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Brief report

Psychosocial stress enhances time-based prospective memory in healthy young men

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Abstract

Forgetting of intentions (such as to take one's medication) is the most frequent everyday memory failure. No study so far has looked into the possible consequences stress might exert on memory for intentions (i.e., prospective memory). Twenty healthy young male adults were exposed to a psychosocial stress test and a non-stress condition. After a delay of 15 min, a time- and an event-based prospective memory task were administered during the peak of cortisol concentrations. Results show that participants performed significantly better in the time-based memory task after stress in comparison to the non-stress condition. In contrast, there was no stress effect on event-based prospective memory. The results demonstrate that prospective memory might be enhanced when participants are exposed to stress prior to the memory task and that this effect is associated to stress-related glucocorticoid effects.

Keywords: HPA axis; Cortisol; Psychosocial stress; Prospective memory

Stress hormones such as glucocorticoids (GCs) have repeatedly been shown to interfere with cognitive capacity (Erickson, Drevets, & Schulkin, 2003). Specifically, the findings reported so far seem to suggest that activation of GC-sensitive pathways enhances memory consolidation (Kuhlmann & Wolf, 2006) while high circulating levels of GCs or infusions of GC receptor agonists into the hippocampus may impair memory retrieval processes (Roozendaal, 2002).

So far, one aspect of human memory has been largely neglected in this line of research—*prospective memory*. Prospective memory (PM) is defined as the ability to remember to perform activities in the future on one's own initiative (Brandimonte, Einstein, & McDaniel, 1996). Remembering to forward a note to a friend, to take medication every two hours, or to switch off the stove after cooking are everyday examples of PM tasks. In fact, PM problems are the most frequent and momentous memory failures in everyday life and have been shown to be of enormous relevance for a number of psychiatric and neuropsychological patient populations (Kliegel et al., 2005). Conceptually, the similarities and differences of prospective memory and other memory functions are currently under debate (see Kliegel, McDaniel, & Einstein, in press). Especially, the relation with working memory is, so far, unclear. While some studies indicate that prospective memory in general requires working memory resources to continuously keep the intention active (e.g., Guynn, 2003; Smith & Bayen, 2004), others report no or only weak relations of working and prospective memory and assume that the prospective intention leaves working memory until the encounter of the relevant moment triggers the retrieval of the intention (McDaniel & Einstein, 2000; McDaniel, Guynn, Einstein, & Breneiser, 2004). Overall, however, there seems to be consensus that prospective memory is a separate and dissociable memory function (e.g., Salthouse, Berish, & Siedlecki, 2004) which is also supported by initial physiological evidence revealing ERP

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components (i.e., N300, Prospective positivity) that seem to be unique for prospective memory (e.g., West & Krompinger, 2005; West & Wymbs, 2004).

Most recently, Nakayama, Takahashi, and Radford (2005) were the first to examine the influence of cortisol on PM. While their results showed that baseline saliva cortisol levels were significantly correlated to a traditional short-term (retrospective) memory task, they did not find a relationship between cortisol levels and PM performance. Although this study appears to suggest that PM might be unaffected by stress hormones, the experimental procedure applied bears two important limitations. First, these authors solely relied on baseline levels of GCs and did not directly examine stress-related GC effects. Second, they only assessed one type of PM; i.e., *event-based* prospective memory (participants had to remember to place a cross on their answer sheets whenever they saw a target word in a short-term memory task). This could be an important limitation as the literature distinguishes between two paradigms of PM tasks (Kliegel, Martin, McDaniel, & Einstein, 2001): *event-based* tasks demand the self-initiated execution of the intended action after the appearance of an externally presented cue (e.g., the appearance of a target word), and *time-based* tasks demand the self-initiated execution of the intended action at a specific point in time (e.g., at noon or every minute). In contrast to event-based tasks, time-based tasks include no external mnemonic cue for the appropriate task switches and are, therefore, more dependent on self-initiated mental activities that require the allocation of (limited) attentional resources and, in consequence, are more susceptible to manipulations that affect participants' cognitive capacity such as induced emotions (d'Ydewalle, Bouckaert, & Brunfaut, 2001; Kliegel et al., 2005, 2001). Thus, especially time-based tasks may be affected by stress-related processes. Therefore, we experimentally induced stress-related changes in GC levels applying a standardized stress protocol that has been demonstrated to reliably induce psychosocial stress and result in stress-related changes of GCs (Kirschbaum, Pirke, & Hellhammer, 1993). We tested whether both event- and time-based PM performance is influenced by experimentally induced stress-related cortisol levels.

Design and participants. The study applied a within-person manipulation of stress (versus rest) with randomized and counterbalanced order of condition (interval: 2 weeks). Twenty male participants (age: $M = 24.45$; $SD = 2.41$) were recruited from the local student populations. Only male participants were included in the study to avoid confounding of our dependent variables by sex-related factors (e.g., Kirschbaum, Kudielka, Gaab, Schommer, & Hellhammer, 1999). All participants were medication-free and non-smokers with normal BMI ($M = 23.54$, $SD = 2.33$, range: 19.45–29.73). Exclusion criteria were acute or chronic somatic or psychiatric disorders, high chronic stress and dispositional stress reactivity. Participants had to abstain from excessive physical activity within 48 h, any sporting activities within 24 h, intake of alcohol and caffeine within 18 h and eating within 60 min before the study.

Materials and procedure. Stress protocol: The Trier social stress test (TSST) was applied (Kirschbaum et al., 1993). The testing took place between 2 pm and 6 pm. *Stress condition:* After a basal saliva sample participants were introduced to the TSST. They had 15 min to prepare their free speech. Following this, participants were exposed to a simulated job interview (5 min) followed by a mental arithmetic task (5 min) in front of an audience. Further samples of saliva were taken 20 min before and immediately before the TSST, immediately after completion of the TSST, and 15, 30, 45, as well as 60 min after completion of the TSST. Between 15 and 30 min, as well as 30 and 45 min after the stress test, participants were completing the prospective memory tasks in counterbalanced order (see below). *Non-stress condition:* Each participant was free to choose a quiet activity with magazines made available. Physiological and psychological variables were assessed at the same intervals as in the TSST condition.

Psychological measures: Manipulation check measures. To assess short-term fluctuations of mood and anxiety during the two conditions, the Multidimensional Mood Questionnaire (MDBF; Steyer, Schwenkmezger, Notz, & Eid, 1994) as well as the State and Trait Anxiety Inventory (STAI; Laux, Glanzmann, Schaffner, & Spielberger, 1981) were applied before and after the stress/rest induction.

Prospective memory tasks. A standard prospective memory paradigm introduced by Einstein et al. (1997; see also Kliegel et al., 2001) was used. The ongoing task was a computerized word rating task, in which words (e.g., house, phone, etc.) had to be rated on four dimensions (concreteness, familiarity, pleasantness, and seriousness). On each trial, one word was presented with one dimension and a rating scale for 5 s on the computer screen. The rating had to be done by pressing the corresponding number key on the computer keyboard. Overall, 104 trials were presented to every participant. The prospective memory task was either to press a target key every 2 min after having started (*time-based*) or whenever a specific target word appeared on the screen as a word to be rated (*event-based*). For the time-based task, participants could monitor the time by pressing a time key resulting in a time counter clock to appear on the monitor for 2 s. The time-based memory task and the event-based memory task were presented to the participants in a counterbalanced order to prevent sequence and learning effects. Each task lasted 8 min and 40 s.

Saliva sampling methods and biochemical analyses. Saliva was collected eight times using Salivette (Sarstedt, Sevelen, Switzerland) collection devices and stored at −20 °C after completion of the session until biochemical analysis took place. After thawing, saliva samples were centrifuged at 3000 rpm for 5 min. Salivary free cortisol was analyzed by using a commercial chemiluminescence immunoassay (LIA) (IBL Hamburg, Germany). Inter- and intraassay coefficients of variation were below 10%. To reduce error variance caused by imprecision of the intraassay, all samples of one participant were analyzed in the same run.