Neurobiology of Learning and Memory 98 (2012) 12–16

Contents lists available at SciVerse ScienceDirect

Neurobiology of Learning and Memory

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

Memory modulation in the classroom: Selective enhancement of college examination performance by arousal induced after lecture

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ARTICLE INFO

Article history:
Received 26 December 2011
Revised 2 April 2012
Accepted 3 April 2012
Available online 11 April 2012

Keywords:
Memory consolidation
Arousal
Applied memory
Study techniques
Memory modulation

ABSTRACT

Laboratory studies examining moderate physiological or emotional arousal induced after learning indicate that it enhances memory consolidation. Yet, no studies have yet examined this effect in an applied context. As such, arousal was induced after a college lecture and its selective effects were examined on later exam performance. Participants were divided into two groups who either watched a neutral video clip ($n = 66$) or an arousing video clip ($n = 70$) after lecture in a psychology course. The final examination occurred two weeks after the experimental manipulation. Only performance on the group of final exam items that covered material from the manipulated lecture were significantly different between groups. Other metrics, such as the midterm examination and the total final examination score, did not differ between groups. The results indicate that post-lecture arousal selectively increased the later retrieval of lecture material, despite the availability of the material for study before and after the manipulation. The results reinforce the role of post-learning arousal on memory consolidation processes, expanding the literature to include a real-world learning context.

1. Introduction

Considerable research has been devoted to developing effective techniques to enhance learning and retention in the classroom environment. Such research has primarily focused on approaches that target encoding and retrieval effectiveness (see Willingham, 2008). Moreover, these approaches typically require students to acquire and apply new skills or study strategies. That is, they require the learner to change his or her approach to learning. Some of the strategies include studying in groups (Johnson & Johnson, 1983; Nastasi & Clements, 1991), active learning (e.g., Cherney, 2008), focusing on key words (Reutzel & Hollingsworth, 1988), using specific note-taking and review strategies that emphasize the encoding specificity principle (Kobayashi, 2006), maintaining congruence of encoding and retrieval conditions (Cassaday, Bloomfield, & Hayward, 2002; Metzger, Boschee, Haugen, & Schnobrich, 1979), and employing imagination (Cooper, Tindall-Ford, Chandler, & Sweller, 2001; Leahy & Sweller, 2005) or mnemonics (Atkinson et al., 1999; Carney & Levin, 2002; Dretzke, 1993; Levin & Levin, 1990; Peters & Levin, 1986; Rummel, Levin, & Woodward, 2003). Yet, some strategies are better than others (Butler & Roediger, 2007; Rickards & McCormick, 1988) and each strategy has limitations. Importantly, approaches that specifically target memory consolidation have been largely untested.

Memory consolidation, the foundation of memory storage, consists of a complex series of neurobiological processes that occur from seconds to days after the original learning (see McGaugh, 1990, 2000; Nielson & Powless, 2007; Revelle & Loftus, 1992; Torras-Garcia, Portell-Cortés, Costa-Miserachs, & Morgado-Bernal, 1997). Importantly, emotional and arousing events are known to be better recollected than neutral events, which is thought due at least in part to the influence of neural and hormonal responses to such events (LaBar & Cabeza, 2006; McGaugh, 2000, 2004). Specifically, stressful and arousing events cause increased release of substances such as glucose, cortisol, and epinephrine (Dickerson & Kemeny, 2004; McCarty & Gold, 1981; McGaugh, 1990, 2000; Merali, McIntosh, Kent, Michaud, & Anisman, 1998; Piazza & Le Moal, 1997), which have been repeatedly associated with memory modulation (e.g., Czech, Nielson, & Laubmeier, 2000; LaBar & Cabeza, 2006; McGaugh, 2000; Nielson, Czech, & Laubmeier, 1999; Nielson & Jensen, 1994; van Stegeren, Everaerd, Cahill, McGaugh, & Gooren, 1998). These substances act, at least in part, by influencing amygdala function, which then modulates the memory consolidation processes (Adolphs, Tranel, & Buchanan, 2005; Canli, Zhao, Brewer, Gabrieli, & Cahill, 2000; Kensinger & Corkin, 2004; McGaugh, 2004). Importantly, memory modulatory effects can be generated during or after learning. During learning, they can influ-

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http://dx.doi.org/10.1016/j.nlm.2012.04.002

ence attention, encoding and consolidation. As such, emotional, arousing, or neurohumoral treatments have often been applied after learning to examine their isolated effects on the memory consolidation process.

A variety of post-learning treatments have demonstrated effectiveness for enhancing memory performance in human participants. These treatments include invasive approaches, such as moderate doses of norepinephrine (Southwick et al., 2002), epinephrine (Cahill & Alkire, 2003), glucose (in older adults; Manning, Parsons, & Gold, 1992), and nicotine (Colrain, Mangan, Pellett, & Bates, 1992); and non-invasive treatments, such as moderate muscle tension (Nielson & Jensen, 1994 (in older and young adults); Nielson, Radtke, & Jensen, 1996), stress (Cahill, Gorski, & Le, 2003), rewards (Nielson & Bryant, 2005) and negative or positive emotional arousal induction (Nielson & Bryant, 2005; Nielson & Powless, 2007; Nielson, Yee, & Erickson, 2005). For the effects produced by emotional arousal, the impact on memory performance is not dependent upon subjective response to the arousal (Nielson & Meltzer, 2009) or semantic relatedness of the stimulus to the memoranda (Nielson & Bryant, 2005; Nielson & Meltzer, 2009; Nielson & Powless, 2007; Nielson et al., 2005), but it can be mediated by emotion regulation traits and a predisposition towards arousal (Nielson & Lorber, 2009). Furthermore, the manipulation of memory storage processes is time-dependent, but it can be effective even when delayed for a considerable time (e.g., 30 min) after the original learning (Gold & van Buskirk, 1975; McGaugh, 1966; Nielson & Powless, 2007; Squire, 1986). While such treatments can enhance long-term retrieval (e.g., Nielson & Jensen, 1994; Nielson & Powless, 2007; Nielson et al., 1996, 2005), they typically impede immediate and short-term retrieval, likely because some aspects of memory consolidation require hours or days to complete (Kleinsmith & Kaplan, 1963; Revelle & Loftus, 1992; Torras-Garcia et al., 1997; Walker, 1958).

The existing studies on memory modulation in humans have commonly employed word lists or pictures as memoranda. While an experimentally sound method to examine learning and memory, performance on such tasks may not adequately index performance on learning and retention of more complex facts, concepts, or skills. Word list studies also may not provide enough ecological validity to assist in translating such approaches to classroom settings. Thus, the present study tested whether a post-learning arousal manipulation could enhance the delayed retrieval of lecture material in a college psychology course. Retrieval was tested two weeks later. Retrieval for material introduced during the lecture on the day of the manipulation was compared with retrieval for material presented prior to and subsequent to the manipulated lecture. It was hypothesized that students who were aroused soon after lecture would exhibit better exam performance for that material, relative to material presented on other lecture days.

2. Materials and methods

2.1. Participants

Undergraduates ($n = 156$, 33 male) enrolled in a psychology course served as participants and all were present in class on each of the three study-relevant lecture days. Anyone who did not attend all three lectures or who chose not to stay to participate in the study opportunity was excluded from analyses ($n = 20$ total). The experiment was performed on two separate occasions in different years with cohorts of similar size (i.e., cohort1 $n = 73$ (37 control, 36 experimental), cohort2 $n = 63$ (29 control, 34 experimental)), but with the same course, lectures and exams. The procedures used were approved by the local IRB.

2.2. Materials and procedures

2.2.1. Lecture material

The last three lecture days of the semester in a cognitive psychology course were used for this experiment, which occurred two weeks prior to the final exam. All three lectures covered language as a primary topic, but each covered non-overlapping subtopics, constructs, theories, and key terms. The amount of material presented each day and length of lecture was comparable—the number of slides, constructs, and key words were controlled, and all subjects learned (and were tested) concurrently. The study manipulation involved only the second of the three lectures, providing a measure of memory performance for information presented on the manipulated day, as well as for the lectures day before and after the manipulation.

2.2.2. Video manipulation

The manipulated lecture was followed by an extra credit opportunity offered to the students that involved viewing and evaluating a video clip immediately after class. Extra credit for research participation and appropriate alternatives were offered as a regular part of the course; this was one opportunity for a portion of the total credit. Participants were randomly assigned to conditions. Those assigned to the control condition were taken to an adjacent room and shown a 3-min video clip of a documentary about the role of cardiovascular health in depression. Students assigned to the experimental (i.e., arousal) condition were simultaneously taken to another adjacent room and shown a 3-min video clip of live-action oral surgery. The videos were shown in previous studies to successfully distinguish arousal induction and memory enhancement by arousal (e.g., Nielson & Lorber, 2009). In both groups, students completed a brief survey about the video afterward; the survey was the same for each group. The survey included a 10-point Likert-type rating of (1) current mood (extremely negative to extremely positive), (2) current arousal state (not at all aroused to extremely aroused), and evaluations of the clip as ranging from "not at all" to "extremely", (3) unpleasant, (4) disgusting, and (5) interesting.

2.2.3. Class performance measures

Exam items considered were all 5-option multiple-choice questions worth one point each on a 100-point exam. For each of the three lecture days, seven questions were included on the final exam. The percentage correct for these sets of questions was used as the performance measure for each of the lecture days. No other course assignments, requirements or options differed between experimental groups. All questions on the exam were presented in quasi-random topical order. Additional performance scores evaluated for this study included the midterm exam score, the final exam score, and the total percentage of points achieved for the course.

3. Results

3.1. Descriptive statistics

Descriptive statistics for each participant group are presented in Table 1. The experimental groups did not differ by age. Video clip evaluation ratings showed experimental group differences in subjective evaluation of the clips, where the experimental group rated their clip (i.e., surgery) as more unpleasant, more disgusting and less interesting than the control group rated its documentary clip. Post-clip subjective ratings for mood and arousal also showed significant group differences, where the experimental group had significantly more negative mood state and greater feelings of