Cognition 166 (2017) 73–83

Contents lists available at ScienceDirect

Cognition

journal homepage: www.elsevier.com/locate/COGNIT

Original Articles

# Negative emotion enhances mnemonic precision and subjective feelings of remembering in visual long-term memory

Weizhen Xie, Weiwei Zhang *

*Department of Psychology, University of California, Riverside, CA, United States*

ARTICLE INFO

*Article history:*
Received 30 November 2016
Revised 14 May 2017
Accepted 16 May 2017
Available online 26 May 2017

*Keywords:*
Emotion
Memory
Quality
Quantity
Vividness

ABSTRACT

Negative emotion sometimes enhances memory (higher accuracy and/or vividness, e.g., flashbulb memories). The present study investigates whether it is the qualitative (precision) or quantitative (the probability of successful retrieval) aspect of memory that drives these effects. In a visual long-term memory task, observers memorized colors (Experiment 1a) or orientations (Experiment 1b) of sequentially presented everyday objects under negative, neutral, or positive emotions induced with International Affective Picture System images. In a subsequent test phase, observers reconstructed objects' colors or orientations using the method of adjustment. We found that mnemonic precision was enhanced under the negative condition relative to the neutral and positive conditions. In contrast, the probability of successful retrieval was comparable across the emotion conditions. Furthermore, the boost in memory precision was associated with elevated subjective feelings of remembering (vividness and confidence) and metacognitive sensitivity in Experiment 2. Altogether, these findings suggest a novel precision-based account for emotional memories.



## 1. Introduction

Human memories are strikingly malleable by emotional experience. In the classic example of *flashbulb memory* (Brown & Kulik, 1977), information encoded under emotional salience (usually with negative valence) was often remembered with exceptional vividness and accuracy (Conway et al., 1994; Levine & Pizarro, 2004; Phelps & Sharot, 2008). Although this phenomenon has been widely studied in affective, cognitive, and clinical sciences (LeDoux, 1997), the nature of these emotional effects on memory processes is under considerable controversy. Does emotion enhance objective measures of memory performance such as accuracy (Kensinger, 2007; Mather & Sutherland, 2011)? Or, does it mainly influence subjective feelings of remembering, such as confidence and vividness, without substantial boost of memory accuracy (Dougal & Rotello, 2007; Phelps & Sharot, 2008; Talarico & Rubin, 2003)?

On the one hand, there is strong evidence supporting the beneficial effects of negative emotion on overall memory accuracy (Kensinger, 2007; Mather & Sutherland, 2011), and specifically on the consistency across multiple memory reports (Conway et al., 1994; Holland & Kensinger, 2012). As for memory representation, negative emotion tends to enhance memory for central features of an event, often at the cost of encoding peripheral information, known as the memory narrowing effect (Brown & Kulik, 1977; Kensinger, Garoff-Eaton, & Schacter, 2007a; Safer, Christianson, Autry, & Österlund, 1998). This narrowing effect often leads to better memory for specific visual details. It could manifest as higher accuracy in discriminating studied items from high-similarity lures for negative materials compared to neutral stimuli (Kensinger & Schacter, 2007; Kensinger, Garoff-Eaton, & Schacter, 2006), or higher accuracy in recalling materials with negative affect (Kensinger, Garoff-Eaton, & Schacter, 2007b).

On the other hand, negative emotional valence does not always boost memory accuracy. For instance, effects of negative emotion on memory performance may be largely subjective in nature (Talarico & Rubin, 2003), in that negative emotion may mainly enhance subjective feelings of vividness or confidence for retrieved memory (Dougal & Rotello, 2007; Talarico & Rubin, 2003), with the magnitude of enhancement being modulated by emotion intensity (Reisberg, Heuer, Mclean, & O'shaughnessy, 1988). Consequently, elevated subjective sense of remembering for emotional contents may be a grand illusion, in that it could simply result from overconfidence or liberal response bias in subjective ratings (Dougal & Rotello, 2007; Thapar & Rouder, 2009; Windmann & Kutas, 2001), without actual increases in accuracy (Phelps & Sharot, 2008; Sharot, Delgado, & Phelps, 2004; Talarico & Rubin, 2003), or even without actual memory for the original events (Neisser &

* Corresponding author at: Department of Psychology, University of California, Riverside, 900 University Ave., Riverside, CA, 92521, United States.

*E-mail address:* weiwei.zhang@ucr.edu (W. Zhang).

http://dx.doi.org/10.1016/j.cognition.2017.05.025
0010-0277/

Harsch, 1992). This dissociation between subjective and objective aspects of emotional memory may result from their dissociable neural mechanisms. That is, confidence for emotional memories is mostly driven by the emotion associated with the memory contents supported by amygdala, whereas memory accuracy is critically dependent on mnemonic details supported by medial temporal lobe structures such as parahippocampus (Phelps & Sharot, 2008; Sharot et al., 2004). It has thus been hypothesized that we retrieve memories for emotionally charged events, along with our initial emotional assessment and reaction to the events (Buchanan, 2007; Smith, Stephan, Rugg, & Dolan, 2006), which may be a significant source for inflated vividness and confidence.

The central issue here is therefore whether phenomenologically extraordinary emotional memories are grounded on greater memory accuracy for specific visual details, and if so whether the boost in memory accuracy is associated with elevated ratings of subjective vividness and confidence. Previous studies using quantity-oriented methods that focused on the likelihood of remembering or the amount of retained memories often failed to show significant emotional effects (e.g., Kensinger & Schacter, 2006; Rimmele, Davachi, Petrov, Dougal, & Phelps, 2011; Windmann & Kutas, 2001). In contrast, studies using quality-oriented methods that focused on memory details have yielded relatively consistent emotional effects (see Kensinger, 2009; Kensinger & Schacter, 2008 for discussions). However, these two approaches were often used in separate studies, and the dependent measures, such as accuracy, consistency, and the amount of details, typically confounded quantitative and qualitative aspects of memory representations. In addition, most of these studies directly compared memory for emotionally charged events and neutral events, leaving doors open for alternative interpretations that various sources of confounds could lead to differences in memory performance (Kensinger & Schacter, 2008). Therefore, it is pivotal to simultaneously and independently assess quantitative and qualitative aspects of memory for neutral contents encoded under different emotion conditions.

The present study examined influences of induced emotion on visual long-term memory (LTM) for emotionally neutral contents (color and orientation of everyday objects) using a quantitative framework that separates out the quantitative and qualitative aspects of memory in a recall task (Brady, Konkle, Gill, Oliva, & Alvarez, 2013; Zhang & Luck, 2008). Participants initially memorized colors (Experiment 1a & Experiment 2) or orientations (Experiment 1b) of everyday objects under negative, neutral, or positive emotions induced with images from the International Affective Picture System (IAPS) during a study phase. In the subsequent test phase, participants reconstructed colors (Experiment 1a & Experiment 2) or orientations (Experiment 1b) of previously learned objects from memory. The likelihood of remembering a test object (memory quantity) was assessed based on its reverse relationship with the probability of memory retrieval failure, whereas the quality of memory representation was assessed as the inverse of variability in memory recall. We predicted that objects encoded under negative emotion should lead to better memory (specifically higher precision) for surface features such as color and orientation (Experiment 1a & 1b) and the modulation of memory precision by negative emotion should be associated with increased subjective report of vividness and confidence (Experiment 2).

## 2. Experiment 1

### 2.1. Participants

A total of 50 participants took part in Experiment 1 at the University of California, Riverside for course credits. Half of them ($n = 25$) participated Experiment 1a (19.60 ± 1.07 [Mean ± SD] years old, 13 female) and the other half ($n = 25$) participated Experiment 1b (19.70 ± 1.38 years old, 16 female). All participants had normal or corrected-to-normal visual acuity and reported having normal color vision. A larger number of trials per condition, especially when guessing rates are high, is needed to ensure bias-free and robust model fits (see Lawrence, 2010; Zhang, 2007). As a consequence, three additional participants in Experiment 1a with over 87.5% of memory retrieval failure in recall were excluded from data analysis due to the lack of reliable model fits for these subjects (see Zhang & Luck, 2008 for details).

### 2.2. Materials and procedure

#### 2.2.1. Stimuli

Stimuli were presented using Psychophysics Toolbox (Brainard, 1997) in Matlab (The MathWorks, Cambridge, MA) on a 60 Hz LCD monitor, calibrated with a X-Rite I1Pro spectrophotometer, with a gray background (6.1 cd/m$^2$) at a viewing distance of 57 cm. Stimuli for emotion induction were drawn from the IAPS library (Lang, Bradley, & Cuthbert, 2008). Sixty images were selected for each of the three emotion conditions (i.e., positive, neutral, and negative). The normative valence ratings on a 9-point scale of these images had medians of 7.25 [Inter-Quartile Range, IQR: 6.94, 7.50], 5.08 [IQR: 4.87, 5.21], and 2.57 [IQR: 2.25, 2.89], for positive, neutral, and negative conditions, respectively. The normative arousal ratings (9-point scale) had medians of 5.56 [IQR: 5.20, 5.88], 3.71 [IQR: 3.35, 4.20], and 5.76 [IQR: 5.23, 6.08], for positive, neutral, and negative conditions, respectively. Wilcoxon rank-sum tests for these skewed ordinal normative ratings showed that the negative images were significantly more negative ($z = -9.44$, $p < 0.0001$) and more arousing ($z = 7.29$, $p < 0.0001$) than neutral images, and positive images were significantly more positive ($z = 9.43$, $p < 0.0001$) and more arousing ($z = 8.28$, $p < 0.0001$) than neutral images (also see Xie & Zhang, 2016b). It is intuitive that the negative images were more negative than the positive images ($z = -9.45$, $p < 0.0001$), but their arousal level were comparable in this study ($z = 1.65$, $p = 0.10$). Each IAPS image was presented twice in the study phase and each time paired with a different object. The orders of the three emotion conditions and IAPS images for each emotion condition were randomly intermixed for each participant. All IAPS images, presented in a rectangular area of $26° \times 34°$ of visual angel, were rendered in gray-scale to minimize potential interference with the subsequent color encoding task.

Three-hundred ninety unique objects (130 for each of the three conditions) for the LTM task in Experiment 1a were randomly chosen from Brady et al.'s (2013) stimuli set which originally included 540 pictures of categorically distinct objects that could be recognized in arbitrary colors. These objects' colors could be randomly rotated in hue space, yielding different color appearance. On each trial, a random color value from 120 evenly distributed color hues in a 360-degree CIELAB color space (Brady et al., 2013) was assigned as the initial color of an object ($6.5° \times 6.5°$ of visual angle). For Experiment 1b, 360 unique objects (120 per condition) were randomly chosen from a total of 382 items, which were selected out of the initial 540 items from Brady et al. (2013) based on the following standards: (1) they were neither axial symmetrical nor central symmetrical so that they could be presented and recognized in any arbitrary orientation; and (2) their prototypical orientations were vertical (90° or 270°) to control for categorical encoding. On each trial, a random value from 120 evenly distributed orientations in a 360-degree orientation space was assigned as the initial orientation of an object. The color of each object was randomized in the same way as Experiment 1a, although color was totally task irrelevant.