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Effects of emotion and motivation on memory dissociate in the context of losses

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ABSTRACT

Both emotion and motivation exert influence over memory processes, but whether they do so via similar or different cognitive mechanisms is not yet fully understood. In the laboratory, the two types of affect are typically manipulated with different procedures, making it difficult to compare their effects on memory. In the current study, a modified monetary incentive delay task was used to induce anticipatory and outcome-related affective states. Participants either had partial control over outcomes (motivation condition) or had no control over outcomes (emotion condition). Reward-unrelated target stimuli were presented in the context of reward anticipation (gain or loss) and in the context of outcome feedback. Incidental memory for the targets was measured after a short delay. Gain and loss anticipation cues did not differentially affect memory performance, suggesting that anticipatory affect − whether emotional or motivational − has little effect on long-term memory. In contrast, outcome feedback did influence the mnemonic fate of target stimuli, but only in the case of loss feedback. Here, memory was better in the motivation condition than in the emotion condition. Overall, these findings suggest that the effects of emotion and motivation on memory dissociate in the wake of negative feedback. We propose that enhanced memory for the circumstances in which a loss is incurred – when the loss is controllable – may serve an adaptive function.

1. Introduction

As noted by LeDoux (2002), stimuli that cause emotional responses can also motivate actions. For example, encountering a threatening animal may elicit fear, as well as prompt a flight response. Emotion and motivation are related concepts, but (at least in humans) they are generally understood to represent different types of affect—where affect refers to states with a positive or negative value or significance to the individual (Pessoa, 2009). Motivation is often defined as an urge to do something (Ryan & Deci, 2000). More specifically, *approach motivation* refers to an impetus for behavior that helps the individual to pursue positive outcomes (e.g., desirable objects, goals). *Avoidance motivation* refers to the drive for behavior that helps the individual to minimize or eliminate negative outcomes (e.g., threatening stimuli). Although we regularly experience a multitude of emotions, finding a description that encompasses the complexity and variability of emotions is difficult. The circumplex model of affect (Posner, Russell, & Peterson, 2005; Russell, 1980) proposes that emotions are not fundamentally distinct from one another, but represent different combinations of two continuous dimensions: valence and arousal. Valence refers to the quality of the emotion and is measured on a continuum ranging from positive to negative. Arousal refers to the intensity of the emotion and is measured on a continuum ranging from high to

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low. Emotion has also been defined as positive or negative affect that is induced by an external stimulus in the environment (Pessoa, 2009). This affective experience may influence cognition and behavior, but not necessarily *goal-directed* behavior or a call-to-action.

1.1. Sense of control

A sense of control or agency is an important dimension on which emotion and motivation tend to dissociate (Roseman, 2008, 2011; see also Chiew & Braver, 2011). Motivations arise because the individual feels, at least partly, in control of whether a goal is attained. Actions and behaviors that lead to goal attainment are usually purposeful and intentional. If the goal is not attained, the fault typically lies with the individual who did not expend enough effort or did not follow the necessary steps to achieve success. Emotion, in contrast, is often characterized by a relative lack of subjective control. As described by Roseman (2008), emotion is relatively impulsive, whereas motivation is relatively deliberative. Emotions are frequently triggered by external stimuli that give rise to subjective experiences and physical expressions that are automatic and involuntary. Indeed, high-intensity emotions often precede "heat of the moment", impulsive decisions and behaviors that are later regretted (e.g., Ariely & Loewenstein, 2006). On the basis of these definitions, the current study compares the effects of emotion and motivation using monetary incentives, manipulating the degree to which outcomes (monetary gains and losses) can be controlled, and observing the effect of the resulting affective states on memory performance.

1.2. Effects of emotion and motivation on memory

Both emotion and motivation are known to influence many aspects of cognition; however, the two types of affect are rarely examined together. As a result, the differences in how they modulate cognition are not well understood. Emotion and motivation effects on episodic memory, for example, are typically studied separately, using different stimuli and experimental paradigms. What is missing from the literature at present is a direct comparison of how emotion and motivation may be common or dissociable, with respect to their effects on memory.

The influence of emotion on memory is one of the most widely studied topics in cognitive psychology and neuroscience. A typical emotional memory experiment involves studying emotional and neutral stimuli for a subsequent memory test. Although not indelible (Talarico & Rubin, 2003), generally, memory for valent and arousing information is remembered better, with more detail and subjective feelings of richness (e.g., Hamann, 2001; Kensinger & Corkin, 2004; Kensinger, 2007, 2009; Levine & Pizarro, 2004; Mather & Sutherland, 2011, 2009; Mickley Steinmetz and Kensinger, 2009; Murty, Ritchey, Adcock, & LaBar, 2011). Research on the effects of motivation—often induced using monetary incentives—on memory has gained popularity in recent years (Adcock, Thangavel, Whitfield-Gabrieli, Knutson, & Gabrieli, 2006; Cohen, Rissman, Suthana, Castel, & Knowlton, 2014; Madan & Spetch, 2012; Murayama & Kitagami, 2014; Murayama & Kuhbandner, 2011; Murty, LaBar, Hamilton, & Adcock, 2011; Shigemune et al., 2010; Shigemune, Tsukiura, Kambara, & Kawashima, 2014). Prior work has shown that both reward anticipation (e.g., Adcock et al., 2006; Spaniol, Schain, & Bowen, 2013) and reward feedback (Mather & Schoeke, 2011) modulate memory performance.

A small number of studies have examined the two types of affective modulation jointly by combining manipulations of stimulus valence with manipulations of monetary incentives. Wittmann, Schiltz, Boehler, and Düzel (2008) found that positive emotional valence and reward anticipation during encoding had additive effects on recognition memory, even though reward was not explicitly tied to the to-be-remembered stimulus, but only presented in close temporal and contextual proximity. Shigemune et al. (2010) examined the effects of negative valence and reward motivation on intentional memory encoding. Participants were cued with either a high or low reward at the beginning of each block that signalled how much they could earn for remembering the following set of negative and neutral images. Unlike the design in Wittmann et al. (2008), in this study participants were rewarded for remembering the images rather than performance on a separate task. Shigemune and colleagues found main effects of both reward motivation and emotion on memory but observed no interaction of the two factors. Similar to Wittmann et al. (2008), Mather and Schoeke (2011) found that reward anticipation improved memory, but this effect was further modulated by the emotional valence of the to-be-remembered stimuli, with a greater reward effect for positive than negative stimuli. Furthermore, reward feedback boosted memory more strongly than reward anticipation. Overall, these studies confirm that emotion and motivation modulate memory, but they leave open questions about the mechanisms underlying their effects.

A series of experiments reported by Gable and Harmon-Jones (2010) addressed the role of attentional scope as a possible mechanism mediating the effects of motivation and emotion on memory. Participants saw words presented either centrally (in the middle of the screen) or peripherally (in one of the four corners of the screen). The words were presented after the high and low value reward cues and after hit and miss feedback (Experiment 1), and after positive or neutral images (Experiment 2). Memory for the words was tested with an incidental old/new recognition task. Memory for central items improved when reward anticipation was high (vs. low) and following positive (vs. neutral) emotional cues. This finding suggests that both reward anticipation and positive emotion lead to a narrowing of attentional scope. In contrast, attention was *broadened* by positive feedback ("hit"), as indicated by enhanced memory for peripherally presented words.

1.3. Comparisons of positive affect in cognitive control

In parallel to the literature on emotion, motivation, and memory, the literature on cognitive control has provided evidence that emotion (induced using positive images) and motivation (induced with monetary rewards) have different modulatory effects on cognition (Chiew & Braver, 2011, 2013, 2014; Dreisbach & Fischer, 2012; Fröber & Dreisbach, 2014). Fröber and Dreisbach (2014) compared emotion and motivation effects on cognitive control while simultaneously manipulating performance-contingent rewards. The study involved two groups of participants that were assigned to either a positive or neutral affect condition which were cued at the beginning of each trial with either positive or neutral images. Participants in both groups performed the same cognitive control task, but some trials involved performance-contingent rewards and some trials involved performance non-contingent (i.e., random) rewards. Replicating prior work (e.g., Chiew & Braver, 2013; Fröber & Dreisbach, 2012), the researchers found that positive emotion and performance-contingent rewards differed in their effects on cognitive control, such that performance contingent rewards led to a strategy shift that increased proactive control and positive affect led to reduced proactive control. A new finding was that random rewards produced effects similar to those of positive emotion. This result suggests that the source of positive affect matters for cognitive control; random rewards do not have the same effect as performance-based rewards. Rather, random reward appears to give rise to a state similar to that induced by positive emotional stimuli.

It is important to note that in all studies described thus far, emotion was manipulated through properties of the to-be-encoded stimuli (e.g., emotional pictures), whereas motivation was manipulated via monetary gains and losses. Despite the evidence that both emotion and reward motivation can modulate memory one of the challenges in trying to strategically compare the effects of these two affective states is in operationally defining these terms to create equivalent conditions. Fröber and Dreisbach (2014) were the first, to our knowledge, to manipulate control over reward outcomes involving performance-based and random rewards. Their findings indicated that random rewards and positive emotion had similar effects on cognitive control and dovetail with the current operational definitions of motivation and emotion, whereby emotion does not lead to *goal-directed* behavior and lacks a sense of agency.

1.4. The current study

The goal of the current study was to examine whether the influences of emotion and motivation on episodic memory are dissociable. To our knowledge there has been no direct comparison of motivation and emotion effects on memory while controlling for potential task and stimulus confounds. As noted, most previous studies have used different means to induce these two types of affect (emotional images vs. monetary gain/loss). This confound needs to be disentangled to properly address questions of emotion and motivation effects on memory. Building on the findings from the study by Fröber and Dreisbach (2014), we operationalized motivation and emotional affect in terms of monetary gains and losses over which participants either had control (motivation condition) or did not have control (emotion condition).[1] To this end, we used a modified version of the Monetary Incentive Delay (MID) task (Knutson, Westdorp, Kaiser, & Hommer, 2000), in combination with an incidental recognition test. The benefit of the MID task is that it allows for the manipulation of reward domain (gain, loss) thereby allowing comparisons of approach and avoidance motivation to positive and negative emotion, the magnitude of reward allowing comparisons of high and low levels of motivation and emotion. Similar to the paradigm used by Gable and Harmon-Jones (2010), we manipulated the spatial location of to-be-remembered words (central vs. peripheral), and their temporal context (after the MID cue vs. after the MID feedback).

1.5. Hypotheses

We expected to replicate prior work (e.g., Adcock et al., 2006; Spaniol et al., 2013) showing that reward anticipation boosts memory, such that recognition performance would be higher following high-value than low-value cues. Additionally, in line with Mather and Schoeke (2011), we predicted that positive ("hit") feedback would boost memory compared to negative ("miss") feedback. Finally, following Gable and Harmon-Jones (2010), we predicted that positive feedback would have similar effects on memory across emotion and motivation blocks, but that following negative feedback memory in the motivation block would be better than in the emotion block. Whether these effects would interact with other factors such as incentive magnitude and domain (gain vs. loss) was an open question. We also sought to test hypotheses about the effect of spatial location of the to-be remembered item (central vs. peripheral) on item recognition and spatial source memory, but this was not possible due to low memory performance for peripheral items (see Results for additional detail). Finally, we assessed whether subjective memory experience, as captured by confidence ratings during the memory test, would be sensitive to the affective manipulations at encoding.

2. Methods

2.1. Participants

Procedures were approved by the Ryerson Ethics Board and all participants provided written informed consent. Participants were recruited with advertisements posted on the Ryerson University campus and community websites (Craigslist.org and Kijiji.ca). Before being scheduled to participate, interested persons completed a health screen to ensure they had no history of brain or head injuries, psychiatric illnesses, current depression or use of psychotropic medication. Participants were compensated $10 per hour for time and travel, in addition to the money earned during the task. Domain (gain vs. loss) was manipulated between-subjects. Participants were randomly assigned to gain and loss conditions. A total of 49 participants completed the gain condition. Three were excluded for

[1] In addition to the findings from Fröber and Dreisbach (2014) we find the example of a slot machine useful to explain our rationale for the use of random, non-controllable rewards as a way to manipulate emotion. When playing a slot machine, one does not have control over the outcome, no matter how hard or fast one pulls the lever. Yet, it is clear that this experience invokes emotion (e.g., excitement, surprise, anger). The emotion manipulation in the current study is similar to the slot machine scenario.

Table 1
Demographic characteristics, questionnaire responses, and experimental payouts separately for gain and loss conditions.

Characteristic	Gain	Loss
N	40	37
Age	22.9 (3.99) +	22.5 (3.40)
Age range	17–32+	18–30
Years of education	15.0 (2.3) +	14.8 (1.6)
Positive mood	29.8 (8.03)	28.8 (6.05)
Negative mood	12.3 (2.33)	12.4 (2.79)
TAS-20	46.4 (10.02)	45.5 (9.98)
Neuroticism*	21.8 (8.5)	23.9 (8.71)
Extraversion*	28.8 (7.96)	26.6 (6.68)
Openness*	29.8 (5.56)	31.8 (6.04)
Agreeableness*	31.6 (5.63)	29.4 (7.38)
*Conscientiousness**	*31.1 (7.51)*	*26.3 (7.62)*
Drive	14.6 (2.26)	15.1 (2.28)
Fun seeking	16.0 (2.72)	16.7 (2.77)
Reward responsiveness	22.4 (2.43)	21.9 (3.03)
Behavioral inhibition	*24.6 (4.35)*	*20.5 (3.66)*
MID payout	$9.69 ($1.67)	$0.16 ($1.60)
MID payout range	$4.52 – $12.53	$ – 3.02 to $2.99

Note. Negative mood and positive mood are Positive and Negative Affect Schedule scores (Watson et al., 1988). T-AS–20 = 20 item Toronto Alexithymia Scale (Taylor et al., 1990). Neuroticism, extraversion, openness, agreeableness, and conscientiousness are from the revised NEO Five-Factor Inventory (Costa & McCrae, 1989). Drive, fun-seeking, reward responsiveness and behavioral inhibition are from the BIS/BAS inventory (Carver & White, 1994). MID: Monetary incentive delay task. Standard deviations are in parentheses.
*Due to time constraints, $N = 36$ and $N = 27$ in the gain and loss conditions, respectively.
+Due to experimenter error, $N = 38$.
Italicized font indicates significant differences between the two groups.

failing to properly complete the task, an additional 6 excluded for not having data in all conditions of interest, leaving 40 participants (18 males) included in the analysis. Forty-seven participants completed the loss condition but two were excluded for failing to properly complete the task, and an additional 8 for not having data in all conditions of interest, leaving 37 (16 males) participants included in the analysis. Refer to Table 1 for participant characteristics.

2.2. Stimuli

A set of 4-letter nouns (e.g., book) were chosen from the MRC Psycholiguistic Database (Coltheart, 1981). Four linguistic properties (Brown-frequency [$M = 35$, $SD = 252$], concreteness [$M = 505.67$, $SD = 94.02$, range = 302–645], familiarity [$M = 519.6$, $SD = 65.4$, range 302–643], and imageability [$M = 513.93$, $SD = 79.12$, range = 302–659]) were used to reduce the stimulus set to 320 neutral words (160 targets and 160 distractors). Stimuli were randomly assigned to the experimental conditions for each participant (except hit/miss, as these were either based on participant performance or randomly assigned). For a list of words used in the experiment, see Section 1 of the supplementary material.

The task was created using E-Prime (Psychology Software Tools, Inc). Stimuli were presented on a Samsung desktop with a 17” screen, positioned approximately 50 cm from the participant. All stimuli were presented in 22-pt white Arial font on a black background.

2.3. Questionnaires[2]

A set of questionnaires assessing mood and personality traits were included to create a short delay between the encoding and retrieval phases.

2.3.1. Positive and Negative Affect Schedule (PANAS)

High scores on the two subscales indicate strong current positive and negative affect (Watson, Clark, & Tellegen, 1988).

2.3.2. Toronto Alexithymia Scale (TAS-20)

A 20-item scale where lower scores indicate less possibility or a smaller degree of alexithymia—an inability to identify one’s own emotions or the emotions of others (Taylor et al., 1990).

[2] On average, participants in gain condition did not differ from participants in loss condition with two exceptions. Participants in gain condition had significantly higher BIS scores, $t(75) = 4.51$, $p < .001$ and consciousness values, $t(61) = 2.52$, $p = .01$.

2.3.3. NEO five-factor inventory

The 60-item scale has five subscales measuring different personality characteristics: neuroticism, extraversion, openness, agreeableness, and conscientiousness (Costa & McCrae, 1989).

2.3.4. Behavioral inhibition system/behavioral avoidance system scales (BIS/BAS)

This scale assesses sensitivity to approach motives (BAS) and avoidance motives (BIS) (Carver & White, 1994). The BAS portion consists of three subscales: drive (persistent pursuit of desired goals), fun-seeking (desire for new rewards and propensity to engage in spontaneous behavior and events to gain potential rewards), and reward responsiveness (focus on positive responses and occurrence or anticipation of rewards).

2.4. Procedure

Participants were told the study would examine the effects of motivation on reaction time, but were not told that their memory would be tested. After giving informed consent, participants completed the PANAS. The researcher gave verbal instructions for the encoding task (detailed below). Participants then completed ten practice trials and had the opportunity to ask questions before completing four experimental blocks of encoding trials. After each block, participants had the option to break briefly before moving on. Before commencing the surprise recognition test, participants completed the NEO-60, TAS-20 and BIS/BAS. The recognition test included all 160 words from the encoding phase, as well as 160 new words that were randomly intermixed and presented one at a time. Participants were asked to make old/new judgments about each word, and were prompted for confidence ratings following each "old" response, using a scale of 1 (very confident) to 4 (just guessing). Participants were also asked to make a judgment about the spatial location of the word during encoding. After the memory test, participants were fully debriefed about the purpose of the study and paid in cash.

2.4.1. Paradigm

Participants were randomly assigned to either the gain condition or the loss condition upon arrival at the lab. In both conditions, a modified MID task served as the incidental encoding task. The MID task (Knutson et al., 2000) is a reaction time task in which participants are instructed to respond as fast as possible to an on-screen target in order to earn a monetary reward (gain condition) or avoid a monetary loss (loss condition). The difficulty of the task was individually titrated so that the participants gained or avoided a loss on 66% of trials. This was achieved by increasing or decreasing the time limit for a response to the target stimulus in increments of 20 ms, depending on the hit rate on all previous trials. The starting duration of the target was the mean reaction time achieved by the end of the practice trials. The classic MID task was modified to produce two types of affective states, motivation and emotion, in separate trial blocks. During motivation blocks, trial outcomes and monetary gains and losses were determined by performance on the MID task. During emotion blocks, trial outcomes were not contingent on performance on the MID task. Participants thus had no control over their monetary rewards and losses and were told that outcomes were random (although the relative frequency of positive outcomes [66%] was the same as in the motivation blocks). Calibration of the target duration was conducted separately for the two types of blocks because pilot tests had shown that during the emotion blocks, participants tended to slow down, thus making the task easier during the subsequent motivation block.

At the beginning of each encoding block, participants were presented with a 5-s cue indicating whether the upcoming block was a "Performance Block" or a "Random Block" (motivation and emotion block, respectively). Block types alternated, and their order (motivation first or emotion first) was counterbalanced across participants. Each block included 20 trials, each lasting approximately 10 s (see Fig. 1 for details). At the beginning of each trial, a monetary cue lasting 2000 ms was presented that indicated how much money the upcoming trial was worth if participants "hit" the target before it disappeared from the screen. Half the trials were high-value (cued with $5.00) and half were low-value (cued with $0.01), and the order of high- and low-value trials was random within each block. The cue was followed by the brief presentation of a word (250 ms) in one of five spatial locations[3]: Half were presented in the center of the screen, and half were presented in one of the four quadrants (equal numbers in each quadrant over each of the two blocks). Following the word presentation, a fixation cross appeared in the center of the screen for a variable length of time so participants could not anticipate when the target stimulus would appear. The target stimulus was a white star that was presented briefly (for up to 1500 ms) in the center of the screen. Participants had to respond to the target via button press before it was replaced by a fixation cross. The next screen provided feedback regarding the monetary outcome of the trial. In motivation blocks, the feedback indicated the monetary outcome based on the participant's performance on the MID task, whereas in the emotion blocks, the feedback indicated the "random" monetary outcome. Table 2 lists all possible cue and feedback combinations. After the feedback screen, another word was presented (250 ms) in one of five spatial locations. Participants were instructed that words would appear in various screen locations at various times during each trial, but that they did not have to make a response to the words. At the end of each trial, participants were asked to provide a rating of their affective state using the affect grid, which allows for a single measure of both pleasure/valence and arousal (Russell, Weiss, & Mendelsohn, 1989). The results of the valence and arousal ratings and an image of the affect grid are presented in Section 2 of the supplementary material.

[3] In E-Prime, the word stimuli were presented within a "SlideState" with a frame of 100% × 100%. Within the frame, five sub-objects were created sized 25% × 25% (which translates to a box that takes up about 12.5% of the screen). The center sub-object was "centered" on the screen. The top left quadrant was positioned at (X = 14%, Y = 15%), top right quadrant at (X = 86%, Y = 15%), bottom right at (X = 14%, Y = 83%), and bottom right at (X = 86%, Y = 83%).

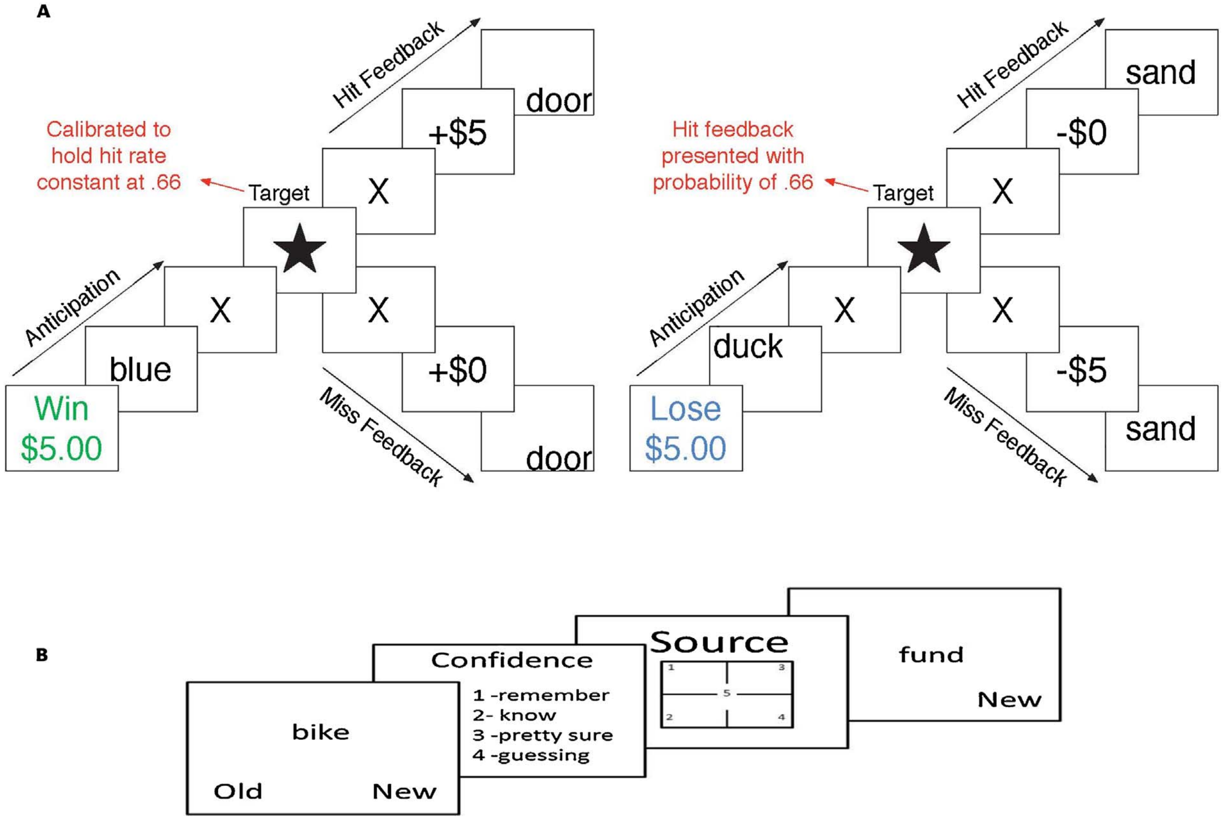

Fig. 1. General schematic of the paradigm for gain and loss conditions. **A**: Modified MID task. *Anticipation* = cue at the beginning of each trial informing participants of the monetary value of the upcoming trial (2000 ms). In reward condition, the cues read either "Win $5.00", "Win $0.01". In loss condition, the cues read "Lose $5.00" or "Lose $0.01". Cue-word presented right after the monetary cue (duration = 250 ms). *Fixation*: variable wait (up to 1500 ms); *Target*: the target stimulus for the MID task. The duration of this target was titrated to the participant's reaction time (max 1500 ms) to achieve a hit rate of 66%. *Hit Feedback*: indicated to the participant a positive trial outcome with the monetary outcome; *Miss Feedback*: indicated to the participant a negative trial outcome with the monetary outcome. Outcome-Word: followed hit and miss feedback. Word placement: cue-words and outcome-words were presented in five locations on the screen: central or one of the four peripheral locations. **B**: Old/new recognition task. If "old" was selected, participants were then asked to rate their confidence on a scale of 1–4 (remember, know, pretty sure, guessing) and indicate the spatial location that word was presented in during the encoding task (1 = top left; 2 = bottom left; 3 = top right; 4 = bottom right; 5 = central). No screen advanced until a response was made (infinite duration).

Table 2
MID Cues and Outcomes for the Gain and Loss Conditions.

	Gain	
Cue	"Hit" Feedback	"Miss" Feedback
Win $5.00	+ $5.00	+ $0.00
Win $0.01	+ $0.01	+ $0.00
Loss		
Cue	"Hit" Feedback	"Miss" Feedback
Lose $5.00	− $0.00	− $5.00
Lose $0.01	− $0.00	− $0.01

Note. Gain = gain condition; Loss = loss condition; Cue = monetary value participants see at the beginning of each trial; Hit Feedback = the monetary outcome associated with a successful trial; Miss Feedback = the monetary outcome associated with an unsuccessful trial. The cues and outcomes are the same for both the emotion and motivation blocks.

2.4.2. Task instructions

The instructions for the gain condition were as follows (presented over a series of screens through which participants toggled using the space bar):

> The goal of this game is to win money. You will start out with a balance of $0. Your task is to hit the SPACE BAR while a white star briefly appears on the screen. There will be two different blocks of trials: "PERFORMANCE" and "RANDOM". At the beginning of each block, you will be told whether the upcoming block of trials is "PERFORMANCE" or "RANDOM". PERFORMANCE BLOCK:

Whether you win money depends on your performance on the task. RANDOM BLOCK: Whether you win money depends on random chance. At the beginning of each trial, you will be given a cue that indicates how much money is at stake for the upcoming trial. The cue will read either: "WIN $5.00" or "WIN $0.01". This indicates the amount you can win on the upcoming trial. If it is a "PERFORMANCE BLOCK", you can win that amount by hitting the space bar on time. If it is a "RANDOM BLOCK", you can win that amount regardless of whether you hit the space bar on time. After each trial you will be told whether or not you have won money on that trial. Remember, if it is a "PERFORMANCE BLOCK", the feedback will indicate whether you won money based on your performance on the star task. If it is a "RANDOM BLOCK", the feedback will indicate whether you randomly won money. At the end of each trial, you will be asked to make a rating about the emotion you are feeling. Using the mouse, click the square in the grid that best describes the type and intensity of the emotion you are feeling. A few more things, words will appear in various locations of the screen during the task. You do not need to make any response to these words. At the end of the experiment you will receive 10% of your earnings in cash if your final balance is positive.

The loss condition was identical to the gain condition except for the valence of the monetary outcome. Specifically, during motivation (i.e., performance) blocks participants could avoid losing money based on their performance on the task and in emotion (i.e., random) blocks, whether they avoided losing money was random. The instructions conveyed to participants were the same with the following exceptions underlined in the text above: 1) You will start out with a balance of $60; 2) "win" wording in the instructions were replaced with "avoid losing".

2.4.3. Design

The design included within-subjects factors: Block (motivation, emotion), incentive magnitude (high, low), word location (central, peripheral), and context (cue, hit feedback, miss feedback); and a between-subjects factor, domain (gain, loss).

3. Analyses

Analyses were conducted using SPSS (Statistical Package for Social Sciences 18.0. SPSS Inc., Chicago, USA). We analysed memory for words presented in the central location only as overall memory performance for words presented in peripheral locations was not significantly different from chance (see below). Inferential statistics were restricted to hit rates because distractor items were never paired with any of the independent variables.

4. Results

4.1. MID task

4.1.1. Median RTs

Median RTs were calculated for trials on which participants responded to the star target before it disappeared from the screen. Median RTs were submitted to a 2 (Block: motivation vs. emotion) x 2 (Magnitude: high vs. low) x 2 (Domain: gain vs. loss) repeated-measures ANOVA. There was a significant effect of magnitude, $F(1, 75) = 35.74$, $p < .001$, $\eta_p^2 = .32$, such that RTs were shorter during high value trials ($M = 215$, $SE = 3$) compared to low value trials ($M = 224$, $SE = 3$). There was also a significant Block x Domain interaction, $F(1, 75) = 15.05$, $p < .001$, $\eta_p^2 = .17$. In the gain condition, RTs were shorter during the emotion ($M = 218$, $SE = 4$) compared to motivation block ($M = 230$, $SE = 5$), $t(39) = 2.59$, $p = .01$, $\eta^2 = .15$, but in the loss condition, RTs were shorter in the motivation block ($M = 208$, $SE = 6$) compared to the emotion block ($M = 220$, $SE = 4$), $t(36) = 2.94$, $p = .01$, $\eta^2 = .19$. No other significant effects emerged, $F(1, 75) \leq 1.91$, $p \geq .17$, $\eta_p^2 \leq .03$.

4.1.2. Proportion of hits

The proportion of MID hits was also calculated for each trial type, and was submitted to a 2 (Block: motivation vs. emotion) x 2 (Magnitude: high vs. low) x 2 (Domain: gain vs. loss) repeated-measures ANOVA. There was a significant effect of magnitude, $F(1, 75) = 17.47$, $p < .001$, $\eta_p^2 = .19$. Hit rates were higher during high value trials ($M = .69$, $SE = .01$) compared to low value trials ($M = .63$, $SE = .01$). There were no other significant effects, $F(1, 75) \leq 0.35$, $p \geq .56$, $\eta_p^2 \leq .01$.

4.2. Recognition memory

4.2.1. Hit rate for central vs. peripheral words

To assess overall memory performance, we calculated corrected recognition scores by subtracting the false alarm rate from the hit rate for central items and for peripheral items, respectively. These values were then submitted to a one-sample *t*-test to determine whether recognition performance was above the chance level (i.e., a value of 0). Corrected recognition scores for central items ($M = .11$, $SE = .01$), was significantly greater than chance, $t(90) = 10.12$, $p < .001$, $\eta^2 = .53$. In contrast, corrected recognition for peripheral items ($M = .02$, $SE = .009$), was not significantly greater than chance, $t(90) = 1.81$, $p = .08$, $\eta^2 = .04$. We therefore limited the remaining analyses to centrally presented items only.

4.2.2. Recognition hit rate for central words

Recognition hit rates were entered into a 2 (Block: motivation vs. emotion) x 2 (Magnitude: high vs. low) x 3 (Context: cue, hit

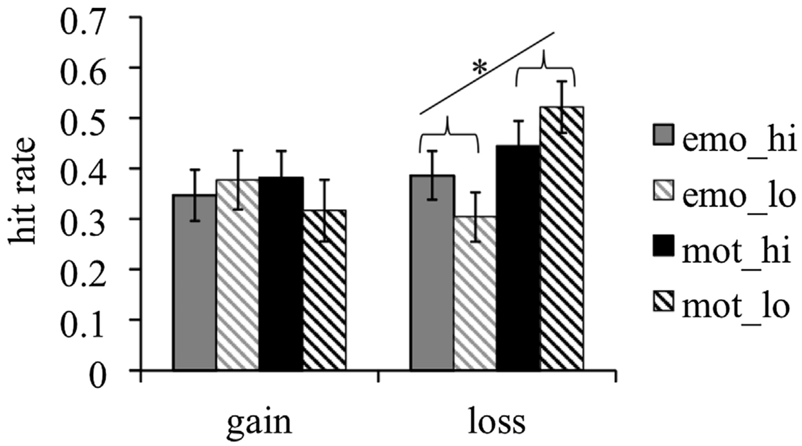

Fig. 2. Hit rates after miss feedback for each trial type separately for gain and loss conditions. emo_hi = emotion block, high value incentive; emo_lo = emotion block, low value incentive; mot_hi = motivation block, high value incentive; mot_lo = motivation block, low value incentive. Error bars = standard error. *indicates significant difference between motivation and emotion in the loss block.

feedback, miss feedback) x 2 (Domain: gain vs. loss) repeated-measures ANOVA. There was a significant main effect of block, $F(1, 75) = 4.19$, $p = .04$, $\eta_p^2 = .05$ and a significant Block x Domain interaction, $F(1, 75) = 6.46$, $p = .01$, $\eta_p^2 = .08$. These were qualified by a significant Block x Magnitude x Context x Domain interaction, $F(2, 150) = 3.42$, $p = .04$, $\eta_p^2 = .04$. We followed up the 4-way interaction by probing the effects of block, magnitude and domain on hit rates separately for each context: cue, hit feedback and miss feedback.

Analysis of hit rate for words presented in the cue phase revealed no significant effects of block, magnitude, or domain, nor any significant interactions (overall $M = .35$, $SE = .02$), $F(1, 75) \leq 2.25$, $p \geq .14$, $\eta_p^2 \leq .03$. Memory for words presented after hit feedback (overall $M = .37$, $SE = .02$) also showed no significant main effects of the independent variables, nor any interactions, $F(1, 75) \leq 0.23$, $p \geq .63$, $\eta_p^2 \leq .003$. In contrast, memory for words presented after miss feedback was affected by the manipulations. There was a significant main effect of Block, $F(1, 75) = 4.41$, $p = .04$, $\eta_p^2 = .06$, a Block x Domain interaction, $F(1, 75) = 6.48$, $p = .01$, $\eta_p^2 = .05$, and a Block x Magnitude x Domain interaction, $F(1, 75) = 3.89$, $p = .05$, $\eta_p^2 = .05$. We probed the 3-way interaction with 2 (Block) x 2 (Magnitude) ANOVAs conducted separately for the gain and loss conditions. For the gain condition, hit rate was not affected by block or magnitude, nor did these factors interact, $F(1, 39) \leq 1.07$, $p \geq .31$, $\eta_p^2 \leq .03$. For the loss condition, there was a significant main effect of Block, $F(1, 36) = 10.11$, $p = .003$, $\eta_p^2 = .22$, driven by significantly higher hit rates in the motivation block ($M = .48$, $SE = .05$) compared to the emotion block ($M = .35$, $SE = .04$). No other effects were significant, $F(1, 36) \leq 3.11$, $p = .09$, $\eta_p^2 \leq .08$. See Fig. 2 for an illustration of the 3-way interaction. See Section 3 of the supplementary material which details a follow-up study replicating these main findings.

4.2.3. Memory confidence for hits

Memory confidence was measured after participants responded "old", using a scale of 1 (high) – 4 (low). Due to the small number of participants with data in all conditions ($N = 9$ and 10 in gain and loss conditions, respectively) the analyses presented next were collapsed across high and low magnitude ($N = 28$ vs. 29, in gain and loss conditions, respectively). Mean confidence ratings were submitted to a 2 (Block: emotion vs. motivation) x 3 (Context: cue, hit feedback, miss feedback) x 2 (Domain: gain, loss) ANOVA. There were no significant effects of the independent variables on memory confidence (overall $M = 2.73$, $SE = .10$), $F(1, 55) \leq 1.48$, $p \geq .23$, $\eta_p^2 \leq .03$.

4.2.4. Memory location accuracy for hits

Accuracy of word location (i.e., participant's judgments of whether an 'old' word was presented centrally or in one of the 4 peripheral locations) was submitted to a 2 (Block: emotion vs. motivation) x 2 (Magnitude: high vs. low) x 2 (Phase: cue, hit feedback, miss feedback) x 2 (Domain: gain, loss) repeated-measures ANOVA for central items only. There was a significant Block x Domain interaction, $F(1, 74) = 4.00$, $p = .05$, $\eta_p^2 = .05$. This was followed up with an independent samples *t*-test which indicated that in the emotion block, location accuracy was similar in the gain ($M = .15$, $SE = .02$) and loss conditions ($M = .16$, $SE = .02$), $t(75) = 0.64$, $p = .53$, $\eta^2 = .005$. In the motivation block, location accuracy was marginally significant, $t(75) = 1.84$, $p = .07$, $\eta^2 = .04$, with lower accuracy in the gain ($M = .14$, $SE = .02$) compared to the loss condition ($M = .19$, $SE = .02$).

5. Discussion

Emotion and motivation are known to modulate memory processes. However, the influences of these two types of affect on memory have typically been studied separately, using different stimuli and experimental paradigms. As a result, little is known about commonalities and differences between emotion- and motivation-modulated memory. The goal of the current study was to induce motivational and emotional states using a single manipulation – monetary incentives – over which the participant either did or did not have control. We compared the effects of these states on incidental memory for unrelated stimuli, while also manipulating the affective context (anticipation, positive feedback, negative feedback), the magnitude of the affective experience (high vs. low) and affective valence domain (gains vs. losses). The key finding was that motivation and emotion indeed affected memory differently, such that negative feedback boosted memory when participants had a sense of control over outcomes ("motivation") as opposed to no sense of control ("emotion") − but only when losses were at stake. No such pattern was seen in the gain condition.

5.1. No effects of anticipatory affect on memory

In the MID task, anticipatory affect was induced with a cue that signals the availability of a reward of variable type (gain, loss) and magnitude (high, low). Contrary to some previous reports (e.g., Adcock et al., 2006; Spaniol et al., 2013) we did not find any cue effects on memory performance in the current study. Neither memory, nor memory confidence, for words incidentally encoded immediately after an incentive cue was sensitive to the type or magnitude of the cue, and unlike Fröber and Dreisbach's (2014) study of cognitive control, to whether the cue signalled a controllable reward (motivation block) or an uncontrollable reward (emotion block). Instead, our findings most resemble those of Mather and Schoeke (2011), who found robust feedback effects, but only modest reward anticipation effects on immediate incidental memory. It is possible that the effects of anticipatory affect depend on time-dependent consolidation processes (McGaugh, 2000) and that immediate memory tests are not sufficiently sensitive to these processes. Indeed, numerous studies have found motivation and emotion effects on delayed but not immediate tests of recognition, suggesting that motivation-modulated memory (Murayama & Kitagami, 2014; Murayama & Kuhbandner, 2011; Spaniol et al., 2013) and emotion-modulated memory (Bowen, Spaniol, Patel, & Voss, 2016; Kensinger, 2004; Sharot, Verfaelli, & Yonelinas, 2007; Sharot & Yonelinas, 2008) may require a period of consolidation. In the current study, given the need for fast-paced presentation of a relatively large number of lexical stimuli, memory performance would likely have been too low after an extended delay. Indeed, this was already the case for items presented in peripheral locations, which had to be excluded from analysis. As such, looking at the interaction of affect type and test delay remains a challenge for future research.

5.2. Feedback effects on memory

The MID task offers two types of feedback—positive ("hit") and negative ("miss"), indicating either gain and non-loss, or non-gain and loss, respectively. Mather and Schoeke (2011) found that stimuli encoded following positive feedback were remembered better than stimuli encoded following negative feedback. We did not replicate this finding, in either the emotion or the motivation condition. We also did not find that memory confidence was affected by any of the experimental factors. While null effects must always be interpreted with caution, it is worth noting that the sample size in the current study was relatively large ($N = 76$ across gain and loss conditions), affording high statistical power to detect a medium-sized effect of feedback type (positive vs. negative; $1 - \beta = 0.99$) (Faul, Erdfelder, Lang, & Buchner, 2007). Furthermore, the results from the MID task confirmed that participants were sensitive to the experimental manipulations, achieving faster reaction times and more MID "hits" after high- than low-magnitude cues, at least in the loss condition and in the motivation blocks. More research is needed to shed light on the robustness and generality of positive feedback effects on incidental memory.

In line with prior findings reported by Gable and Harmon-Jones (2010), the current data do reveal differences in how emotional and motivational states influence memory in the context of negative feedback. Memory for words presented after negative feedback was better in the motivation compared to the emotion block, but only in the loss condition. In other words, when participants received feedback that their effort to avoid a (controllable) loss was unsuccessful, they were more likely to remember words presented immediately following the feedback, compared to a scenario in which the loss was not controllable. One speculative explanation for this finding is that negative loss feedback while in a motivational state focuses attention in service of goal attainment on the next trial or detection of information that may provide an explanation for why the goal was not achieved, thus incidentally guiding successful memory for item and item location for stimuli present in the vicinity. Conversely, this attentional narrowing in service of avoiding a punishment does not occur to the same extent when in an emotional state and outcomes are not under control of the individual. Instead, attention is allowed to vary to a greater extent and memory is negatively affected.

It is interesting that memory was influenced by manipulations of loss and negative feedback (i.e., failing to attain a reward or incurring a monetary penalty) but not to manipulations of gains and positive feedback. Individual differences in characteristics between participants in the gain and loss conditions (see Footnote 2) could have contributed to this finding; however, we were able to replicate these results in another sample of participants presented in the supplementary material. There is evidence that "losses loom larger than corresponding gains" (Tversky and Kahneman, 1991, p. 1039), that people are generally risk averse and that "bad is stronger than good" (Baumeister, Bratslavsky, Finkenauer, & Vohs, 2001). These findings add to that literature suggesting that this is true particularly in the context of controllable losses. Risk aversion may be an adaptive feature of memory: remembering the circumstances of avoidable negative events is particularly important for future behavior.

5.3. Limitations and future directions

In addition to the aforementioned issue regarding the role of consolidation processes that was not examined in the current study, there are several other issues that should be addressed in future work. First, memory was influenced by monetary loss but not monetary gain. It is possible that reinforcers more potent than the small financial bonuses used in the current study are needed to produce reliable effects of positive affect on memory. On the other hand, many previous studies have found influences on behavior using financial rewards of equivalent or lower value (Gable & Harmon-Jones, 2010; Mather & Schoeke, 2011; Spaniol, Bowen, Wegier, & Grady, 2015; Spaniol et al., 2013). Why approach motivation and positive affect had less influence on memory than avoidance motivation and negative affect remains to be studied in future research.

Second, we manipulated control over outcomes to operationalize the difference between emotion and motivation, rather than relying on different experimental stimuli or paradigms as was done in prior work. We recognize that sense of control is only one of several dimensions that separate the constructs of emotion and motivation. However, it is important to note that similar approaches to differentiating between emotion and motivation have been used successfully in studies of affect and cognitive control (Chiew & Braver, 2011, 2014; Fröber & Dreisbach, 2014). Testing alternative methods for separating emotional and motivational affect—for example, by drawing on work differentiating "liking" versus "wanting" (e.g., Berridge, Robinson, & Aldridge, 2009)—is an important challenge for future work.

6. Conclusions

This study is the first to examine the consequences of controllable and uncontrollable monetary gains and losses during encoding to contrast the effects of motivation and emotion on episodic memory. Our findings suggest that differences in the mnemonic consequences of the two types of affect emerge during the feedback stage after an outcome is known and are specific to the loss context. When losses are perceived as controllable, memory for items that are encoded after loss feedback is improved relative to when losses are perceived as outside one's control. Interestingly, the same asymmetry was not observed for gains. The findings fit with theories regarding the potentially adaptive function of enhanced learning and memory for information experienced in the context of losses (Baumeister et al., 2001) and add that this may be particularly true in the context of avoidable losses. Overall, the current findings contradict the suggestion that emotion and motivation are interchangeable constructs (Laming, 2000) and instead support the idea that the two types of affect are dissociable (see Berridge et al., 2009; Berridge & Robinson, 2003; Berridge, 1996). More research is needed to delineate the neural mechanisms contributing to the asymmetric effects of loss-related motivation and emotion on long-term memory formation.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.lmot.2017.05.003.

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