Available online at www.sciencedirect.com
ScienceDirect
Acta Psychologica 127 (2008) 513–531
acta psychologica
www.elsevier.com/locate/actpsy

The influence of stress hormones on emotional memory: Relevance for psychopathology

Oliver T. Wolf *

Department of Psychology, University of Bielefeld, Postfach 10 01 31, D-33501 Bielefeld, Germany

Available online 27 September 2007

Abstract

Substantial progress within recent years has led to a better understanding of the impact of stress on emotional memory. These effects are of relevance for understanding and treating psychopathology. The present selective review describes how emotional memory is modulated through stress hormones. Acute as well as chronic effects are discussed and information from rodent models is compared to human experimental studies and clinical observations. Finally, the relevance of these findings for emotional memory disturbances in psychiatric disorders is exemplified by discussions on neuroendocrine alterations in depression, post traumatic stress disorder and phobias.

PsycINFO classification: 2343; 2560

Keywords: Stress; Memory; Hormones; Limbic system

1. Overview

Most psychiatric disorders are characterized by emotional memory or emotional learning disturbances. Brain regions involved in these processes are the two medial temporal lobe structures, amygdala and hippocampus, and several brain regions within the prefrontal cortex (PFC; LaBar & Cabeza, 2006). These learning and memory alterations are not just secondary symptoms but are key components of these disorders. For example, PTSD patients experience vivid flashbacks in which they relive the trauma (Nemeroff et al., 2006; Rauch, Shin, & Phelps, 2006; see also Holmes & Bourne, 2008). Patients with major depression in contrast have a memory bias with a preferred storage and retrieval of negative information (Leppanen, 2006). Finally phobic patients display an exaggerated conditioned fear response which they cannot control cognitively (Centonze, Siracusano, Calabresi, & Bernardi, 2005). The examples illustrate that emotional memory dysfunctions appears to underlie several psychiatric disorders.

In this context, actions of neuroendocrine stress mediators are of relevance. The goal of the present review is thus to highlight the influence of stress hormones on emotional memory and emotional learning. Starting from a basic science perspective, experimental work on animals and humans will be reviewed. Afterwards potential clinical implications are outlined using depression, PTSD and phobias as examples. Two systems will be considered: The hormones of the sympathetic nervous system (SNS; adrenalin and noradrenalin) and the hormones of the hypothalamus pituitary adrenal (HPA) axis (CRH, ACTH, and cortisol/corticosterone). These stress responsive systems interact at multiple levels in the periphery and the brain. Together they influence emotional memory in a complex manner.

2. The neuroendocrinology of stress

Most often stress is used to refer to a state in which the individual perceives a real or anticipated challenge to homeostasis, which requires some sort of adaptive response

* Tel.: +49 (0)521 106 4433; fax: +49 (0)521 106 6422.
E-mail address: oliver.wolf@uni-bielefeld.de

0001-6918/$ - see front matter © 2007 Elsevier B.V. All rights reserved.
doi:10.1016/j.actpsy.2007.08.002

(De Kloet, Joels, & Holsboer, 2005; McEwen, 1998). A stressor is the specific event which induces the stress. It can be physical (e.g. thirst, pain) or psychological (e.g. fear or work overload) in nature. A stressor can be acute (an upcoming oral exam) or chronic (constant work overload, inadequate housing conditions, etc.). The subjective evaluation of the stressor and the evaluation of available coping resources is important in determining the individual impact of a stressor (Lazarus, 1993; Mason, 1968a; Ursin & Eriksen, 2004).

When a stressor is encountered the organism responds with secretion of neuroendocrine mediators. These hormones interact with affective and cognitive processes in order to facilitate adaptation (De Kloet et al., 2005; Herbert et al., 2006; McEwen, 1998). The process of maintaining stability through change has been termed allostasis, which is in the short run adaptive and beneficial, but can in the long run oppose a health burden on target systems in periphery and brain (McEwen, 2000, 2003).

The first rapid response is orchestrated by the SNS. Initiated by the hypothalamus, neurons in the spinal cord signal to the adrenal medulla. This results in a rapid release of adrenalin and noradrenalin. These hormones lead to physical alterations, typical of 'feeling stressed' (e.g. increases in heart rate, breathing frequency and sweat production; De Kloet et al., 2005; Mason, 1968b). Adrenalin and noradrenalin cannot easily pass the blood brain barrier, but can stimulate the vagus nerve, which causes an increased noradrenergic tone in the brain by its action on regions in the brain stem (locus coeruleus and nucleus of the solitary tract). These regions stimulate several brain areas most importantly the amygdala (Roozendaal, Okuda, de Quervain, & McGaugh, 2006).

A second slower response is orchestrated by the HPA axis. Here corticotrophin releasing hormone (CRH) together with vasopressin is released from the paraventricular nucleus of the hypothalamus into the portal blood system. In addition to its neuroendocrine function CRH also acts outside the hypothalamus as a neurotransmitter in the CNS and is a regulator of the anxiety system (Dunn & Berridge, 1990; Mitchell, 1998). On reaching the pituitary, CRH stimulates adrenocorticotrophin (ACTH) release into the peripheral blood stream. ACTH initiates the secretion of glucocorticoids (GCs; corticosterone in most laboratory animals, cortisol in humans) from the adrenal cortex (Charney, 2004; De Kloet et al., 2005). Increasing cortisol levels cause a negative feedback by their action at several levels of the HPA axis (pituitary and hypothalamus) but also by influencing the hippocampus, the amygdala and the prefrontal cortex (PFC; De Kloet, Vreugdenhil, Oitzl, & Joels, 1998; Gold, Drevets, Charney, & Drevets, 2002; Jacobson & Sapolsky, 1991). In contrast to the catecholamines, naturally occurring GCs (like all other steroid hormones) can pass the blood brain barrier. In the brain GCs can act via two different intracellular receptors (sometimes referred to as type I or mineralocorticoid (MR) and type II or glucocorticoid (GR) receptor), which differ in their distribution and affinity (De Kloet et al., 1998; Herbert et al., 2006; Joels, 2001). Moreover, GCs can exert rapid non-genomic effects, which sometimes also depend on the MR receptor (De Kloet et al., 2005; Karst et al., 2005). GCs can influence neuronal excitability, neuronal plasticity, dendritic remodeling and neurogenesis (De Kloet et al., 2005; Herbert et al., 2006; Joels, 2001; McEwen, 2003). Besides, multiple neurotransmitter systems like the cholinergic, noradrenergic, serotonergic and dopaminergic system are influenced by GCs (Charney, 2004; De Kloet et al., 2005; Herbert et al., 2006; Joels, 2001; McEwen, 2003). In addition, the effects of GCs on the CNS are modulated at multiple additional levels (see Karssen et al., 2001; Seckl & Walker, 2004). In sum, GCs can have rapid as well as long-lasting effects on the function and structure of the brain.

3. Emotional memory

Emotional information is processed differentially than neutral information. Examples can be found at the level of stimulus perception but also in the domains of attention, working memory or long-term memory (Dolan, 2002; LaBar & Cabeza, 2006; Ohman, 2005; Phelps, 2004). The evolution of such a privileged processing assures that information most relevant to survival is given high priority. This is adaptive under normal circumstances but becomes maladaptive in the case of psychiatric disorders (Dolan, 2002; LaBar & Cabeza, 2006; Ohman, 2005; Phelps, 2004). In fact, several psychiatric disorders are characterized by alterations in emotional memory or emotional learning.

This review will put its focus on episodic memory, which is a system concerned with the explicit and voluntary storage and retrieval of specific events (LaBar & Cabeza, 2006). In addition, working (short-term) memory and associative emotional learning exemplified by fear conditioning will be touched upon.

3.1. Episodic memory

A long-lasting body of research has demonstrated that emotional material is remembered better than neutral material (LaBar & Cabeza, 2006). Some researchers suggest that the emotional arousal (ranging from high to low) is more important than the emotional valence (ranging from positive to negative). Arousal appears to be closer linked to the activity of the amygdala, which is especially important for emotional processing (Kensinger, 2004; LaBar & Cabeza, 2006). The analysis of the valence of a specific stimulus appears to be processed predominantly in prefrontal regions of the brain (Kensinger, 2004).

In human experimental studies subjects remember emotional pictures, words or stories better than neutral ones. The temporal development of this phenomenon is, however, still debated. The initial pioneering studies from