Neurobiology of Learning and Memory xxx (2013) xxx–xxx

Contents lists available at ScienceDirect

Neurobiology of Learning and Memory

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

Encoding negative events under stress: High subjective arousal is related to accurate emotional memory despite misinformation exposure ☆

Siobhan M. Hoscheidt [a,b,*], Kevin S. LaBar [a,b], Lee Ryan [c], W. Jake Jacobs [c], Lynn Nadel [c]

[a] Center for Cognitive Neuroscience, Duke University, Durham, NC, USA
[b] Department of Psychology and Neuroscience, Duke University, Durham, NC, USA
[c] Department of Psychology, University of Arizona, Tucson, AZ, USA

ARTICLE INFO

Article history:
Received 15 June 2013
Revised 14 August 2013
Accepted 10 September 2013
Available online xxxx

Keywords:
Misinformation
Stress
Arousal
Emotional memory
Eyewitness testimony

ABSTRACT

Stress at encoding affects memory processes, typically enhancing, or preserving, memory for emotional information. These effects have interesting implications for eyewitness accounts, which in real-world contexts typically involve encoding an aversive event under stressful conditions followed by potential exposure to misinformation. The present study investigated memory for a negative event encoded under stress and subsequent misinformation endorsement. Healthy young adults participated in a between-groups design with three experimental sessions conducted 48 h apart. Session one consisted of a psychosocial stress induction (or control task) followed by incidental encoding of a negative slideshow. During session two, participants were asked questions about the slideshow, during which a random subgroup was exposed to misinformation. Memory for the slideshow was tested during the third session. Assessment of memory accuracy across stress and no-stress groups revealed that stress induced just prior to encoding led to significantly better memory for the slideshow overall. The classic misinformation effect was also observed – participants exposed to misinformation were significantly more likely to endorse false information during memory testing. In the stress group, however, memory accuracy and misinformation effects were moderated by arousal experienced during encoding of the negative event. Misinformed-stress group participants who reported that the negative slideshow elicited high arousal during encoding were less likely to endorse misinformation for the most aversive phase of the story. Furthermore, these individuals showed better memory for components of the aversive slideshow phase that had been directly misinformed. Results from the current study provide evidence that stress and high subjective arousal elicited by a negative event act concomitantly during encoding to enhance emotional memory such that the most aversive aspects of the event are well remembered and subsequently more resistant to misinformation effects.

1. Introduction

Witnessing a disturbing event such as an act of violence is likely to elicit arousal and to be stressful. Research conducted in the area of emotion and memory has provided substantial evidence that stress influences long-term memory processes (see de Quervain, Aerni, Schelling, & Roozendaal, 2009 for review). These effects vary as a function of several modulatory factors, such as the stage of memory processes influenced by stress and the arousing nature of to-be-remembered materials (Buchanan & Lovallo, 2001; Cahill, Gorski, & Le, 2003; Jelicic, Geraerts, Merckelbach, & Guerrieri, 2004; Kuhlmann et al., 2005). Stress induced just prior to encoding has been shown to preserve or enhance memory for negative emotional, relative to neutral, information (Payne et al., 2006, 2007).

Enhanced emotional memory in this context may be attributed in part to the interaction of arousal-based modulation of perception and attention systems and the concomitant influence of stress hormones on brain regions involved in emotion and memory. Negatively arousing materials and events influence perceptual and attentional resources, implicitly biasing perception and attention towards aversive information (Alpers, 2008; Bradley, Hamby, Low, & Lang, 2007; Calvo & Lang, 2005; Nobata, Hakoda, & Ninose, 2010; Nummenmaa, Hyönä, & Calvo, 2006). Spontaneous preferential allocation of attention and perception towards aversive information creates circumstances under which this information has privileged access to further processing in long-term memory systems (see Compton, 2003 for review). Stress-based activation of

* Corresponding author. Address: C03J Levine Science Research Center, Duke University, Box 90999, Durham, NC 27708, USA.
E-mail address: siobhan.hoscheidt@duke.edu (S.M. Hoscheidt).

1074-7427/$ - see front matter © 2013 The Authors. Published by Elsevier Inc. All rights reserved.
http://dx.doi.org/10.1016/j.nlm.2013.09.008

the hypothalamic–pituitary–adrenal (HPA) and sympathetic adrenomedullary (SAM) axes further facilitates processing of emotional information in memory systems, triggering the release of stress hormones (i.e. cortisol and adrenaline/noradrenaline) that enhance neural plasticity (Duvarci & Paré, 2007) and increase functional activation in the amygdala (van Stegeren et al., 2005, 2007), a brain region critical for emotional learning (Buchanan & Adolphs, 2002; Canli, Zhao, Brewer, Gabrieli, & Cahill, 2000). Stress hormones also affect learning in the hippocampus, a region of the brain that plays an integral role in episodic memory. Although stress hormones, such as cortisol, can have impairing effects on hippocampal function overall (Dedovic et al., 2009; Henckens, Hermans, Pu, Joëls, & Fernández, 2009; Pruessner et al., 2008), stress hormone-driven facilitation of neural plasticity within the amygdala influences the hippocampus (Strange & Dolan, 2004) by potentiating learning in this region (Kukolja, Klingmuller, Maier, Fink, & Hurlemann, 2011). In this way, stress and arousal likely interact to create ideal behavioral and neurophysiological conditions for optimal encoding of negative emotional information.

A study conducted by Payne et al. (2007) illustrates that emotional memory enhancement effects depend, at least in part, on the interaction of stress and arousal during encoding. In this study participants underwent a psychosocial stress induction, or control task, after which they viewed identical slideshows (Cahill, Prins, Weber, & McGaugh, 1994) with differing narrations. One group heard a negatively arousing story about a violent car crash and surgical procedures performed on victims of the car wreck. By contrast, the other group was told a story about procedures involved in a standard hospital drill. One week later, participants in the stress/negatively-arousing narration group showed significantly better memory for the slideshow compared to the no stress group. By contrast, memory performance in the stressed/non-arousing slideshow condition was impaired (see also Payne et al., 2006). These results provide evidence that concomitant activation of stress and arousal during encoding create ideal cognitive-neurobiological conditions for negative emotional information to be strengthened in memory.

Somewhat independently, research investigating the fidelity of eyewitness memory has provided ample evidence that people exposed to misleading information often remember false details as veridical components of an experienced event (for a recent review see Loftus, 2005). This phenomenon, known as the misinformation effect (Loftus, 1975; Loftus & Hoffman, 1989; Loftus & Palmer, 1974), has been reported in a multitude of studies and has, over the years, become a classic demonstration of the susceptibility of episodic memory to distortion. From the time of its discovery in the late 1970s, the misinformation effect has had clear implications in the legal domain, providing empirical evidence that in the face of misleading information eyewitness memory is prone to fallibility. Traditionally, studies of misinformation have involved post-event exposure to a single critical piece of misinformation after which subsequent endorsement of the misleading detail is typically observed (Loftus, 1975; Loftus & Palmer, 1974). For example, in the original studies of the misinformation effect (e.g. Loftus, Miller, & Burns, 1978) participants viewed a series of slides that depicted a car running through a stop sign and striking a pedestrian. Later, a subgroup of participants was exposed to a misleading detail when asked, "how fast was the car going when it ran through the yield sign?" The misinformed subgroup was subsequently more likely to erroneously report that the car had run through a yield sign, compared to their non-misinformed counterpart. Misinformation effects also occur when multiple items are misinformed (Cann & Katz, 2005; English & Nielson, 2010; Tomes & Katz, 1997, 2000; Zhu et al., 2012). In such cases memory for an event may become highly distorted after exposure to a number of misleading details (Luna & Migueles, 2009; Okado & Stark, 2005).

Emotional memory enhancement effects, presumably driven by the interaction of stress and arousal during encoding, have interesting implications for eyewitness accounts, which in real-world contexts frequently involve negatively arousing events that likely elicit activation of the physiological stress response and ensuing release of stress hormones. Although negatively arousing events may be subsequently well remembered, this may or may not preclude these memories from susceptibility to misinformation endorsement. Indeed, in some cases memory for negative materials and events has been shown to be more susceptible to incorporation of false information compared to memories for positive or neutral materials (Nourkova, Bernstein, & Loftus, 2004; Porter, Bellhouse, McDougall, ten Brinke, & Wilson, 2010; Porter, Spencer, & Birt, 2003; Porter, Taylor, & ten Brinke, 2008). For example, despite the fact that publicized negative events are typically well remembered, memory for these events is nonetheless susceptible to incorporation of false details (Granhag & Strömwell, 2002; Nourkova et al., 2004; Ost, Vrij, Costall, & Bull, 2002; Porter et al., 2008). From this contradiction arose the notion that although negative emotion generally facilitates memory it may also increase susceptibility to misinformation (Paradoxical Negative Emotion hypothesis; Porter et al., 2008). Some evidence, however, argues against this notion. For example, higher levels of self-reported emotional impact of an eyewitness event have been associated with greater memory accuracy. Furthermore, in such cases subsequent memory reports remain highly accurate despite exposure to false post-event information (Odinot, Wolters, & van Koppen, 2009).

Some studies have demonstrated that stress has overall deleterious effects on eyewitness memory (for review see Deffenbacher, Bornstein, Penrod, & McGorty, 2004; Valentine & Mesout, 2009) whereas others have shown that memory is preserved. For example, Morgan et al. (2004) investigated memory accuracy for an abusive interrogator in individuals undergoing military training. Participants were randomly assigned to high- and low-stress interrogation contexts after which recognition memory for the interrogator was assessed using live line-up and photo-spread methods. Results revealed that more participants in the low-compared to high-stress group had better eyewitness memory, specifically memory for features of the individual who interrogated them. On the contrary, other studies have shown that high subjective stress during encoding predicts highly accurate subsequent memory for an aversive witnessed event (for review see Christianson, 1992). This finding has been reported in cases of eyewitness memory for crimes such as robbery, physical assault and murder where high subjective ratings of stress and arousal experienced during the witnessed event related to highly accurate memory for the event (e.g. 96% accuracy) directly, and for a number of months, following the event (Odinot et al., 2009; Woolnough & MacLeod, 2001; Yuille & Cutshall, 1986).

While investigations of the fidelity of eyewitness memory have been informative in their own right, interpretations of results in light of the effects of stress and/or arousal on memory and subsequent misinformation effects remains unclear. As results are mixed, it is important to investigate factors known to influence memory processes in a manner that could moderate misinformation effects. Critical factors in this regard include the role of stress and emotional arousal, both likely activated during encoding of an eyewitness event and, as previously discussed, are known to influence multiple memory processes (Buchanan & Lovallo, 2001; Cahill & Alkire, 2003; Chamberlain, Müller, Blackwell, Robbins, & Sahakian, 2006; Harris & Pashler, 2005; Kuhlmann and Wolf, 2006; Laney, Campbell, Heuer, & Reisberg, 2004). Regarding laboratory studies of misinformation effects interactions of stress and arousal, particularly arousal evoked by a to-be-remembered event, have typically not been examined. Furthermore, to our knowledge, a systematic

Please cite this article in press as: Hoscheidt, S. M., et al. Encoding negative events under stress: High subjective arousal is related to accurate emotional memory despite misinformation exposure. *Neurobiology of Learning and Memory* (2013), http://dx.doi.org/10.1016/j.nlm.2013.09.008