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Relative frontal brain asymmetry and cortisol release after social stress: The role of action orientation

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ABSTRACT

Social evaluation is a potent stressor and consistently leads to an activation of the hypothalamic–pituitary–adrenal system. Here, we investigated whether individual differences in action orientation influence the relationship between the cortisol response to social-evaluative threat and relative left frontal electroencephalographic (EEG) alpha asymmetry as a brain marker of approach motivation. Forty-nine participants were exposed to a camera-based variant of the Trier Social Stress Task while salivary cortisol and resting EEG frontal alpha asymmetry were assessed before and after stress induction. Higher relative left frontal activity was associated with higher changes in cortisol levels as measured by the area under curve with respect to increase, particularly in individuals low in action orientation. We discuss the role of the left frontal cortex in coping, the potential role of oxytocin, and negative health consequences when the left-frontal coping process becomes overstrained.

1. Introduction

Social inclusion and approval are essential resources for humans and are actively defended when threatened in situations of social evaluation (Beckes and Coan, 2011). However, some individuals, so-called prospectively action-oriented individuals, are able to fluently initiate actions, for example to defend their social inclusion. On the other hand, individuals low in action orientation (AO), that is, prospectively state-oriented individuals, show a tendency toward hesitation, extensive planning and perseverative cognition (i.e., rumination) before engaging in action (Kuhl, 1994b; Stiensmeier-Pelster, 1994). As a consequence, these individuals rest in an approach-motivational state without taking action. In this study, we investigated how action versus state orientation influences the association between the cortisol response to social-evaluative threat and left relative frontal cortical activation (RFA) as a typical electroencephalographic (EEG) indicator of approach motivation (e.g., Harmon-Jones, Gable, & Peterson, 2010).

Fear of actual or expected social evaluation and potentially concomitant rejection is a potent everyday stressor in a human's life (Dickerson and Kemeny, 2004; Mason, 1968). Individuals often cope with it by engaging in social approach as it helps them to reinstate social inclusion. For example, it has been shown that the threat of exclusion increased selective attention to smiling faces reflecting an attunement to signs of social acceptance (DeWall, Maner, & Rouby, 2009). Likewise, exposure to a threat-related film clip increased implicit positive affect, which correlated positively with the speed of recognizing a happy face among an angry crowd (Quirin, Bode, & Kuhl, 2011). Also, rejection concerns have been found to direct attention toward social acceptance or rejection cues depending on individual differences in active approach versus avoidance coping, respectively (Ståhl, van Laar, Ellemers, & Derks, 2012).

A well-established neuroendocrine marker of social-evaluative and rejection threat is secretion of the glucocorticoid cortisol (Dickerson and Kemeny, 2004), a marker of activity of the hypothalamic–pituitary–adrenal (HPA) system (Dedovic, Duchesne, Andrews, Engert, & Pruessner, 2009; Sapolsky, Romero, & Munck, 2000). Cortisol mobilizes energy for active coping, especially if there is threat to one's social status and if this coping requires extended effort as in the case of perseverative cognition (Denson, Spanovic, & Miller, 2009; Mason, 1968; Zoccola, Dickerson, & Zaldivar, 2008). In fact, increased cortisol has been found to be associated with rumination (Denson et al., 2009; Zoccola et al., 2008) and rumination was predicted by rejection sensitivity (Pearson, Watkins, & Mullan, 2011). In turn, the activation of coping resources deriving from social inclusion help

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individuals to conserve metabolically costly somatic resources such as the downregulation of cortisol responses (Beckes and Coan, 2011).

According to much evidence, a neural marker of approach motivation is reflected in left RFA as indicated by reduced activity in the EEG alpha power spectrum (Allen, Coan, & Nazarian, 2004; Coan, Allen, & McKnight, 2006; Davidson, 1992; Harmon-Jones et al., 2010). In fact, numerous studies have shown that left RFA is linked to both state and trait differences in approach motivation (Coan & Allen, 2003a, 2003b, 2004; Hewig, Hagemann, Seifert, Naumann, & Bartussek, 2006; for a critical review, see Wacker, Chavanon, & Stemmler, 2010).

Left RFA has been associated with active, adaptive coping with challenges as indicated by better mood (Koslov, Mendes, Pajtas, & Pizzagalli, 2011), significant attenuation of eyeblink-startle responses (Goodman, Rietschel, Lo, Costanzo, & Hatfield, 2013; Jackson et al., 2003), and lower levels of the stress hormone cortisol (Baeken et al., 2014). Interestingly, in contrast to participants showing rightward RFA change during preparation for a social evaluative (speech) task, participants showing leftward RFA change did not show attentional bias toward angry faces or away from happy faces after speech preparation (Pérez-Edgar, Kujawa, Nelson, Cole, & Zapp, 2013). This finding tentatively suggests that during subsequent social evaluation, left RFA activation may be associated with relatively increased attention towards happy faces that characterizes social approach coping (Ståhl et al., 2012). In the study by Koslov et al. (2011), only among participants submitted to social rejection, greater left RFA at baseline was associated with more adaptive cardiovascular profiles and more self-reported approach-oriented emotions. Extending such observations to experimentally increased cortical activation, left dorsolateral prefrontal cortical repetitive transcranial magnetic stimulation attenuated cortisol responses to critical feedback (Baeken et al., 2014).

However, although individuals may show social approach motivation, they often do not or cannot immediately engage in social behavior and hence start to deliberate or ruminate (e.g., about whether they did something wrong or how to maintain their social esteem). Ultimately, however, in the context of social exclusion threat, persevering cognitions serve to reinstate or defend social inclusion, or to prevent potential social exclusion in the future as an attempt of social problem solving. This is compatible with action control models according to which deliberation and reappraisal aim to resolve conflicts, incongruency and indecisions before non-automatized, difficult actions can be implemented (Gollwitzer, Heckhausen, & Steller, 1990; Kuhl, 1984; Tops, Boksem, Quirin, IJzerman, & Koole, 2014). As such, left RFA may not only reflect processes of approach motivation that immediately facilitate action (i.e., behavioral approach) but, depending on context and individual differences, sustain perseverative cognition in states of indecisiveness and hesitation that prevent or delay action (see also Roth and Cohen, 1986; Tops, Boksem et al., 2014). Indeed, there is evidence that rumination in general (Heller, Nitschke, Etienne, & Miller, 1997; Stewart, Levin-Silton, Sass, Heller, & Miller, 2008), and rumination over public speaking in particular (Hofmann et al., 2005) are associated with left RFA (see also Andrews and Thomson, 2009).

Individual differences in the ability to flexibly shift from mindsets of deliberation to action implementation are reflected in the concept of action orientation (Kuhl, 1994a). Specifically, high AO individuals are able to block extended perseveration of thought and thus to buffer against mind wandering and intrusive thoughts in order to remain functional in everyday life. This includes the ability to flexibly regulate one's emotional responses as this facilitates decision-making and the maintenance of goal pursuit (Koole, 2009; Kuhl, 2000; Quirin, Kuhl, & Düsing, 2011). By contrast, low AO individuals (so-called state-oriented individuals) show a tendency toward hesitation and indecision. As a consequence, low AOs tend to rest in a state of deliberation on their goals rather than to switch to an action-implementation mindset (cf. Gollwitzer and Brandstätter, 1997).

Quirin, Kuhl et al. (2011) investigated the relationship between AO and cortisol response to a powerful social evaluation stressor, the Trier Social Stress Task (TSST; Kirschbaum, Pirke, & Hellhammer, 1993). They found that participants with low AO showed significantly higher cortisol responses to the TSST than participants with high AO. This suggests that individuals with low AO show increased cortisol responsivity to social evaluative stress. Therefore, AO as an individual differences marker of adaptive self-regulation may moderate the neuroendocrine effects of social evaluation stress.

1.1. Present research and hypotheses

The present study investigates how individual differences in AO influence the relationship between frontal alpha asymmetry and the cortisol response to social-evaluative stress as induced by a variant of the TSST. Specifically, we assessed both saliva cortisol and EEG before and after participants completed the TSST and examined their relationship as a function of AO.

Assuming that the left frontal cortex is implicated in the perseveration of thoughts aiming at approach-related actions to defend social inclusion, we hypothesized increases in left RFA being associated with increases in cortisol. Particularly, we expect that low AO individuals, that is, those with a tendency to cognition perseveration show this association between increased left RFA and stress-related cortisol elevation. Because of active coping in AOs we expect no or a negative association between left RFA and cortisol responses for this group of participants.

Whereas action orientation refers to abilities in regulating emotions once aroused (e.g., Kuhl, 1994a), individual differences in Behavioral Inhibition (BIS) and Behavioral Activation system (BAS) refer to a sensitivity of emotional systems, which is the readiness by which punishment-related (negative) or reward-related (positive) emotions become aroused, respectively (Gray, 1987). As BIS and BAS have repeatedly been associated with frontal asymmetry (for a critical view, see Wacker et al., 2010), we will control for these variables in order to identify unique effects of AO on the relationship between cortisol response and RFA.

2. Method

2.1. Sample and procedure

Forty-nine participants (32 female) with a mean age of 22.48 years (SD = 3.33) were recruited by an experimenter via flyers and postings and received 15€ or course credit for participation in the study. Participants were informed about the EEG procedure and gave written consent to participate. All experimental sessions started between 1200 h and 1500 h and lasted for approximately 2.5 h. In a first session, participants filled out a battery of measures that included the AO scale and, in addition, the BIS and BAS scales. Individual appointments were made for a second session taking place about one week later, in which resting EEG was recorded by two experimenters while the participant sat in a comfortable chair. Resting state EEG was recorded at two times during the session, directly before the preparation phase of the stress test (t1) and immediately after the stress test (t2). EEG was recorded in occasions of eight 1-min resting periods, where four occasions were recorded with eyes open and four with eyes closed. The measurements were counterbalanced across participants according to one of two sequences of eyes open (O) and eyes closed (C) conditions (O–C–C–O–C–O–O–C or C–O–O–C–O–C–C–O). Participants