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Acute social stress before the planning phase improves memory performance in a complex real life-related prospective memory task

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ABSTRACT

Successful execution of intentions, but also the failure to recall are common phenomena in everyday life. The planning, retention, and realization of intentions are often framed as the scientific concept of prospective memory. The current study aimed to examine the influence of acute stress on key dimensions of complex "real life" prospective memory. To this end, we applied a prospective memory task that involved the planning, retention, and performance of intentions during a fictional holiday week. Forty healthy males participated in the study. Half of the subjects were stressed with the Socially Evaluated Cold Pressor Test (SECPT) before the planning of intentions, and the other half of the participants underwent a control procedure at the same time. Salivary cortisol was used to measure the effectiveness of the SECPT stress induction. Stressed participants did not differ from controls in planning accuracy. However, when we compared stressed participants with controls during prospective memory retrieval, we found statistically significant differences in PM across the performance phase. Participants treated with the SECPT procedure before the planning phase showed improved prospective memory retrieval over time, while performance of controls declined. Particularly, there was a significant difference between the stress and control group for the last two days of the holiday week. Interestingly, control participants showed significantly better performance for early than later learned items, which could be an indicator of a primacy effect. This differential effect of stress on performance was also found in time- and event-dependent prospective memory.

Our results demonstrate for the first time, that acute stress induced before the planning phase may improve prospective memory over the time course of the performance phase in time- and event-dependent prospective memory. Our data thus indicate that prospective memory can be enhanced by acute stress.

1. Introduction

The management of daily routines requires the ability to formulate and execute intentions directed to the future. The processes contributing to this ability are integrated in the concept of prospective memory (PM) (Brandimonte, Einstein, & McDaniel, 1996). PM contains future directed mnemonic functions. It allows us to plan intentions, retain them in memory, retrieve them at a certain time or in response to a particular event in the future, and translate planned intentions into actions (Ellis, 1996; Kliegel, McDaniel, & Einstein, 2012). Finally, the outcome of eventually executed intentions is evaluated (Ellis, 1996; Kliegel et al., 2012). Respectively, PM processes are subdivided into the following consecutive phases of processing: planning, retention, retrieval, performance and evaluation phase (Ellis, 1996; Kliegel et al., 2012). The planning phase includes the formation of an intention to perform an action in the future, as well as the determination of a retrieval criterion (i.e. a criterion that determines at which point in time or related to which specific event an intention is supposed to be retrieved and brought to action) (Kliegel et al., 2012). Thereafter, the retention phase begins. It is conceptualized as an interval between the encoding and retrieval of intentions. During this interval planned intentions and actions are maintained in memory, typically, for hours, days, or weeks. Retention thus needs to be stable across potentially distracting events of everyday life (Ellis, 1996; Kliegel et al., 2012). Within the subsequent performance phase, planned intentions are retrieved and brought into action (Ellis,

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1996; Kliegel et al., 2012). Retrieval and execution of intentions are strongly interrelated. Eventually, preceding performance is evaluated either as a success or in an event of failure, intention could be re-planned.

PM is further differentiated contextually into event-dependent and time-dependent memory processes (Kliegel, Martin, McDaniel, & Einstein, 2001). This distinction is particularly important with respect to the success of the retrieval and execution phases. Event-dependent PM describes an initiation of an intention after a certain event (e.g. taking the medicine *after lunch*). Time-dependent PM is rather an internally initiated intention after a certain time or at a specific time point (e.g. taking the medicine *at 1 o'clock*; Kliegel, Mcdaniel, & Einstein, 2000; Kliegel et al., 2001). This distinction has been supported by a study of the neurofunctional correlates of time- and event-dependent PM. Okuda et al. (2007) reported that different neuronal substrates may contribute to either type of PM. They found that the right superior frontal gyrus, the anterior medial frontal lobe, and the anterior cingulate gyrus are relevant for time-dependent PM processes. In contrast, activation in the left superior frontal gyrus was associated with the processing of event-dependent PM.

In recent years, research revealed diverse effects of acute stress on cognitive functions, including memory processes mediated through the glucocorticoid system.

Nonetheless, to date, the influence of stress on the different stages of PM has only rarely been addressed. Nakayama, Takahashi, and Radford (2005) were the first to investigate the influence of cortisol on PM performance, but the authors did not find an effect of baseline cortisol on PM performance (i.e. cortisol level in the absence of stress treatment). Note, however, that Nakayama et al. (2005) investigated only indirectly the influence of baseline salivary cortisol levels and solely focused on event-dependent PM. Nater et al. (2006) tested the influence of experimentally induced acute stress on time- and event-dependent PM utilizing a computer paradigm first used by Einstein, Smith, McDaniel, and Shaw (1997). During this rather limited experimental PM paradigm, participants were asked to press a target key every 2 min (time-dependent PM), or whenever a target word appeared on a computer screen (event-dependent PM). Nater et al. (2006) revealed enhanced time-based PM after the exposure to stress compared to the performance of non-stressed participants. No effect of stress was found for event-dependent PM. More recently, Scholz et al. (2009) investigated the influence of PM demands on action control under experimentally induced social stress. During a go-no-go task, that was embedded in a dual task paradigm participants learned meaningless consonant-vowel combinations while they had to press a button whenever a number (but not a letter) was additionally presented on the screen. Scholz et al. (2009) found that the implementation of intentions was an efficient strategy to improve go-no-go performance under stress. Ihle, Schnitzspahn, Rendell, Luong, and Kliegel (2012) accomplished a study on the effects of everyday stress on PM performance to explain putative aging-related differences in PM. The study design required participants to remember and implement intentions that were formed the day before over a period of 5 days. Information on stress was assessed and controlled by telephone interviews. Overall, Ihle et al. (2012) found lower stress levels to be beneficial for better PM performance. Ihle et al. (2012) also found better PM performance in older participants. However, this PM improvement in older age was not associated with lower stress levels. In a further study, Ihle et al. (2014) investigated in a laboratory test situation, whether aging-dependent differences in time-dependent PM performance could be related to higher stress levels in older participants. Young and older healthy adults were instructed to press a computer button every minute during a working memory task. Half of the participants completed a relaxation intervention before the time-based PM task. Stress levels were assessed by a questionnaire and measures of blood pressure. Ihle et al. (2014) found no association between better PM performance and stress levels in older participants.

Taken together, the few studies addressing the impact of stress on PM draw an inconsistent picture of results. Importantly, none of these studies differentiated between the different stages of PM processing such that putative differential effects of stress on distinct stages of PM have not been considered in previous research. It is also important to note that the PM paradigms used in former studies were experimentally reduced to a high degree and can thus hardly claim a sufficient external validity. Thus, previous paradigms may have not tapped the main high cognitive demands of everyday-related PM. It is therefore reasonable to assume that this experimental reduction in previous studies may at least in part explain the finding that event-based PM performance is not affected by stress (i.e. Nater et al., 2006).

It is also known from diseases caused by situations of extreme stress (i.e. Posttraumatic Stress Disorder; PTSD) that they may alter a range of retrospective memory functions (e.g. Vasterling, Brailey, Constans, & Sutker, 1998), in particular in the domain of real life memory (e.g. Beblo et al., 2006; Driessen et al., 2004; Piefke et al., 2008). For instance, referring to PM, Moradi, Doost, Taghavi, Yule, and Dalgleish (1999), reported deficits in PM performance in children and adolescents with PTBS. Given that PTSD is caused by situations of extreme stress and the reported vulnerability of PM in this clinical population, it may also be of particular relevance to investigate the influence of acute stress on different phases of PM with high external validity. The aim of the present study was to investigate the influence of experimentally induced stress before the planning phase of PM in healthy adults by using a complex real life-related PM task. Based on previous research on the effects of acute stress on PM we hypothesized that experimentally induced stress before the planning phase may enhance PM. Since the present study applies a highly complex real life-related PM task that requires a high PM capacity for both time- and event-based PM it is reasonable to propose, that acute stress may also have an altering effect on event-dependent PM.

2. Method

2.1. Participants

In this experiment, we included 49 male participants. 24 participants were assigned to the control group (mean age = 23.64 years, standard deviation (SD) = ±4.28) and 25 participants were assigned to the stress group (mean age = 23.95 years, standard deviation (SD) = ±4.19). In addition, the stress group and the control group were matched for IQ. The participants had been recruited among students of the universities in Witten/Herdecke, Bochum, and Dortmund. All volunteers were evaluated for normal or corrected-to-normal vision and a body mass index (BMI) between 19 and 28. Upon completion of the experiment participants received a financial reimbursement or course credit for their studies. All participants were non-smokers and not affected by an acute or chronic psychiatric, neurological disorder or other medical diseases. Also, they were free from medication. Due to the diurnal rhythm of the stress hormone cortisol, testing always took place between 12:00 p.m. and 6:00 p.m. Persons who had previous experiences with the Socially Evaluated Cold Pressor-Test (SECPT; Schwabe, Haddad, & Schachinger, 2008; see Section 2.3) were excluded from the study. Each participant gave written informed consent and the study was approved by the Ethics Committee of Witten/Herdecke University.