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Stress and emotional memory retrieval: Effects of sex and cortisol response

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Abstract

In some situations, memory is enhanced by stressful experience, while in others, it is impaired. The specific components of the stress–response that may result in these differing effects remain unclear, and the current study sought to address this knowledge gap. Forty healthy participants (20 women, 20 men) were exposed to emotionally arousing and neutral pictures. Twenty-four hours later, 20 participants underwent a social stressor (speech and math tests), and 20 underwent a control reading task, both followed by a delayed free recall task. Cortisol responders to the stress condition (5 men and 1 woman) showed reduced memory retrieval for both neutral and emotionally arousing pictures. Men and women in the stress condition who did not produce a cortisol response showed increased retrieval of unpleasant pictures compared to controls. The results provide further evidence that cortisol is a primary effector in the stress-induced memory retrieval deficit. At the same time, stress can enhance memory retrieval performance, especially for emotional stimuli, when the cortisol response is absent.

Keywords: Stress; Emotion; Memory retrieval; Cortisol

1. Introduction

Memory performance is affected by stress. The direction of this effect, however, depends on many factors: the nature of the stressor, the emotional arousal of the to-be-remembered material, sex of the stressed individuals, and interactions among these factors. Such factors have led to mixed findings with regard to the effects of stress on memory. Stress after learning can improve memory *consolidation* (see Roozendaal, 2000 for review). By contrast, stress before memory testing can impair memory *retrieval* performance (Buchanan, Tranel, & Adolphs, 2006; de Quervain, Roozendaal, & McGaugh, 1998; Kuhlmann, Piel, & Wolf, 2005). Roozendaal and colleagues have documented that these differences in the effects of stress on the different phases of memory are dependent on the amygdala. Specifically, the stress enhancement of consolidation as well as the impairing effects of stress on retrieval is dependent on the integrity of the basolateral amygdala (see Roozendaal, 2000 for review). This discrepancy in how stress affects memory—enhancing consolidation while impairing retrieval—may help explain some of the discrepant findings on stress and memory.

While a stress response is typically defined by an increase in corticosteroid release, there are considerable individual differences in this response, which have been well-documented in human studies (Pruessner et al., 1997). Some individuals show persistent, large cortisol increases in response to stress while others show little or no such response (Kirschbaum et al., 1995). In addition to individual differences in the cortisol stress response, situational factors inherent in stress tasks influence whether or not a cortisol response will be elicited. These situational factors are a perceived lack of control and experience of distress (Dickerson & Kemeny, 2004; Lundberg & Frankenhaeuser, 1980). Situations associated with challenge,

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such as moderate physical exercise, may result in autonomic nervous system (ANS) activity, but not a corticosteroid response (Lovallo et al., 1985). In situations associated with challenge, but without a cortisol response, mild stress may have a different effect on memory performance than a more severe stressful situation.

Studies have documented differential effects of moderate stress on memory. We recently showed that subjects who produced a cortisol response to a cold pressor task showed impaired memory retrieval performance for words learned one hour before the stressor (Buchanan et al., 2006). Subjects who produced a skin conductance response to the cold pressor (indicative of ANS activity), but not a cortisol response did not show reduced retrieval performance. These results suggest that cortisol, and not activation of the sympathetic nervous system, is the primary actor in the stress-induced retrieval deficit. There are important nuances to this effect, though. Some studies have shown that a mild stressor or a small dose of corticosterone can actually improve memory performance. Domes and colleagues (2005) showed that subjects who had lower salivary cortisol levels after a 25 mg dose of cortisol showed improved memory retrieval performance compared to both a placebo group and a high responder group, demonstrating the so-called inverted-U pattern of cortisol on performance (ala, Yerkes & Dodson, 1908).

Sex differences are often reported both in responses to stress (Kudielka & Kirschbaum, 2005) and in studies of learning and memory (Cahill, 2005; Wolf, 2006, among many other domains that are beyond the scope of our review). Men tend to show a greater cortisol stress response than women in laboratory studies (Kirschbaum, Kudielka, Gaab, Schommer, & Hellhammer, 1999). Studies examining sex differences have shown that men are more affected by stress than women on both declarative memory retrieval (Wolf, Schommer, Hellhammer, McEwen, & Kirschbaum, 2001) as well as in fear conditioning (Jackson, Payne, Nadel, & Jacobs, 2006; Zorawski, Blanding, Kuhn, & LaBar, 2006; Zorawski, Cook, Kuhn, & LaBar, 2005). The reason for this sex difference is unclear, although there has been speculation on the potential beneficial effects of female sex hormones (Wolf, 2006) and sex differences in cortisol response to stress (Kudielka & Kirschbaum, 2005).

The current study was designed to examine the effects of stress on memory retrieval in men and women. If corticosteroids are the main actor in producing a stress-induced retrieval deficit, then individuals who do not produce a cortisol response may show no effect (or even a beneficial effect, if the stress is not severe) of stress on memory retrieval. Additionally, if sex differences in cortisol response to stress are responsible for the sex differences in stress-induced memory effects, then it would be predicted that in the absence of a cortisol response, men and women may show similar memory performance. Finally, we investigated how this stress–effect interacted with the emotional arousal of the memory material, by using emotional and neutral pictures as to-be-remembered stimuli.

2. Methods

2.1. Participants

Forty healthy volunteers (20 women, 20 men) between the ages of 18 and 25 (mean age: 20 ± 2.0) participated in the study for class credit. Participants were excluded from the study if they were taking any psychiatric, neurological, or corticosteroid-based medications or if they reported working overnight shift work. One of the females in the control group and 4 females in the stress group (including the one female who showed a cortisol response) were taking oral contraceptives. The study was approved by the Institutional Review Board of the University of Iowa, and written informed consent was obtained from all participants.

2.2. Procedure

All participants were tested individually on 2 consecutive days. On both days, each participant reported to the laboratory between 1200 and 1600 h to control for the diurnal cycle of cortisol. Next, participants were connected to recording electrodes for measurement of heart rate. On the first day, participants were shown 20 color photographs, consisting of 10 unpleasant (e.g., mutilated bodies) and 10 neutral (e.g., a classroom setting) pictures chosen from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2005). Each photograph was presented for 8 s on a computer monitor and was accompanied by a simple, single-sentence narrative description. An example of the narrative description for a photograph of a classroom setting read as follows: "The philosophy students listened to the guest speaker with much interest." Participants were told to watch the stimuli and listen to the narrative for the expressed purpose of monitoring their psychophysiological response to the visual and auditory stimuli. No mention of a memory test was made, and thus, encoding of the stimuli was incidental. Photographs were presented in a different, random order for each participant.

Immediately after stimulus presentation, participants completed a free recall test, during which they wrote down as much information as they could recall about the photographs and the narratives. Participants were allowed 10 min for the completion of the free recall task. After completion of the free recall task, participants were excused and asked to return at the same time the next day for completion of the "stress portion" of the experiment. Participants were not informed of their inclusion in the stress or control group until the following day.

Twenty-four hours later, participants returned to the laboratory. During a 10 min adaptation period, they filled out the Positive Affectivity/Negative Affectivity Schedule (PANAS; Watson, Clark, & Tellegen, 1988) for assessment of baseline affective state. Next, a baseline saliva sample was collected and participants were connected to recording electrodes for measurement of heart rate. At this point, half the participants were randomly assigned to the stress condition and the other half were assigned to perform the control reading task.

Participants in the stress condition were given instructions for a speech and math test, which is a modified version of the Trier Social Stress Test (TSST; Kirschbaum, Pirke, & Hellhammer, 1993). In this modified version, participants remained seated in the room in which they had prepared for their speech during the speech and math test, only 2 experimenters were in the room (as opposed to the 3 experimenters typically employed in the TSST), and were allowed to keep their notes prepared during the preparation period. The traditional TSST and other versions of this type of stress task (al'Absi et al., 1997; Buchanan, al'Absi, & Lovallo, 1999) typically require the participant to stand before a committee of experimenters, and the participants are not allowed to use their prepared notes. Additionally, no provocation of the participants was included in the current version of the speech and math test. Participants were given 10 min alone, to prepare for their speech, during which time heart rate data were