Mind your thoughts: Associations between self-generated thoughts and stress-induced and baseline levels of cortisol and alpha-amylase

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ABSTRACT

Stress is a major health burden in today's society. Research shows that negative cognitive styles are associated with increased stress reactivity, low mood and accelerated cellular aging. Our study sought to unravel the relationship between the content of self-generated thoughts and psychosocial stress measured in terms of hypothalamic-pituitary-adrenal axis and sympathetic activity. Features of self-generated thoughts were assessed using thought sampling while participants performed cognitive tasks following a stress induction or in a baseline condition. More negatively toned emotional thoughts and more social temporal thoughts with a past focus were associated with increased cortisol and alpha-amylase levels, both after stress and at baseline. More social temporal thoughts with a future focus, on the other hand, had an overall attenuating effect on the levels of both stress markers. Our results indicate a fundamental link between the thoughts and stress levels we experience. Understanding the mechanisms governing this mind-body association may have important implications for understanding and counteracting the high incidence of stress-related disorders in today's society.

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1. Introduction

Stress is a major health factor in today's complex and fast-paced society. Stress disorders are among the most commonly occurring of all mental disorders (WHO International Consortium in Psychiatric Epidemiology, 2000) and the estimated costs for stress at the workplace have been calculated to exceed US$ 300 billion annually in the US economy (American Institute of Stress, 2001). However, not everybody develops stress disorders, raising the question as to the resilience factors protecting these individuals. We suggest that one key to successful coping with stressful life events lies in the thoughts that individuals generate consequent to these events. Accordingly, the goal of this study was to unravel the associations between thoughts and stress, aiming specifically to identify those types of post-stress thoughts that protect individuals from the negative impact of a stressor.

We focused our investigation on cognitive and affective experiences produced by the individual without a referent in the immediate sensory environment known as self-generated thoughts (SGT) (Smallwood, 2013). These unconstrained thoughts cover a wide category of experiences including daydreaming, mind wandering, rumination and planning, and have recently become an important focus of research at the level of both psychology and neuroscience. Capitalizing on smart-phone technologies, experience-sampling studies have found that SGT such as mind wandering or daydreaming are common in the laboratory and in daily life (Killingsworth & Gilbert, 2010). SGT have also been implicated in states of creativity (Baird et al., 2012) and unhappiness (Killingsworth & Gilbert, 2010) demonstrating that the capacity for SGT plays an important role in human life.

A similar property of complex self-generated behavior is evident in neural processing. Almost all of the neural systems that exhibit co-ordinated responses as part of an external task show the same patterns of spatially organized behavior during periods of wakeful rest (Smith et al., 2009). Moreover, the behavior of these resting state networks is predictive of important aspects of an individual's psychological profile including their meta-cognitive accuracy (Baird, Smallwood, Gorgolewski, & Margulies, 2013), their capacity for reading (Smallwood, Gorgolewski, et al., 2013) and various psychological disorders. Recent research, therefore, has highlighted that SGT is a natural and influential property at both psychological and biological levels, making it important to understand its relationship to stress.

SGT have a documented relationship to negative affect. Laboratory studies have shown that the induction of negative mood

increases participants' SGT levels (Smallwood, Fitzgerald, Miles, & Phillips, 2009; Smallwood & O'Connor, 2011) and that this effect is stronger in individuals who are chronically unhappy (Smallwood & O'Connor, 2011). Experience sampling studies have found the occurrence of SGT to be associated with more concurrent negative mood, which can persist for several hours (Killingsworth & Gilbert, 2010). The emotional aspects of SGT also have implications at the biological level. Women who reported the highest frequency of negatively toned mind wandering had significantly shorter telomerase length, an epigenetic marker of cellular aging (Epel et al., 2013). An unhappy mood not only increases SGT, it also shifts the temporal focus of the experience toward the past (Smallwood & O'Connor, 2011). In a recent examination, we found that while a focus on the past led to a reduction in positive mood, a focus on the future triggered more positive mood several minutes later (Ruby, Smallwood, Engen, & Singer, 2013). This has led to the hypothesis that the content of SGT can determine its relationship to functional outcomes (Andrews-Hanna, Smallwood, & Spreng, 2014).

Considering the potential of our thoughts to impact on our well-being – in both a beneficial and a detrimental fashion – we aimed to examine the relationship between the content of SGT and an acute physiological stress experience as well as the process of recovery from it. Beyond sympathetic nervous system (SNS) activation as unspecific sign of general arousal, stress experience requires the activation of the hypothalamic-pituitary-adrenal- (HPA) axis resulting in cortisol release (Chrousos, 2009; Hellhammer, Wust, & Kudielka, 2009).

Previous studies examining associations between cognitive processes and cortisol regulation in community samples have focused mainly on rumination and yielded inconsistent results. Rumination has been defined as compulsively focused attention on the symptoms of one's distress and its possible causes and consequences as opposed to its solutions (Nolen-Hoeksema, Wisco, & Lyubomirsky, 2008). According to the Perseverative Cognition Hypothesis by Brosschot, Gerin, and Thayer (2006), rumination entails an ongoing mental representation of a stressor, which should be associated with prolonged activation of stress-related physiological systems. Indeed, state rumination measured after laboratory-induced social evaluative threat was linked to higher reactive cortisol levels (Zoccola, Dickerson, & Zaldivar, 2008). Likewise, the induction of rumination led to reduced diurnal cortisol decline in individuals scoring higher on depressive mood (Kuehner, Huffziger, & Liebsch, 2009). When observing rumination as a trait, individuals with high levels of habitual rumination in response to negative mood showed an attenuated cortisol awakening response (Kuehner, Holzhauer, & Huffziger, 2007) and reduced cortisol reactivity to social evaluative threat in the lab (Zoccola et al., 2008), while stress-related trait rumination was positively correlated with evening cortisol levels (Rydstedt, Cropley, Devereux, & Michalianou, 2009).

To experimentally induce stress in the current study, participants underwent the Trier Social Stress Test (TSST) (Kirschbaum, Pirke, & Hellhammer, 1993; Kudielka, Hellhammer, & Kirschbaum, 2007), a psychosocial laboratory stressor. Subsequent to stress induction, SGT were assessed using a thought sampling technique that addressed the temporal (past-future), emotional (negative-positive) and social (referent of thought self-other) features of thoughts. To identify statistically independent patterns of SGT, these reports were decomposed using Principal Component Analysis. Our previous research using the same technique revealed three distinct covariance patterns (Ruby, Smallwood, Engen, et al., 2013): two reflected social temporal thoughts with either a past or a future focus. A third covariance pattern reflected an emotional element to cognition, i.e., whether thoughts were positively or negatively toned. In order to provide a stress-independent thought sampling baseline, participants came to the laboratory on a separate day and SGT were assessed in the same way but following a period of rest.

Repeated measurements of salivary cortisol and alpha-amylase as indicators of HPA-axis and SNS activation were captured throughout both testing sessions.

Based on previous research exploring SGT and rumination, we hypothesized social temporal thoughts with a past focus and negative in tone, a pattern of cognition that may be considered an index of rumination, to be positively associated with the total impact and duration of stress-induced cortisol and alpha-amylase levels. In contrast, because future thinking is neither a cause nor a consequence of unhappy mood and may in fact reduce negative affect (Ruby, Smallwood, Engen, et al., 2013; Smallwood & O'Connor, 2011), we expected social temporal thoughts with a future focus to be linked to a relatively decreased physiological response to and accelerated physiological recovery from the stressor.

2. Materials and methods

2.1. Participants

Participants between 18 and 35 years of age were recruited by posting ads on an electronic billboard of the city of Leipzig. 99 participants underwent the baseline phase of this study and provided thought sampling data (52 women; mean age ± SD: 25.30 ± 3.85 years). Out of these 99 participants, 46 (selected on the basis of availability) additionally took part in the stress session (23 women; mean age ± SD: 25.70 ± 3.61 years). Given a potential effect on cortisol activity, regular recreational drug users (cannabis within the last two months, any other recreational drug within the past year), regular smokers (>5 cigarettes/week) and individuals reporting chronic illness (including psychological disorders) or taking medication targeting the HPA-axis were excluded. All participants had at least a post-secondary education. Female participants did not use hormone-based birth control. Both study sessions took place in the luteal phase of their cycle (assessed by self-report) to control for the confounding effects of hormonal status on cortisol levels (Kajantie & Phillips, 2006). The study was approved by the Research Ethics Board of Leipzig University (ethics number: 360-10-13122010) and performed in agreement with the Declaration of Helsinki. All participants gave their written informed consent and could withdraw from the study at any time.

2.2. Experimental procedure

Since the secretion of both cortisol and alpha-amylase is characterized by a strong circadian rhythm (Dallman, Bhatnagar, & Viau, 2000; Fries, Dettenborn, & Kirschbaum, 2009; Nater, Rohleder, Schlotz, Ehlert, & Kirschbaum, 2007), testing was performed between 1 pm and 6 pm. Stress and baseline session (duration 120 min; spaced two days apart) were carried out in counterbalanced order in a within-subjects design. To control for the pre-test exposure to food and stress, participants had a little snack upon arrival, after which they rested for 40 min. In the stress session, they were subsequently brought to the TSST room and given the test instructions. Stress induction started after a 10-min anticipation phase and lasted for 10 min. In the baseline session, participants spent the same duration of time at rest. Following the stress (or resting) phase, participants immediately proceeded with the cognitive testing, which lasted for 50 min after stressor cessation (see Fig. 1A+B for an overview). Throughout the testing period, participants refrained from eating and drinking anything but water.

2.3. Stress induction

We applied the standard TSST as described elsewhere (Kirschbaum et al., 1993; Kudielka et al., 2007). Compared to other social-evaluative laboratory stressors, the TSST provokes the most reliable physiological stress responses (Dickerson & Kemeny, 2004). In short, after a preparatory anticipation phase (10 min) the TSST requires the participant to give a 5-min audio- and video-taped mock job talk and engage in 5 min of difficult mental arithmetic while being probed and evaluated by a committee of two "behavioral analysts".

2.4. Cognitive testing

We sampled cognitive data from a total of 99 participants (46 of whom took part in both stress and baseline sessions, and 53 of whom took part in only the baseline session). In both sessions (stress and baseline) participants performed two rounds of two cognitive tasks in counterbalanced order: a Choice Reaction Time Task (CRT) and a Working Memory Task (WM). This paradigm is routinely used in studies of SGT (e.g., Smallwood, Ruby, & Singer, 2013; Smallwood, Schooler, et al., 2011). Each round lasted 400 s and participants could take a break between rounds if desired. During the CRT task, participants observed a sequence of black digits on a computer screen while waiting for a target (a colored digit) to appear, at which point they had to indicate the parity of this target (odd or even) with a button push. In the WM task, participants were exposed to the same sequence of black digits, and were