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Short communication

Emotional attentional control predicts changes in diurnal cortisol secretion following exposure to a prolonged psychosocial stressor

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ABSTRACT

Hypothalamic–pituitary–adrenal (HPA) axis irregularities have been associated with several psychological disorders. Hence, the identification of individual difference variables that predict variations in HPA-axis activity represents an important challenge for psychiatric research. We investigated whether self-reported attentional control in emotionally demanding situations prospectively predicted changes in diurnal salivary cortisol secretion following exposure to a prolonged psychosocial stressor. Low ability to voluntarily control attention has previously been associated with anxiety and depressive symptomatology. Attentional control was assessed using the Emotional Attentional Control Scale. In students who were preparing for academic examination, salivary cortisol was assessed before (time 1) and after (time 2) examination. Results showed that lower levels of self-reported emotional attentional control at time 1 ($N = 90$) predicted higher absolute diurnal cortisol secretion and a slower decline in cortisol throughout the day at time 2 ($N = 71$). Difficulty controlling attention during emotional experiences may lead to chronic HPA-axis hyperactivity after prolonged exposure to stress. These results indicate that screening for individual differences may foster prediction of HPA-axis disturbances, paving the way for targeted disorder prevention.

1. Introduction

Disturbances in the hypothalamic–pituitary–adrenal (HPA) axis, either in baseline diurnal variations or in response to a psychological stressor, have been implicated in – and proposed as a risk factor for – several psychological disorders, including major depressive disorder, and anxiety disorders (e.g., Adam et al., 2014; Lopez-Duran et al., 2009).

Hence, an important challenge for psychiatric research lies in the identification of individual difference variables that predict variations in HPA-axis activity. This may help to identify individuals at risk for psychopathology and pave the way for targeted prevention. In recent years, a growing amount of research has shown a relationship between elevated HPA-axis activity and cognitive system irregularities, such as rumination or threat-related attentional biases (e.g., Hakamata et al., 2013; Zoccola et al., 2011). In the present study, we investigated whether self-reported attentional control in emotionally demanding situations prospectively predicted variation in salivary cortisol levels after waking and across the day. For individuals who have difficulty controlling their attention in the presence of emotion, the impact of psychosocial stressors may be stronger or longer lasting. As a consequence, physiological stress responses may be more pronounced in these individuals. Here, we report on cortisol changes over time in participants who were facing six weeks of psychosocial stress as they prepared for academic examination. From a diathesis-stress perspective on maladaptive or undesirable health outcomes (i.c., HPA-axis disturbances) arising from a combination of life stress and individual differences in vulnerability to stress, we expected the effect of a prolonged psychosocial stressor on HPA-axis functioning to be more pronounced in individuals with a lower ability to control their attention in the presence of emotion. More specifically, we investigated whether individuals low in emotional attentional control would show elevated HPA-axis activity following exposure to a prolonged psychosocial stressor. That is, we predicted that individuals who reported low emotional attentional control would exhibit higher cortisol levels after termination of academic examination, while controlling for cortisol levels before examination.

Attentional control was assessed using the Emotional Attentional Control Scale (eACS; Barry et al., 2013)—an adaptation of the Attentional Control Scale. The eACS measures individual dif-

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ferences in the ability to focus attention and shift it between tasks in emotionally demanding situations. Low emotional attentional control (eAC) is associated with difficulty shifting attention away from emotional provocative thoughts or stimuli in the environment, which is particularly relevant in the context of psychological disorders. In support of this view, a recent study demonstrated that the eACS explained unique variance in anxiety symptomatology, over and above the variance explained by the original, emotionally neutral Attentional Control Scale (ACS; Barry et al., 2013). Further, previous research with the original ACS has shown a relationship between attentional control and anxiety and depressive symptomatology in adults and in children (Ólafsson et al., 2011; Reinholdt-Dunne et al., 2012; Susa et al., 2012). From a theoretical perspective on the relation between attentional control and psychopathology, individuals who lack the ability to voluntarily control their attention, especially in the presence of emotion, are more prone to experience difficulty regulating emotion. Emotional dysregulation may in turn contribute to the development of psychological complaints such as anxiety or depressive symptomatology.

In order to investigate whether individual differences in emotional attentional control predicted HPA-axis activity following a prolonged psychosocial stressor, we examined diurnal cortisol secretion, the cortisol awakening response (CAR), and diurnal peak-to-evening decline before and after academic examination. Diurnal cortisol secretion was measured as the area under the curve, $AUC_{diurnal}$, reflecting the overall cortisol secretion during the day (Fekedulegn et al., 2007). The CAR is a robust 50–100% increase in cortisol levels shortly after waking and was measured as the increment in cortisol from awakening to 30 min later (Wüst et al., 2000). Finally, diurnal decline refers to the gradual decrease in cortisol values throughout the day and was measured as the slope mean decline per hour from morning peak to evening values (Lamers et al., 2013).

Elevated cortisol levels could be indicative of HPA-axis hyperactivity. HPA-axis abnormalities have previously been associated with (elevated risk for) psychopathology (e.g., Adam et al., 2014; Cullen et al., 2014; Lamers et al., 2013; Lopez-Duran et al., 2009; Spijker and van Rossum, 2012; Veen et al., 2011). The three cortisol measures included in this study can all capture elevated HPA-axis activity, but reflect different diurnal variations. The CAR provides information on individual differences in cortisol responses to waking, and we predicted that individuals low in emotional attentional control would show a higher CAR after a prolonged psychosocial stressor. The diurnal slope reflects differences in cortisol decrease throughout the day. For individuals with low attentional control in the presence of emotion, cortisol levels may remain higher throughout the day due to difficulty in shifting attention away from psychosocial stressors, which may prolong their impact. Further, higher $AUC_{diurnal}$ values in individuals who report low emotional attentional control would indicate higher absolute cortisol secretion in these individuals. Finally, in addition to emotional attentional control, we also looked at the effect of gender, given well documented gender differences in HPA axis responding to stress (Kudielka and Kirschbaum, 2005). We also assessed trait anxiety and depressive symptomatology at Time 1 to investigate whether the eACS would still have predictive value for Time 2 cortisol levels when controlling for these variables.

2. Method

2.1. Participants

Participants were 90 undergraduate students (56 women) at the University of Leuven, Belgium, who were facing academic examination (M_{age} = 20.2; SD_{age} = 5.4). After examination, 71 participants (78%) returned for follow-up testing. All participants gave written informed consent. All procedures were approved by the Internal Review Board of the Ethics Committee of the University of Leuven.

2.2. Measures

2.2.1. Emotional attentional control scale

Emotional Attentional Control (eAC) was measured using the emotional Attentional Control Scale (eACS). This is a 14-item self-report measure of individual differences in focusing and shifting of attention in the presence of emotion. For example, 'My attention easily shifts to my emotions'. Responses are given on a 4-point scale from 1, almost never, to 4, always (Barry et al., 2013). A high score on the eACS represents good eAC and vice versa.

2.2.2. Salivary cortisol

Saliva samples were collected using Salivettes (Sarstedt, Nümbrecht, Germany) at four time points on a weekday outside of the weekend: upon awakening, and 30 min, 8 h, and 11 h later. Samples were frozen and stored at −20 °C until analysis. After thawing, salivettes were centrifuged at 3000 rpm for 5 min, resulting in a clear supernatant of low viscosity. Salivary concentrations were measured using commercially available chemiluminescence immunoassay with high sensitivity (IBL International, Hamburg, Germany). The intra- and interassay coefficients for cortisol were below 8%. Three summary measures were calculated: area under the curve with respect to ground for the total diurnal response, $AUC_{diurnal}$, cortisol awakening response, CAR, and decline from morning peak to evening values (i.e., last sample of the day). $AUC_{diurnal}$ was obtained using the trapezoid formula and reflects the surface area under the curve represented by the four sample values, with the measurements themselves as heights, and time distances between measurements as widths (Fekedulegn et al., 2007). CAR was calculated by subtracting cortisol values at awakening from cortisol values 30 min later. Diurnal decline was measured as the slope mean decline per hour as: diurnal slope = $(cortisol_{30\,mins} - cortisol_{evening})/(time_{evening} - time_{30\,min})$.

2.2.3. Trait anxiety and depressive symptomatology

Trait anxiety was measured using the Trait version of the State and Trait Anxiety Inventory (STAI-T; Spielberger, 1983). The STAI-T is a 20-item questionnaire with scores ranging from 20 to 80; higher scores reflect higher trait anxiety. Depressive symptomatology was measured using the depression subscale of the short version of the Depression, Anxiety, and Stress Scales (DASS-D; Lovibond and Lovibond, 1995). The DASS-D subscale ranges from 0 to 21, with higher scores reflecting more depressive symptomatology. Finally, we asked participants to report whether they were suffering from psychiatric illness and whether they were taking psychotropic medication.

2.3. Procedure

Participants were invited before and, to avoid measuring acute stress responses, two weeks after academic examination. This allowed us to assess the presence of elevated HPA-axis activity after termination of the psychosocial stressor. Academic examination lasted for six weeks, consisting of three weeks of preparation and three weeks of examination (with each exam separated by a number of days). For most of the participants, except for those repeating their first year, this was their first examination period at the university. Before as well as after examination, participants received a personalized kit containing four samples, and were requested to collect the samples the next day while following their normal daily routine. They were instructed to refrain from brushing their teeth,

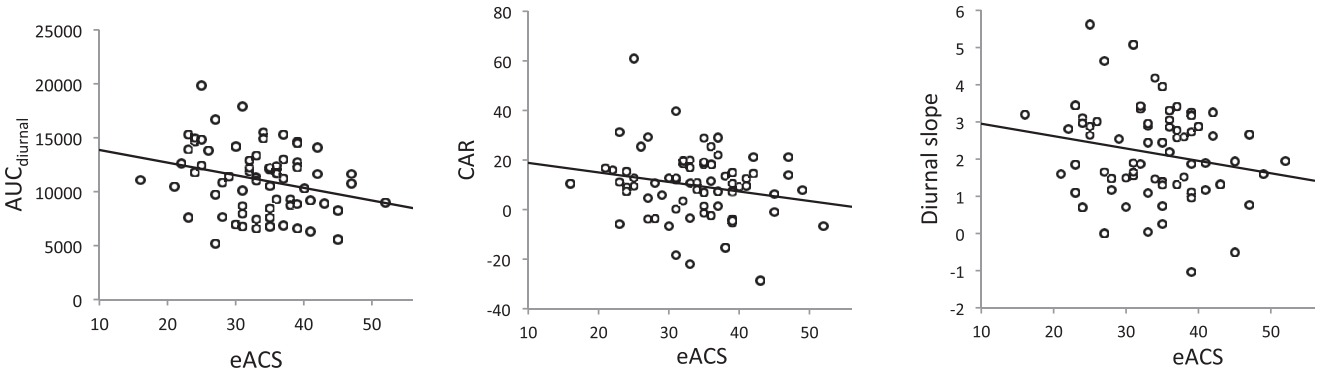

Fig. 1. Scatterplots of Time 2 cortisol diurnal area under the curve ($AUC_{diurnal}$), Time 2 cortisol awakening response (CAR), and Time 2 morning peak to evening Slope, against Time 1 emotional attentional control scores (eACS).

smoking, eating, or drinking at least one hour before each sample, and were asked not to drink alcohol during the day of sampling as well as the night before. Each participant received a personal logbook to record the exact timing of awakening and collection of the four samples.

3. Results

At Time 1, mean salivary cortisol values (and standard deviations) were 25.11 (11.10) at awakening, 36.75 (14.43) at 30 min, 8.96 (5.38) at 8 h, and 8.46 (7.15) at 11 h after awakening. At time 2, after academic examination, this was 20.81 (9.90), 30.52 (12.00), 8.78 (4.31), and 6.76 (4.94) respectively. For the total sample, the mean eACS score at Time 1 was 34.00 (SD = 7.22; range = 16–52). Nine participants reported that they were currently using psychotropic medication, and one participant reported to be suffering from a psychiatric illness (i.c., anorexia nervosa).

To investigate whether individual differences in emotional AC had predictive value for salivary cortisol changes after exposure to a prolonged psychosocial stressor[1], multiple regression analyses were carried out with Time 2 $AUC_{diurnal}$, CAR, and diurnal slope as dependent variables. For all regression analyses, we examined scatterplots and histograms of residuals to check for violations of assumptions (e.g., linearity, homoscedasticity, normality of residuals). Fig. 1 shows the scatterplots of Time 2 $AUC_{diurnal}$, CAR, and diurnal slope, against Time 1 emotional attentional control scores (eACS). With respect to $AUC_{diurnal}$, results showed that low scores on the eACS (reflecting lower emotional AC) predicted higher diurnal cortisol secretion after academic examination, even after controlling for baseline $AUC_{diurnal}$ (i.e., before examination; Table 1).[2] Although $AUC_{diurnal}$ at baseline significantly predicted $AUC_{diurnal}$ at follow-up, eACS scores explained unique variance in diurnal cortisol secretion as well (the effect of gender was not significant).

With time 2CAR as the dependent variable, lower eACS scores were associated with a higher Time 2CAR (i.e., greater morning increase in cortisol), after controlling for CAR at Time 1, but this association was not significant ($p = .063$). Again, the effect of gender was not significant. Finally, with Time 2 diurnal slope as the dependent variable, eACS scores again explained unique variance after controlling for diurnal slope before academic examination, with lower emotional AC predicting a slower decline from morning peak to evening values. Here, we did find an effect of gender, with a steeper diurnal slope in men, indicating a greater decline from morning peak to evening in men relative to women (Table 1).

Further, we reran the regression analyses in which eACS scores were a significant predictor (i.e., $AUC_{diurnal}$ and diurnal slope) to assess whether low emotional AC was still associated with higher cortisol levels at Time 2 when depressive symptomatology or trait anxiety were included as predictors in the model. For $AUC_{diurnal}$, eACS scores were still a significant predictor when DASS depression scores were added as predictor to the model described in Table 1, $\beta = -.354$, $t(63) = -2.94$, $p = .005$. DASS depression scores were no significant predictor for Time 2 $AUC_{diurnal}$, $\beta = -.028$, $t(63) = -0.24$, $p = .814$. With trait anxiety added to the model, lower eACS scores were still associated with higher Time 2 $AUC_{diurnal}$, $\beta = -.431$, $t(63) = -3.00$, $p = .004$, whereas trait anxiety itself was no significant predictor, $\beta = -.135$, $t(63) = -0.95$, $p = .348$. With respect to diurnal slope, however, lower eACS scores no longer predicted a slower diurnal decline in cortisol levels at Time 2, $\beta = -.199$, $t(65) = -1.82$, $p = .073$, when controlling for DASS depression scores, which were no significant predictor either, $\beta = -.110$, $t(65) = 1.02$, $p = .310$. With trait anxiety added to the model, lower eACS scores no longer predicted a slower diurnal decline in cortisol values at Time 2, $\beta = -.220$, $t(65) = -1.65$, $p = .104$, and trait anxiety was not a significant predictor either, $\beta = .037$, $t(65) = 0.28$, $p = .784$.

Finally, we reran all analyses with smoking status (smoker vs. non-smoker) and the use psychotropic medication (currently taking psychotropic medication or not) as covariates. Neither smoking status, nor the use of psychotropic medication were significant predictors, and they did not change the status of the other covariates (results not shown).

4. Discussion

Lower self-reported emotional attentional control prospectively predicted higher diurnal cortisol secretion after academic examination. Both higher overall diurnal cortisol secretion and a slower morning peak to evening decline were predicted by lower emotional attentional control before examination. Lower eACS scores were associated with a higher cortisol awakening response as well, but this association was only supported at trend level. We also found a greater decline in cortisol values throughout the day in men relative to women. Together, these results lend support to the predictive validity of self-reported emotional attentional control for changes in diurnal cortisol secretion after exposure to a prolonged psychosocial stressor.

[1] Of the 71 participants who returned at Time 2, we collected subjective stress data from the last 32 (45%). Participants were requested to answer the statement 'The past exam period was very stressful for me' on a scale ranging from 1 (not at all), to 5 (extremely). The average score was 3.73. Although incomplete, these data indicate that the exam period was subjectively experienced as stressful.

[2] Because three participants (one at Time 1, two at Time 2) failed to collect one of the two evening samples, analyses with $AUC_{diurnal}$ as the dependent variable are based on a total of 68 participants, and with diurnal slope as the dependent variable on a total of 70 participants.

Table 1
Multiple regression analyses predicting Time 2 cortisol diurnal area under the curve ($AUC_{diurnal}$), Time 2 cortisol awakening response (CAR), and Time 2 morning peak to evening Slope, from emotional attentional control (eACS), gender, and Time 1 (T1) $AUC_{diurnal}$,CAR, and Slope.

	$AUC_{diurnal}$			CAR			Slope	
	β	t		β	t		β	t
T1 $AUC_{diurnal}$	.428	3.92**	T1CAR	.333	2.97*	T1 Slope	.506	5.14**
Gender	.160	1.45	Gender	.096	0.83	Gender	.279	2.78†
eACS (T1)	−.344	−3.11*	eACS (T1)	−.217	−1.89‡	eACS (T1)	−.244	−2.43†

Note: $R^2_{AUCdiurnal}$ = .258, adjusted $R^2_{AUCdiurnal}$ = .223; R2CAR = .157, adjusted R2CAR = .119; R2Slope = .362, adjusted R2Slope = .333;
* $p < .005$.
** $p < .001$.
† $p < .05$.
‡ $p = .063$.

Low eACS scores remained a significant predictor for Time 2 $AUC_{diurnal}$ when controlling for depressive symptomatology and trait anxiety. For diurnal slope, however, the eACS was no longer a significant predictor when adding these variables to the model. Further, it is noteworthy that cortisol levels decreased from T1 to T2 over the total sample. A possible explanation for this is presence of anticipatory stress at T1. At T2, after termination of academic examination, physiological stress responding may have returned to baseline for most individuals. Nevertheless, we found that cortisol levels were higher two weeks after academic examination in individuals who reported low emotional attentional control.

Chronic stress and HPA-axis irregularities are implicated in the development and maintenance of psychopathology. Hence, the investigation of individual difference variables that predict changes in HPA-axis activity, especially after exposure to psychosocial stressors, provides an important tool to identify at-risk individuals. Based on our findings, individuals who report having difficulty controlling their attention in emotionally-demanding situations may be more prone to prolonged HPA-axis hyperactivity after psychosocial stress.

Identification of at-risk individuals could facilitate more targeted and effective disorder prevention. For instance, individuals with low emotional AC may benefit from training interventions that are known to enhance attentional control (Chambers et al., 2007). Interestingly, attentional training has been shown to lower cortisol release in response to experimentally induced stress (Dandeneau et al., 2007).

In this study, we used a self-report measure of emotional AC. Current findings evidence the capacity of the eACS to predict changes in HPA-axis activity over time, demonstrating its predictive validity. An added advantage of the eACS is its easy applicability, making it an interesting instrument from a clinical point of view. Still, many studies investigating attentional control in the context of psychopathology have used behavioral measures of reaction time in tasks where neutral target stimuli follow threat-related stimuli (e.g., Hakamata et al., 2013). Future research could investigate the predictive validity of these behavioral measures for changes in HPA-axis activity, and could assess the correlation of the eACS with behavioral measures of attentional control in the presence of threat or emotion (Reinholdt-Dunne et al., 2012). Interestingly, recent evidence indicates that self-reported AC moderates the relation between attentional biases toward threat and anxiety symptomatology (Susa et al., 2012). This suggests that self-reported (emotional) AC may be a separable construct from attention biases, with its own predictive relationship with anxiety.

This study demonstrated a longitudinal relationship between emotional AC and changes in diurnal cortisol secretion. Relations between attentional control, stress, and cortisol are likely multi-directional and more complex than was portrayed here. For instance, Liston et al. (2009) showed that prolonged psychosocial stress impaired attentional control and disrupted functional connectivity in a frontoparietal network involved in attentional shifting. These cognitive impairments may in turn fuel abnormal HPA-axis reactivity to stress, suggesting a positive feedback loop. These interactions may contribute to the development of physical and mental health complaints related to stress. Further, whereas several studies have evidenced a relationship between HPA-axis hyperactivity and (risk for) psychopathology, it is noteworthy that other studies have found associations with HPA-axis hypoactivity (e.g., Yehuda et al., 2000). In this study, we found evidence for elevated HPA-axis activity after prolonged psychosocial stress in individuals low in emotional attentional control. However, future studies could investigate whether more chronic stressors and stress-related diseases such as post-traumatic stress disorder or burnout are associated with HPA-axis hypoactivity in individuals low in emotional attentional control.

Limitations of this study include the assessment of diurnal cortisol values on a single day at Time 1 and Time 2, as previous studies have shown that more stable estimates of individual differences in daily cortisol secretion are obtained when assessed over multiple days (Hellhammer et al., 2007). Further, we assessed cortisol at four time points during the day. With respect to the CAR, for instance, the morning peak value was assessed at 30 min after awakening, but for some individuals this peak may occur earlier or later in time. Future studies could use several daily measurements for both time points, and could assess the CAR with more than two measurements after awakening. Another limitation is that we measured subjective stress in only 45% of the total sample. Although data from these individuals suggest that the exam period was subjectively experienced as stressful, it remains a distinct possibility that not all participants effectively experienced prolonged psychosocial stress. We also did not control for the potential confounding influence of BMI on cortisol levels. Finally, our main goal was to predict variations in HPA-axis activity following a naturally occurring psychosocial stressor. Still, future studies could employ stressor tasks in a more controlled laboratory setting, allowing for more firm causal inferences on the relation between emotional attentional control and HPA-axis irregularities.

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