Psychoneuroendocrinology (2011) 36, 569—578

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# Implications of psychosocial stress on memory formation in a typical male versus female student sample

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Received 7 April 2010; received in revised form 3 September 2010; accepted 3 September 2010

**KEYWORDS**
Psychosocial stress;
Declarative memory;
Working memory;
Sex differences;
Cortisol;
Salivary alpha-amylase

**Summary** Stress is known to differentially modulate memory function. Memory can be impaired or strengthened by stress, depending on e.g. the memory type and phase under study, the emotional value of the learned information and the sex of the subjects. Here, we addressed the latter and investigated the impact of psychosocial stress on long-term memory for neutral and emotional pictures and working memory in typical samples of male versus female students. In total, 77 subjects (54 women of which 39 used oral contraceptives) were exposed to either the Trier Social Stress Test (TSST) or a control condition, and then engaged in a long-term memory task (emotionally arousing and neutral pictures; surprise recall after one week) and a working memory (*n*-back) task. During the experiment salivary cortisol and alpha-amylase levels as well as subjective affect state were assessed. As expected, stress hormone concentrations as well as subjective negative affect states increased significantly in response to the stress task. Men reacted more to the stressor in terms of cortisol responses than women, probably due to oral contraceptive use of the latter. Results show that, in male as well as in female students, memory for emotional arousing information was better than for neutral information, in both the stress and control condition. Stress enhanced recognition memory for emotional versus neutral pictures only in male subjects. Moreover, stress enhanced working memory, particularly in males, during the first block of a 2-back task. The lack of stress effects on memory in women might be explained by

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0306-4530/$ — see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.psyneuen.2010.09.002

oral contraceptive use, leading to blunted HPA-axis responses and secondary to reduced stress effects on memory. The results emphasize that stress affects both long-term and working memory differentially in male versus female students.
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## 1. Introduction

Stress activates the autonomic nervous system (ANS) and the hypothalamic-pituitary-adrenal (HPA) axis. The activation of these systems leads to a rapid release of catecholamines from the adrenal medulla, and a somewhat slower release of corticosteroids (corticosterone in rodents and cortisol in humans) from the adrenal cortex, respectively. Human and animal studies have shown that acute stress and elevated stress hormone levels modulate memory function (Joels et al., 2006; Roozendaal and Okuda, 2006; Sandi and Pinelo-Nava, 2007; van Stegeren, 2008; Wolf, 2009). Memory can be strengthened or impaired by stress, depending on factors like memory type and phase under study (Luethi et al., 2008; Smeets et al., 2009), emotional value of the learned information (Roozendaal and Okuda, 2006; van Stegeren, 2008), sex of the subjects (Wolf et al., 2001; Andreano and Cahill, 2009; Schoofs and Wolf, 2009) and time of the day (Maheu et al., 2005).

Several studies have focused on the effects of stress on declarative long-term memory. While stress enhances memory consolidation, especially for emotional arousing information (Cahill et al., 2003; Abercrombie et al., 2006; Andreano and Cahill, 2006; Payne et al., 2007; Smeets et al., 2008), delayed retrieval of previously learned (emotional) material has repeatedly been found to be impaired by stress (Domes et al., 2004; Kuhlmann et al., 2005; Smeets et al., 2008; Tollenaar et al., 2008).

Effects of stress on working memory are more equivocal. Several studies reported that working memory performance after stress is impaired (Elzinga and Roelofs, 2005; Oei et al., 2006; Luethi et al., 2008; Schoofs et al., 2008; Schoofs et al., 2009). However others found that working memory after stress or corticosteroid administration was improved or unaffected (Kuhlmann et al., 2005; Duncko et al., 2009; Oei et al., 2009; Weerda et al., 2010). There are many potential explanations for these discrepancies, one being that men and women differ in their responses to stress (Kudielka and Kirschbaum, 2005). Generally men show a higher cortisol response to stress than women and stress responses in women depend on the menstrual cycle phase and the use of oral contraceptives (Kirschbaum et al., 1999). In most studies, stress effects on memory were only tested in men, but at least some studies that examined sex differences have shown that generally men seem to be more affected by stress than women (Wolf et al., 2001; Andreano and Cahill, 2006).

The aim of the current study was to investigate the effects of stress on both neutral and emotional long-term memory and on working memory, in a sample of male and female students that is typical for The Netherlands. All subjects were exposed to a psychosocial stressor or a control task, after which they viewed neutral and emotional pictures and performed a working memory task. One week later, subjects returned to the lab for a surprise free recall and recognition test of the pictures. To assess the stress response and the role of both the ANS and the HPA axis, salivary samples were repeatedly taken during both sessions of the experiment and analyzed on alpha-amylase and cortisol levels.

## 2. Methods

### 2.1. Participants

One entire cohort of healthy second-year psychobiology students at the University of Amsterdam ($n = 77$, i.e. 23 men, 54 women; mean age = 20.44 (SD = 1.18, ranging from 18 to 25 years) and mean BMI = 22.00 (SD = 2.52, ranging from 18 to 30)) participated in this study. Self-reported medical or psychiatric problems or taking medication known to influence the HPA-axis (except for oral contraceptives) served as exclusion criteria, as well as heavy drinking, smoking and regular drug consumption. Thirty-nine women were using contraceptives; of the 15 natural cycling women, 6 were tested in the follicular phase of the menstrual cycle and 7 in the luteal phase. Information on cycling day was missing for two women. This distribution is typical for psychobiology students. The study was approved by the Ethical Committee of the Department Psychology at the University of Amsterdam. All participants received course credits for their participation and provided written informed consent before their participation. They were ignorant about the theory and practice of stress research at the time of the experiment. One subject did not participate in the picture task and another subject did not finish the working memory task. Three subjects did not participate in the second session due to illness.

### 2.2. Stress manipulation

Psychosocial stress was induced with the Trier Social Stress Test (TSST; Kirschbaum et al., 1993). The TSST consisted of a 3 min preparation period, a 5 min video- and audio-taped free speech simulating a job interview while standing in front of a non-responsive audience and subsequently a 3 min mental arithmetic task. Subjects in the control condition were instructed to read magazines for a comparable period of 11 min.

### 2.3. Salivary sampling and biochemical analysis

Salivary samples were obtained using Salivette sampling devices (Sarstedt, Nümbrecht, Germany) at ten time points during the experiment (Fig. 1). Salivary samples were stored at $-20\ ^{\circ}C$ until further analysis. Free cortisol levels were measured using a commercially available immunoassay (IBL, Hamburg, Germany). Salivary alpha-amylase levels were measured by a quantitative enzyme kinetic method as described elsewhere (van Stegeren et al., 2006).

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