Acta Psychologica 182 (2018) 82–90

Contents lists available at ScienceDirect

Acta Psychologica

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

Acute stress affects prospective memory functions via associative memory processes

Ágnes Szőllősi[a,*], Péter Pajkossy[a,b], Gyula Demeter[a,b], Szabolcs Kéri[a,c], Mihály Racsmány[a,b]

[a] Department of Cognitive Science, Budapest University of Technology and Economics, Budapest, Hungary
[b] Research Group on Frontostriatal Disorders, Hungarian Academy of Sciences, Budapest, Hungary
[c] National Institute of Psychiatry and Addictions, Nyírő Gyula Hospital, Budapest, Hungary

ARTICLE INFO

Keywords:
Prospective memory
Acute stress
Associative memory
Executive control processes

ABSTRACT

Recent findings suggest that acute stress can improve the execution of delayed intentions (prospective memory, PM). However, it is unclear whether this improvement can be explained by altered executive control processes or by altered associative memory functioning. To investigate this issue, we used physical-psychosocial stressors to induce acute stress in laboratory settings. Then participants completed event- and time-based PM tasks requiring the different contribution of control processes and a control task (letter fluency) frequently used to measure executive functions. According to our results, acute stress had no impact on ongoing task performance, time-based PM, and verbal fluency, whereas it enhanced event-based PM as measured by response speed for the prospective cues. Our findings indicate that, here, acute stress did not affect executive control processes. We suggest that stress affected event-based PM via associative memory processes.

1. Introduction

Effective functioning in everyday life relies heavily on the ability of performing intended actions. Moreover, adaptive behaviour frequently requires the delayed execution of such intentions, i.e., prospective memory (PM) – see Meacham (1982). The execution of a delayed intention (the PM response) can be triggered by specific external PM cues (event-based PM), or in other cases, the intended action has to be executed at a specific time in the future (time-based PM) – see Einstein and McDaniel (1990, 2005).

1.1. The role of executive control in prospective remembering

The term "executive functions" refers to a set of processes that are necessary when automatic responses are not enough for optimal behaviour and the attention-demanding control of behaviour is needed (see e.g., Engle, 2002; Miyake et al., 2000; Norman & Shallice, 1986; Smith & Jonides, 1999). PM involves various executive control processes, such as planning and maintaining information in working memory (Kliegel, Martin, McDaniel, & Einstein, 2002), cognitive flexibility to switch attention to the PM cue and the inhibition of ongoing behaviour (Bisiacchi, Schiff, Ciccola, & Kliegel, 2009; Kliegel, Mackinlay, & Jäger, 2008) as well as monitoring for the PM cue (Einstein & McDaniel, 1990; Smith & Bayen, 2004). Event- and time-based PM differ in several aspects (see e.g., Guynn, 2008; Kvavilashvili & Ellis, 1996; Marsh, Hicks, & Cook, 2008; McDaniel & Einstein, 2000; Smith, Bayen, & Martin, 2010) and one important distinction is related to executive functions.

In time-based PM situations, successful intention execution always depends on executive control processes, because responses are triggered by internal cues and are driven by self-initiated retrieval processes (see Einstein & McDaniel, 1990; Sellen, Louie, Harris, & Wilkins, 1997). Most of the dominant theories highlight the important role of executive control in event-based PM as well (McDaniel & Einstein, 2000; McDaniel, Guynn, Einstein, & Breneiser, 2004; Smith, 2003; Smith & Bayen, 2004). However, the multiprocess model proposes that the retrieval of an event-based PM response could be triggered automatically and spontaneously by environmental cues and the involvement of executive control depends on various factors, e.g., on the focality of the PM cue (McDaniel et al., 2004; McDaniel & Einstein, 2000). Specifically, in focal PM situations there is an overlap between the processing of the PM stimuli and the processing of the PM cue, whereas in non-focal PM tasks there is no overlap between them. Therefore, performing a non-focal PM task requires attention demanding executive control processes, rather than when one performs a focal PM task. The multiprocess model also highlights that there is a tendency to minimize the

* Corresponding author at: Department of Cognitive Science, Budapest University of Technology and Economics, 1111-Budapest, Egry Jozsef utca 1, Hungary.
E-mail addresses: aszollosi@cogsci.bme.hu (Á. Szőllősi), ppajkossy@cogsci.bme.hu (P. Pajkossy), gdemeter@cogsci.bme.hu (G. Demeter), szkeri@cogsci.bme.hu (S. Kéri), racsmany@cogsci.bme.hu (M. Racsmány).

https://doi.org/10.1016/j.actpsy.2017.11.012
Received 10 April 2017; Received in revised form 9 October 2017; Accepted 8 November 2017

requirement of executive control in event-based PM situations, and individuals prefer to use more automatic retrieval strategies whenever circumstances allow this (Einstein et al., 2005; Einstein & McDaniel, 2005; McDaniel & Einstein, 2007). Moreover, it seems that performance is better when the execution of PM responses involves automatic memory processes rather than executive control (Einstein et al., 2005). In these situations, PM responses are driven by associative memory (McDaniel & Einstein, 2007; see also Moscovitch, 1994). That is, individuals form associations between the anticipated PM cue and the intended action. Later, when the cue is encountered, PM retrieval does not require effortful searching processes (i.e., executive control), instead, a reflexive-associative memory system triggers retrieval and brings the intended action to consciousness (see also Einstein & McDaniel, 1996; McDaniel & Einstein, 2000).

Event-based PM is usually tested in dual-task situations where individuals perform a simple ongoing task while they have to maintain and execute delayed intentions. A reliable index of executive control requirement is the so-called ongoing cost of remembering (Smith, 2003; for a review, see e.g., Cohen & Gollwitzer, 2008). That is, if capacity-demanding attentional resources are needed for optimal performance in PM situations, individuals tend to show reduced performance (i.e., slower response speed) on the primary ongoing task when they have to maintain delayed intentions. However, the exact nature of the relationship between the ongoing cost and PM performance is still under debate (Einstein et al., 2005; Heathcote, Loft, & Remington, 2015; Scullin, McDaniel, & Einstein, 2010; Smith, 2003). According to some previous studies, in addition to executive control involvement (as indicated by the ongoing cost), associative memory processes can contribute to prospective remembering (e.g., Scullin et al., 2010).

1.2. Effects of stress on executive functions and prospective memory

Experiencing stressful situations triggers the activation of the hypothalamic-pituitary-adrenal (HPA) axis and the secretion of stress hormones, such as glucocorticoids (GCs) – in humans: cortisol (see e.g., Charmandari, Tsigos, & Chrousos, 2005; O'Connor, O'Halloran, & Shanahan, 2000). It is widely known that the presence of everyday and laboratory-based stressors influences cognitive functioning, including executive functions and memory.

Regarding the effect of stress on executive functions, the existing findings are contradictory (see e.g., Lupien, Maheu, Tu, Fiocco, & Schramek, 2007). However, a recent meta-analytic review (Shields, Sazma, & Yonelinas, 2016) has shown that in most cases acute stress impairs specific components of executive functions including cognitive flexibility, working memory, and cognitive inhibition. Several theorists suggest while stress impairs executive functioning, it prompts a shift to a more associative, automatic, and reflexive processing (Arnsten, 2015; Hermans, Henckens, Joëls, & Fernández, 2014; Schwabe & Wolf, 2013; Shields et al., 2016). Furthermore, it seems that cortisol secretion counteracts the detrimental effect of stress on executive processing by improving the maintenance of task relevant information (Weckesser, Alexander, Kirschbaum, Mennigen, & Miller, 2016).

Interestingly though, in comparison with stress-related executive functions, only a few studies focused on whether and how stress affects the maintenance and execution of delayed intentions. Results suggest that in laboratory settings, baseline stress levels show no relationship with PM performance, irrespective of whether the PM cue is an event (Nakayama, Takahashi, & Radford, 2005) or a specific point in time (Ihle et al., 2014). Accordingly, prolonged exposure to high cortisol levels also shows no relationship with event-based PM performance (McLennan, Ihle, Steudte-Schmiedgen, Kirschbaum, & Kliegel, 2016).

Regarding the relationship between acute stressors and PM, in a study by Walser, Fischer, Goschke, Kirschbaum, and Plessow (2013), psychosocial stress exposure had no effect either on ongoing or on event-based PM performance as measured by hit rates and reaction times (RTs). Accordingly, psychosocial stress did not affect the number of event-based PM responses in a study by Nater et al. (2006). However, in a time-based task, participants in the stress group gave more correct PM responses and showed an increased monitoring activity (i.e., checked a time counter clock more frequently) when compared to control subjects. Recently, Glienke and Piefke (2016) reported somewhat different results. They found enhanced event- and time-based performance (using a task developed to measure PM in a complex realistic situation) in subjects who encountered acute combined (physical-psychosocial) stressors.

In brief, there is no consensus under which circumstances and how stress affects different types of PM, if at all. The contribution of executive control in PM might resolve this controversy. To investigate this issue, following stress induction, we used one time-based PM task and two event-based PM tasks differing in executive control requirement. The rationale for using both event- and time-based PM tasks is that performing an intended time-based action always depends on executive control processes, whereas event-based PM tasks are suggested to be existing on a continuum between controlled and automatic processing (Gilbert, Gollwitzer, Cohen, Burgess, & Oettingen, 2009; Gilbert, Hadjipavlou, & Raoelison, 2013; Scullin, McDaniel, & Shelton, 2013).

Moreover, to acquire further evidence whether stress-related changes in PM performance is associated with altered executive control process, we applied a control task frequently used to measure executive functions. Due to the complex nature and multiple roles of executive control in prospective memory, we applied the letter fluency test which involves various executive processes, such as switching between effective strategies (Abwender, Swan, Bowerman, & Connolly, 2001; Troyer, Moscovitch, & Winocur, 1997), inhibition of responses that do not fit the requirements (McDowd et al., 2011), maintaining sets in working memory (Daneman, 1991), and self-monitoring to avoid repetitions (Phillips, 1997; see also Lezak, Howieson, Bigler, & Tranel, 2012).

In brief, the main purpose of the present study to examine PM performance following stress induction in tasks requiring different executive control demand. Executive control requirement was assessed by multiple measures, including ongoing cost in two event-based PM tasks, hit rate and monitoring behaviour in the time-based PM task, and letter fluency performance.

It is possible that stress exerts its effect on PM through executive control processes. In this case, stress should have an effect on performance depending on to what extent the task requires executive control processes (in the time-based PM task, certainly). Furthermore, we can also assume that, even with no evidence for a relationship between stress and those executive processes, which were involved in the PM tasks we used, stress can exert its effect on PM through altered associative memory processes. In this case, stress should have an effect on PM performance only in those (event-based PM) tasks where executive control processes are less loaded.

2. Materials and methods

2.1. Participants

Participants were 61 Hungarian undergraduate students (23 men; age range: 19–27 years; M_{age} = 21.7 years, SD = 1.9) who received extra course credits for their participation. Subjects were randomly assigned into either a stress (n = 30; 11 men; M_{age} = 21.6 years, SD = 1.9) or a control group (n = 31; 12 men; M_{age} = 21.7 years, SD = 2.0). Based on a self-reported questionnaire, participants had no history of any known psychiatric, neurological, or chronic medical problems. Participants were not on medication except for four subjects who were on contraception (three subjects in the stress group and one subject in the control group).[1]

[1] When these four subjects were excluded from the sample the pattern of results did not change in either of the three PM tasks or on the letter fluency test.