points. Bowen and Spaniol equated the experimental conditions using the same stimuli and paradigm (i.e., monetary gains and losses in a reaction time task) to induce both emotional and motivational states, and manipulated participant control over the

[2] Emotions may not always be triggered by an external event. For example, depressive symptoms may emerge due genetics or hormonal imbalance [106]. Further, impulsivity and lack of control associated with emotion may only be an immediate reaction. After some time and cognitive reappraisal, humans can regulate their emotions quite effectively [107].

outcome. This created high internal validity, but perhaps at the cost of lower external validity.

A final consideration for dissociating emotion and motivation concerns the direction of information processing. In the majority of emotional memory research, participants view affective stimuli, and via bottom-up influences that result from the emotional characteristics of the stimulus [82], this information is prioritized in memory. In studies of motivated-memory, participants view a cue signaling a potential future reward, and via top-down influences of extrinsic motivation [83], the associated information is prioritized in memory. A few recent studies have tested which of these is prioritized in memory when pitted against one another. Eich and Castel [84] examined how well older and younger adults could cognitively control their memory when bottom-up emotional information was competing for cognitive resources against top-down, goal-relevant reward information. To do this, emotional and neutral words were paired with a value ranging from 1 to 12, and participants were instructed to remember the words, but to focus on those associated with a high value to maximize their points. Both groups effectively prioritized high over low value items during intentional encoding, in line with their goals, even in the face of emotionally salient distraction. Sleep also seems to support the prioritization of motivationally relevant information: when top-down (reward) and bottom-up (emotion) goals are present for the same stimulus, memory for top-down information is enhanced after sleep, suggesting that motivation and emotion are not given the same status during memory consolidation [85]. These findings dovetail with the results of Bowen and Spaniol. In all cases, motivation had stronger effects on memory compared to emotion. These three findings also fit with many empirical studies and cognitive theories detailing whether and how emotion and motivation compete for perceptual resources and cognitive control during information processing [71, 86] and whether this prioritization of one type of affect over the other depends on task demands and goal-relevance of the affect [87, 88].

Future Directions

This paper details the few memory studies that have examined interactions between emotion and motivation, or compared their effects by inducing them separately within the same experiment using the same experimental task. In addition to much-needed replication, the results leave many unanswered questions. For instance, additive effects of emotion and motivation on episodic memory emerged during incidental encoding [41, 62], but not during intentional memory formation [34, 63]. If emotion and motivation are in fact separable constructs, why do additive effects emerge only when participants are unaware that their memory will be tested? Further, these effects seem specific to reward motivation and positive emotion, but not negative emotion, perhaps pointing to a valence congruency effect. Recent neuroimaging work revealed a potential shared valence mechanism across motivation and emotion [89]. However, when comparing emotion and motivation effects on memory, there is reason to speculate that negative emotion and reward motivation would have similar effects on memory despite their valence differences. Traditionally, it was thought that negative emotion narrowed and positive emotion broadened attentional scope [72, 90, 91], but more recent findings indicate factors beyond valence may account for this effect, given that (positive) reward anticipation can also narrow attention [42••, 92–95]. In younger adults, negative emotion enhances subjective and sometimes objective aspects of memory compared to positive emotion [6], while rewards seem to be superior to punishment for declarative memory formation [32] and lead to enhanced recollection compared to losses [63••]. One overarching methodological question for comparisons of emotion and motivation is to establish which approach to take—tight internal control, matching the emotion, and motivation conditions as closely as possible [42••], or potentially more externally valid paradigms, involving emotional stimuli and monetary rewards and losses [77]? Each approach can contribute something unique, but choosing one over the other may depend on the particular research questions.

Implications

The large majority of research on emotion and motivation has been carried out in parallel lines of study. Currently, there is no theoretical consensus on whether emotion and motivation are separable or the same construct, but see Cromwell et al. [58•] for a new perspective on this idea. Using episodic memory as a way to compare and test interactive effects of emotion and motivation may move us closer to an understanding of how and when they are common or dissociable. Further, deciding how best to define emotion and motivation has been an enduring debate, but considering them together within the same experimental context may elucidate characteristics about these constructs that can be used to help refine their definitions.

In addition to theoretical importance, there are significant implications for understanding the emotion-motivation-memory relationships. Below are four areas where this research could have substantial practical importance.

1) Education. There is a longstanding debate about whether extrinsic rewards undermine a student's intrinsic interest in a subject [83, 96]. A review paper by Hidi [10] focused on motivation and learning in an educational context, nicely articulates both sides of that debate. If it is the case that extrinsic rewards undermine intrinsic enthusiasm for

a subject, it might be beneficial to incorporate extrinsic rewards when students have low intrinsic motivation or a negative reaction to a subject. Many students suffer from math anxiety—a "feeling of tension, apprehension, or fear that interferes with math performance" p. 181 [97]. Exploration into whether extrinsic reward motivation could override these negative emotions would be beneficial to student academic performance. There is some evidence that already supports this idea for boring information [98].

2) Aging. Aging is associated with well-documented declines in declarative memory, but reward sensitivity [30, 37, 46, 99, 100] and emotional functioning [5] remain relatively intact in healthy aging. Building on the strengths that older adults already possess, future work on how emotion and motivation might work together or distinctly to improve cognition, could stimulate the development of nonpharmacological memory interventions.
3) Dopamine deficiencies. Dopamine deficiencies, such as in Parkinson's disease, can lead to cognitive [101] and reward-learning [102, 103] deficits. To potentially counteract this dysfunction, Ridderinkhof and colleagues [102] assigned one group of medicated Parkinson's patients to watch an emotionally positive (Charlie Chaplin) video and another to watch a neutral video. The positive affect induced by the amusing content in the Charlie Chaplin clip led to better performance on a subsequent rewarded cognitive task. The ability to rescue performance on reward-learning tasks by tapping into phasic dopamine release by inducing positive affect, may be a beneficial avenue of research for other conditions characterized by dopamine deficiencies such as older age and addiction.
4) Anxiety and depression. Cognitive, emotional, and motivational impairments are defining symptoms of anxiety and depression, as well as an array of other psychological disorders. A review by Crocker and colleagues [104] notes that most psychopathology research has focused on emotion-cognition interactions without examining motivational factors, despite extensive evidence that motivation is related to the emotional and cognitive symptoms. Studying emotion-motivation-cognition interactions in healthy individuals will provide a basis for understanding how these processes can go awry in psychopathology, informing treatment-based research.

Conclusions

Emotion and motivation are similar constructs, but their influences on memory have largely been investigated in separate lines of research. The studies detailed in this review form marked exceptions that have incorporated both affective and motivational significance in the same experimental paradigm. The findings suggest that these two types of affect interact, and can have similar and distinct modulatory influences on memory processes. There continue to be theoretical debates about whether emotion and motivation are different constructs, and additionally, whether they can be separated, but the findings from the episodic memory literature reviewed here indicate growing support that they are dissociable. There is still much to be learned about emotion-motivation-memory interactions and studies aimed to integrate them would have theoretical impact for all three domains. This work would serve practical and clinical importance, aiding in elucidating mechanisms to target for interventions ranging from education to psychological disorders.

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Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

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•• Of major importance

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