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Acute stress does not impair long-term memory retrieval in older people

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ABSTRACT

Previous studies have shown that stress-induced cortisol increases impair memory retrieval in young people. This effect has not been studied in older people; however, some findings suggest that age-related changes in the brain can affect the relationships between acute stress, cortisol and memory in older people. Our aim was to investigate the effects of acute stress on long-term memory retrieval in healthy older people. To this end, 76 participants from 56 to 76 years old (38 men and 38 women) were exposed to an acute psychosocial stressor or a control task. After the stress/control task, the recall of pictures, words and stories learned the previous day was assessed. There were no differences in memory retrieval between the stress and control groups on any of the memory tasks. In addition, stress-induced cortisol response was not associated with memory retrieval. An age-related decrease in cortisol receptors and functional changes in the amygdala and hippocampus could underlie the differences observed between the results from this study and those found in studies performed with young people.

1. Introduction

Aging involves important changes in cognitive performance, especially memory. Although individual differences exist, elderly people usually perform worse on delayed recall and recognition tasks than younger people (Davis et al., 2003; Huh, Kramer, Gazzaley, & Delis, 2006). These memory deficits due to increasing age have been related to structural and functional changes in the prefrontal cortex, hippocampus and amygdala (Hedden & Gabrieli, 2004). Interestingly, these same brain regions are closely associated with important processes related to stress. In fact, a large number of studies have shown that exposure to stress can modulate memory performance through the activity of the prefrontal cortex, hippocampus and amygdala (for reviews see: Lupien, Maheu, Tu, Fiocco, & Schramek, 2007; Wolf, 2009). However, most of these studies have been performed in young people, and more research is needed to find out whether the same effects occur in older people.

Stressful situations provoke the activation of both the Hypothalamus–Pituitary–Adrenal axis (HPA-axis) and the Sympathetic Nervous System (SNS), resulting in the release of glucocorticoids (cortisol in humans) and several SNS biomarkers (e.g. catecholamines, salivary alpha-amylase) (Sapolsky, Romero, & Munck, 2001). It has been suggested that acute stress would affect memory processes through both the influence of cortisol on the hippocampus, prefrontal cortex and amygdala (Wolf, 2009) and the noradrenergic activation of the amygdala (McGaugh & Roozendaal, 2002). Additionally, studies performed mainly in young people have shown that the impact of stress on memory depends on several factors, such as the phase of the memory tested (i.e. learning, consolidation or retrieval) and the emotional valence of the material to be remembered (i.e. positive, negative or neutral) (Lupien et al., 2005).

Most studies performed in young people have revealed that stress-induced or pharmacologically-induced increases in cortisol levels usually enhance consolidation (Buchanan & Lovallo, 2001; Cahill, Gorski, & Le, 2003; Smeets, Otgaar, Candel, & Wolf, 2008), but they impair memory retrieval (e.g., Buchanan & Tranel, 2008; de Quervain, Roozendaal, Nitsch, McGaugh, & Hock, 2000; Kuhlmann, Kirschbaum, & Wolf, 2005; Kuhlmann, Piel, & Wolf, 2005; Smeets, 2011; Smeets et al., 2008). This effect has been explained as a blocking effect of cortisol on retrieval processes, in favor of consolidation processes, in order to allow the brain to consolidate new important information to be used in the future (Roozendaal, 2002). Furthermore, noradrenergic activation of the amygdala and amygdala–hippocampal interactions have been shown to be necessary in order to observe cortisol effects on hippocampus-dependent memory performance (for a review see: Roozendaal, McEwen, & Chattarji, 2009).

However, it is not clear whether these effects of stress on memory processes occur in older populations as well, because only a few studies are available, and most of them investigated the effects

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of stress without distinguishing between the different memory phases (i.e. learning, consolidation and retrieval). Moreover, their results have not been consistent, as two studies observed that stress impaired learning (Almela, Hidalgo, Villada, Espín, et al., 2011; Lupien et al., 1997), while two studies found no effect (Bohnen, Houx, Nicolson, & Jolles, 1990; Domes, Heinrichs, Reichwald, & Hautzinger, 2002). To the best of our knowledge, only one study has investigated the effects of cortisol on memory retrieval in older people (Wolf et al., 2001). In this study, cortisol (0.5 mg/kg of hydrocortisone sodium succinate) was injected into young (from 19 to 30 years old) and older (from 59 to 76 years old) men 75 min after they had learned a list of neutral words. The authors found that hydrocortisone impaired memory retrieval in both age groups. However, there are major neuroendocrine differences between pharmacologically-induced glucocorticoid elevations and stress-induced glucocorticoid elevations (for more details see: Lupien & Schramek, 2006; Raison & Miller, 2003). Obviously, stress is not equal to glucocorticoid increases; many other psychological and physiological changes occur in stress that are not present with exogenous glucocorticoid administration, including mood changes or SNS activation, which also play a role in memory modulation.

In this context, it is important to study the effects of exposure to an acute psychosocial stressor on long-term memory retrieval in older men and women. Furthermore, despite the lack of studies investigating this matter, several findings suggest that the relationship between stress and memory retrieval could be affected by some age-related changes in the hippocampus and amygdala. Thus, older people may be less sensitive to the effects of cortisol on memory, due to (i) an age-related reduction in cortisol receptor density and sensitivity in the hippocampus (Bhatnagar et al., 1997; Heffelfinger & Newcomer, 2001; Mizoguchi et al., 2009; Newcomer, Selke, Kelly, Paras, & Craft, 1995; Nichols, Zieba, & Bye, 2001) and (ii) reduced functional interconnectivity between the amygdala and hippocampus in memory processes (Mather, 2006; Murty et al., 2010; St. Jacques, Dolcos, & Cabeza, 2009). Nevertheless, it is not currently known whether these age-related changes in the brain can affect the relationship between stress and memory retrieval in older people.

The main goal of the present study was to investigate the effects of stress on hippocampus-dependent memory retrieval in older people. To this end, older men and women learned a series of pictures, words and stories. Then, 1 day later, they were exposed to an acute psychosocial stressor (or a control task) before recovery of the material learned the previous day. Additionally, to investigate whether stress has different acute effects on memory retrieval for emotional or neutral material, the pictures presented on the learning day were neutral, positive and negative. According to previous studies performed with young people, we expected that stress would impair memory retrieval.

2. Methods

2.1. Participants

The sample was composed of 76 participants (38 men and 38 women) ranging in age from 56 to 76 years (Men: $M = 64.63$, $SD = 4.57$; Women: $M = 63.74$, $SD = 3.67$). Most of them had an educational level beyond high school (84.2%), and their subjective socioeconomic status was medium–high (subjective SES scale: Adler, Epel, Castellazzo, & Ickovics, 2000). Participants were randomly assigned to a stress (19 men and 18 women) or control group (19 men and 20 women). There were no significant differences between the stress and control groups in age, Body Mass Index (BMI), SES and educational level (all $p > 0.163$). Men and Women had similar ages, SES and educational levels ($p = 0.168$), but men had higher BMI (Men, $M = 27.83$, $SD = 3.34$; *Women* = 25.99, $SD = 3.67$; $p = 0.026$). All of the female participants were postmenopausal and had had their last menstrual period more than 3 years before the testing time. None of the participants scored less than 28 on the MEC (Spanish version of the Mini-Mental Status Examination; Lobo et al., 1999), indicating the absence of cognitive impairment.

Participants belonged to a study program at the University of Valencia for people over 55 years of age. Exclusion criteria were: smoking more than 10 cigarettes a day, alcohol or other drug abuse, visual or hearing problems, diabetes, presence of an HPA-axis, neurological or psychiatric disease, using any medication directly related to emotional or cognitive functioning or able to influence hormonal levels, such as glucocorticoids, psychotropic substances or sleep medications, having been under general anesthesia once or more than once in the past year, and the presence of a stressful life event during the past year. Because hypertension is a common problem in the older population (Virdis et al., 2011), we decided not to exclude participants who were taking anti-hypertensive medication (men-stress = 7; women-stress = 5; men-control = 4; women-control = 8). Nevertheless, the statistical results and conclusions of this study do not change if we exclude those participants taking anti-hypertensive medication.

2.2. Memory assessment

2.2.1. Picture recall

Participants were shown 30 color pictures (10 negative, 10 positive and 10 neutral) chosen from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2005). Pictures were presented individually for 5 s on a computer screen, and then separated by a black screen that appeared for 15 s. Participants were told to look at the stimuli for the entire 5 s and, when the black screen was displayed, rate the emotional valence (from 1 = *very negative* to 9 = *very positive*) and arousal (from 1 = *low arousal* to 9 = *high arousal*) of the pictures with the Self-Assessment Manikin (SAM; Lang, 1980). Ratings of the pictures showed that negative pictures ($M = 1.21$, SEM = 0.08) were rated lower on emotional valence than neutral ($M = 4.26$, SEM = 0.22) and positive pictures ($M = 7.16$, SEM = 0.12) (for all $p < 0.001$). Neutral pictures were rated lower on valence than positive pictures (for all $p < 0.001$). There were no significant differences between groups or sex (all $p > 0.434$). Positive ($M = 4.30$, SEM = 0.18), and negative pictures ($M = 7.94$, SEM = 0.13) were rated as more arousing than neutral pictures ($M = 3.62$, SEM = 0.13; all $p < 0.004$). Women rated all the pictures as more arousing than men did (Women: $M = 5.53$, SEM = 0.20; Men: $M = 5.03$, SEM = 0.21; $p = 0.003$), and there were no differences between the control and stress groups (Control: $M = 5.27$, SEM = 0.21; Stress: $M = 5.31$, SEM = 0.21; $p = 0.738$).

The following day, participants were instructed to try to recollect as many pictures as possible from the set they had seen the previous day. They had 10 min to write a short detailed description of the pictures. Two independent judges, blind to the group to which each participant belonged, determined which picture (if any) was described by each description. Agreement between judges was 93%, and discrepancies were resolved by consensus. One man in the control group was removed from the free picture-recall analysis because his descriptions could not be matched to any pictures, as they were too vague. After that, participants performed a recognition test. The 30 originally-viewed pictures and 30 new pictures (10 negative, 10 positive and 10 neutral) were presented individually on a computer screen. Participants were asked to determine whether the picture was new or had been presented the previous day. D-prime (d') was used for the recognition analysis (MacMillan & Creelman, 1991).