View metadata, citation and similar papers at core.ac.uk

brought to you by CORE

provided by Scholarship; Research; and Creative Work at Bryn Mawr College

Bryn Mawr College
Scholarship, Research, and Creative Work at Bryn Mawr College

Psychology Faculty Research and Scholarship | Psychology

2016

Trait positive and negative emotionality differentially associate withdiurnal cortisol activity

Karissa G. Miller

Aidan G.C. Wright

Laurel M. Peterson
Bryn Mawr College, lmpeterson@brynmawr.edu

Thomas W. Kamarck

Barbara A. Anderson

See next page for additional authors

Let us know how access to this document benefits you.

Follow this and additional works at: http://repository.brynmawr.edu/psych_pubs


Part of the Psychology Commons

Custom Citation

Miller et al. "Trait positive and negative emotionality differentially associate withdiurnal cortisol activity." Psychoneuroendocrinology 68 (2016); 177-185.

This paper is posted at Scholarship, Research, and Creative Work at Bryn Mawr College. http://repository.brynmawr.edu/psych_pubs/47

For more information, please contact repository@brynmawr.edu.

Authors
Karissa G. Miller, Aidan G.C. Wright, Laurel M. Peterson, Thomas W. Kamarck, Barbara A. Anderson, Clemens Kirschbaum, Anna L. Marsland, and Matthew F. Muldoon

This article is available at Scholarship, Research, and Creative Work at Bryn Mawr College: http://repository.brynmawr.edu/psych_pubs/47

Psychoneuroendocrinology 68 (2016) 177–185

Contents lists available at ScienceDirect

Psychoneuroendocrinology

journal homepage: www.elsevier.com/locate/psyneuen

Trait positive and negative emotionality differentially associate with diurnal cortisol activity

Karissa G. Miller[a,*], Aidan G.C. Wright[a], Laurel M. Peterson[b], Thomas W. Kamarck[a], Barbara A. Anderson[a], Clemens Kirschbaum[c], Anna L. Marsland[a], Matthew F. Muldoon[d], Stephen B. Manuck[a]

[a] Department of Psychology, University of Pittsburgh, Pittsburgh, PA 15260, USA
[b] Department of Psychology, Bryn Mawr College, Bryn Mawr, PA 19010, USA
[c] Department of Psychology, Technische Universität Dresden, 01069 Dresden, Germany
[d] Division of Cardiology, University of Pittsburgh School of Medicine, Pittsburgh, PA 15261, USA

ARTICLE INFO

Article history:
Received 11 November 2015
Received in revised form 2 March 2016
Accepted 2 March 2016

Keywords:
Cortisol
HPA
Affect
Personality
Neuroticism
Extraversion

ABSTRACT

Inter-individual variability in metrics of hypothalamic-pituitary-adrenocortical (HPA) activity, such as the slope of the diurnal decline in cortisol, cortisol awakening response (CAR), and total cortisol output, have been found to associate inversely with trait ratings of extraversion and positive affect (E/PA) and positively with neuroticism and negative affect (N/NA) in some, but not all, investigations. These inconsistencies may partly reflect varied intensity of cortisol sampling among studies and reliance on self-rated traits, which are subject to reporting biases and limitations of introspection. Here, we further examined dispositional correlates of HPA activity in 490 healthy, employed midlife volunteers (*M* age = 43 years; 54% Female; 86% white). Trait ratings were requested from participants and 2 participant-elected informants using the Positive and Negative Affect Schedule (PANAS) and Extraversion and Neuroticism dimensions of NEO personality inventories. CAR was assessed as percent increase in cortisol levels from awakening to 30 min after awakening; and the diurnal slope and total output of cortisol [Area Under the Curve (AUC)] were determined from cortisol measurements taken at awakening, +4 and +9 h later, and bedtime, across 3 workdays. Structural equation modeling was used to estimate multi-informant E/PA and N/NA factors. We used 3 days of measurement as indicators to model each of the three latent cortisol factors (slope, CAR, and AUC). With the two latent emotionality and three latent cortisol indices included there was good fit to the data ($\chi^2_{(200)} = 278.38$, $p = 0.0002$; RMSEA = 0.028, 90% CI = 0.02–0.04; CFI/TLI = 0.97/0.96; SRMR = 0.04). After controlling for covariates (age, sex, race), results showed higher latent E/PA associated with a steeper diurnal slope (Standardized $\beta = -0.19$, $p = 0.02$) and smaller CAR (Standardized $\beta = -0.26$, $p = 0.004$), whereas N/NA did not associate with any cortisol metric (Standardized β's = −0.12 to 0.13, p's = 0.10 to 0.53). These findings suggest that positive emotionality may be more closely associated with indices of diurnal cortisol release than negative emotionality.

© 2016 Elsevier Ltd. All rights reserved.

1. Introduction

The hypothalamic-pituitary-adrenocortical (HPA) system has long been considered a pathway by which psychological factors, such as emotionality, may influence health. States of positive and negative affect have been found to relate, respectively, to lower and higher levels of concurrently assessed plasma or salivary cortisol concentrations (e.g., Smyth et al., 1998). Much research, too, has examined whether people who differ in their propensity to experience positive or negative affect (i.e., whereby some individuals experience these mood states more frequently than others) differ on indices of aggregated HPA activity, such as the slope of declining cortisol levels during waking hours, magnitude of the cortisol awakening response, or total cortisol release over the day. Positive and negative affect are now also commonly viewed as intrinsic features of two prominent personality factors,

* Corresponding author at: Department of Psychology, University of Pittsburgh, 210 South Bouquet Street, Pittsburgh, PA 15260, USA.
E-mail addresses: kgm18@pitt.edu (K.G. Miller), aidan@pitt.edu (A.G.C. Wright), lmpeterson@brynmawr.edu (L.M. Peterson), tkam@pitt.edu (T.W. Kamarck), baa1@pitt.edu (B.A. Anderson), clemens.kirschbaum@gmx.de (C. Kirschbaum), marsland@pitt.edu (A.L. Marsland), mfm10@pitt.edu (M.F. Muldoon), manuck@pitt.edu (S.B. Manuck).

http://dx.doi.org/10.1016/j.psyneuen.2016.03.004
0306-4530/© 2016 Elsevier Ltd. All rights reserved.

(extraversion and neuroticism; Clark and Watson, 2008; McCrae and Costa, 2003). Thus, trait measures of positive affect correlate highly with extraversion, but not neuroticism, and trait negative affect with neuroticism, but not extraversion, prompting speculation that these personality dimensions are rooted in corresponding affective temperaments (Watson, 2000). In extension, it may be asked whether extraversion and neuroticism likewise associate with indices of HPA activity.

Findings from the existing literature associating trait affect and personality with HPA activity are mixed. There is some evidence that, in adults, higher levels of extraversion and greater positive affect (assessed by trait questionnaire or by averaging self-reported states of positive affect over repeated measurements) associate with a steeper diurnal slope, smaller awakening response, lower total cortisol output, and lower cortisol levels obtained from single measurements taken at varying times during the day (Brummett et al., 2009; Hoyt et al., 2015; Lai et al., 2005; Mikolajczak et al., 2010; Nater et al., 2010; Polk et al., 2005; Steptoe et al., 2007, 2008, 2005; Steptoe and Wardle, 2005; Turner-Cobb et al., 2008; Vedhara et al., 2006). And conversely, some studies have shown higher levels of neuroticism or trait negative affect related to a flatter diurnal slope, larger morning awakening response, higher total output, and higher cortisol levels on single measurements (Doane et al., 2011; Garcia-Banda et al., 2014; Hauner et al., 2008; Mikolajczak et al., 2010; Nater et al., 2010; Oishi et al., 2012; Polk et al., 2005; Portella et al., 2005). Yet in other studies, similarly assessed personality dimensions and trait affect do not correlate with the same indices of HPA activity (Brummett et al., 2009; Dettling et al., 1999; Ellenbogen et al., 2006; Garcia-Banda et al., 2014; Gerritsen et al., 2009; Hauner et al., 2008; Hoyt et al., 2015; Munafo et al., 2006; Schommer et al., 1999; Steptoe et al., 2008; Turner-Cobb et al., 2008; van Eck et al., 1996; Vedhara et al., 2006; Laceulle et al., 2015) or do so in an opposite direction (Polk et al., 2005; van Santen et al., 2011; Atkinson et al., 2015).

These inconsistencies may reflect, in part, a number of methodological differences among studies. For example, null effects appear to predominate among studies involving younger participants, smaller samples, or more limited cortisol sampling protocols (e.g. Dettling et al., 1999; Hauner et al., 2008; Munafo et al., 2006; Schommer et al., 1999; Vedhara et al., 2006; Laceulle et al., 2015). In contrast, positive findings tend to emerge more often in studies including mid-life adults, larger (i.e., better powered) study samples, or a more thorough assessment of cortisol activity involving measurements taken at multiple times of the day and on multiple days (e.g. Garcia-Banda et al., 2014; Hauner et al., 2008; Mikolajczak et al., 2010; Nater et al., 2010; Steptoe et al., 2008; van Santen et al., 2011). Another potential cause of variability in results is a uniform reliance on self-rated personality and trait affect, which are subject to potential sources of inaccuracy, such as presentation biases, deficiencies of introspection, and defensive self-appraisal (see Vazire, 2010). In this regard, peer ratings provide a complementary approach to personality assessment and, elsewhere, have been shown to predict behavioral and health outcomes independently of self-reported traits (e.g. Connelly and Ones, 2010). Alternatively, including informant-ratings along with self-reports can enhance reliability of measurement through aggregation of multiple indicators (see McDonald, 2008).

Informed by the foregoing methodological considerations relating to sampling procedures, cohort size, participant age, and informant source, the purpose of the present study was to further investigate the relation of trait emotionality to metrics of HPA activity. Specifically, we use structural equation modeling (SEM) here to examine associations of latent positive and negative emotionality, as derived from both self- and informant-reported traits of extraversion, neuroticism, and positive and negative affect, with three common indices of HPA activity (diurnal slope, awakening response, total cortisol output). In addition, cortisol indices were calculated from multiple daily samples obtained on a large midlife study cohort and collected on multiple days.

2. Methods

2.1. Participants

Participants (N = 490) were drawn from the Adult Health and Behavior Project – Phase 2 (AHAB-II), a study of risk factors for heart disease in midlife adults. Our sample is derived from participants who completed all phases of the AHAB-II protocol. AHAB-II participants were recruited between February 2008 and October 2011 through mass mailings of recruitment letters to individuals randomly selected from voter registration and other public domain lists. All participants were between 30 and 54 years of age and employed at least 25 h per week. During screening, volunteers provided sociodemographic and substance use information. Among other assessments, medical history and detailed listing of all prescription and non-prescription medications and supplements were reviewed by a study nurse, and anthropometric measurements (e.g. height, weight) were obtained. The following exclusion criteria were applied: (a) history of cardiovascular disease, schizophrenia or bipolar disorder, chronic hepatitis, renal failure, major neurological disorder, lung disease requiring treatment, or stage 2 hypertension (SBP/DBP $\geq$ 160/100); (b) cancer if requiring treatment in the past 12 months, (c) high alcohol consumption ($\geq$5 portions 3–4 times per week); (d) use of fish-oil supplements (because of the requirements for an AHAB-II substudy); (e) use of insulin, glucocorticoid, antiarrhythmic, antihypertensive, lipid-lowering, psychotropic, or prescription weight-loss medications; (f) pregnancy; or (g) shift work schedules. The AHAB-II protocol was approved by the University of Pittsburgh Institutional Review Board and informed consent was obtained at enrollment.

2.2. Measures

2.2.1. Trait measurements

Self-reported Extraversion and Neuroticism were assessed using the 240-item NEO Personality Inventory – Revised (NEO PI-R; Costa, 2008) and trait positive and negative affect by the Positive and Negative Affect Schedule–Expanded (PANAS-X; Watson et al., 1988). Participants nominated two individuals [spouses/partners (32%), parents (13%), siblings (11%), other close relatives (11%), close friends (27%), other (6%)] to complete corresponding measurements about the participant. Informants were given shorter versions of personality and affect measures phrased in the third person and asked to return these forms in a postage-paid envelope also provided. All participants had at least one informant, and 77% (N = 376) had two informant ratings. Informant-reports of extraversion and neuroticism were obtained from the 60-item NEO Five Factor Inventory (NEO-FFI; Costa and McCrae, 1992), and informant-reported positive and negative affect were derived from the 20-item Positive and Negative Affect Schedule (PANAS; Watson et al., 1988). The NEO is the most prominent measure of the five primary dimensions of personality commonly identified in factor analytic studies of lexically derived trait ratings: Neuroticism, Extraversion, Openness, Conscientiousness, and Agreeableness. On the NEO-PI-R, each domain is indexed by 48 Likert items, and on the NEO FFI, by 12 items each. The PANAS-X and the PANAS are comprised of affect-referent adjectives rated on a 5-point Likert scale indicating the degree to which the participant "generally feels or acts this way on average," and items from the self-reported PANAS-X were identical to those on the informant administered PANAS.

2.2.2. Cortisol

As part of study participation, subjects were asked to collect salivary cortisol samples 5 times per day (upon awakening, 30 min after awakening, 4 and 9 h after awakening, and at bedtime) on three workdays and one non-workday. Participants were prompted by an electronic diary (PDA) to collect each sample by gently chewing on a cotton swab for 2 min, placing the swab into a salivette, and storing the salivette in their refrigerator until their next lab visit. At each collection, participants were prompted to indicate whether (yes/no) they had consumed any food or beverage or taken any over-the-counter medication in the preceding hour. To improve compliance, following each sampling prompt, the PDA displayed a unique 4-digit code that remained on the screen for 5 min, and participants were instructed to copy the code onto the salivette label after collection. Cortisol samples, expressed as nmol/L, were assayed in duplicate using a commercial chemiluminescence immunoassay (IBL-International) with a cortisol-biotin conjugate as a tracer with a sensitivity of 0.43 nmol/L in the laboratory of Dr. Clemens Kirschbaum [Dresden, Germany]. The intra and interassay coefficients of variance for cortisol were below 8%.

2.3. Statistical analysis

2.3.1. Cortisol

Cortisol samples that fell below the lowest reliably detected levels (.3 nmol/L) or outliers above 60 nmol/L (determined from examining preliminary distributions) were excluded. On average, 95% of participants' samples were successfully collected and assayed (median = 95%, range 45–100%). Log transformed cortisol values were used in the calculation of diurnal slope, where a regression line was fitted for each participant, with successive cortisol measurements predicted from hours since awakening (Matthews et al., 2006). In order to account for variation in day length (time from awakening to bedtime), slope values were regressed on day length and the residuals used in analyses. Total cortisol output was expressed as area under the curve (AUC-ground), estimated from raw cortisol values by trapezoidal integration (Pruessner et al., 2003). Raw values were also used to compute a cortisol awakening response (CAR) as percent change in cortisol levels from awakening to 30 min post-awakening. Calculating CAR as the absolute change in cortisol from awakening was highly correlated with the percent change (within-day r's = 0.81–0.83), and substituting this metric for CAR in analyses did not alter any study findings. Cortisol samples not taken within 10 min of the 30-min post-awakening instructions were excluded from CAR calculations, and 30-min samples were excluded from the calculation of diurnal slope and AUC to minimize the influence of the awakening response on these indices. Calculated slope, CAR and AUC values were all normally distributed.

Preliminary analyses showed that for the majority of cortisol samples, cortisol levels on the non-work day correlated less strongly with corresponding samples taken on the three workdays (average $r = 0.22$) than the workday samples correlated with each other (average $r = 0.33$). Similarly, most summary indices (slope, CAR, AUC) calculated on the non-work day correlated less strongly with indices calculated on each of the three workdays (average $r = 0.29$) than indices on workdays correlated with one another (average $r = 0.38$). Additionally, a series of repeated measures Analyses of Variance (ANOVA) showed that, in general, mean cortisol levels were significantly lower on the single non-workday than on each workday, whereas workday values did not differ from each other (see Supplemental Table 1). For this reason, only workday measures of cortisol activity were used in the current analysis, although including the non-workday did not significantly alter study findings.

2.3.2. Main analyses

Data were analyzed using structural equation modeling (SEM) with Mplus 7 (Muthén and Muthén, 2012). Using SEM allowed us to estimate latent affective trait and cortisol factors, in order to enhance reliability of measurement. Distributions of all study variables were examined and found to satisfy assumptions of normality (skewness, kurtosis). Missing data amounts were generally modest and were handled using Full Information Maximum Likelihood (FIML) under the assumption that data were missing at random. We first used confirmatory factor analysis (CFA) to establish a measurement model of study constructs. In this CFA, latent Extraversion/Positive Affect (E/PA) and Neuroticism/Negative Affect (N/NA) factors were estimated using the corresponding self- and informant-reported personality and trait affect measures as observed variables, and each of the three latent cortisol indices (slope, CAR, AUC) were estimated using the three days of measurement as observed variables. In this model all latent factors were allowed to freely correlate. We then estimated a structural model in which latent cortisol indices were simultaneously regressed on latent trait dimensions to examine their unique associations with each trait emotionality factor. Because sex differences have been reported previously on trait measures of Extraversion and Neuroticism, as well as in HPA activity, (Weisberg et al., 2011; Burns and Machin, 2010; Kunz-Ebrecht et al., 2004), we entered sex as a covariate along with age and race, and in secondary analyses, tested for sex-dependent interactions. Multiple alternative fit indices were used to evaluate model fit, including RMSEA (values <0.05 indicating good fit), CFI and TLI (values of 0.95 and greater indicating good fit), and SRMR (values <0.05 indicating good fit; Brown, 2014) because the chi-square test of model fit is sensitive to negligible sources of ill fit in large samples.

3. Results

3.1. Participant characteristics

Participants in our sample were 43 years of age on average, 54% female, 86% white, and had completed an average of 17 years of education. Table 1 shows the mean values of self- and informant-reported E/PA and N/NA ratings, and the mean values of cortisol indices. Hereditary or acquired medical disorders of the HPA axis were not reported by any study participants, nor did any participants meet criteria for a current mood disorder evaluated via the Mini International Neuropsychiatric Interview (Sheehan et al., 1998).

3.2. Measurement model

A confirmatory factor analysis (CFA) model consisting of the two latent emotionality factors (E/PA and N/NA) and three latent cortisol factors (slope, CAR, AUC) showed good fit to the data ($\chi^2_{(200)} = 278.38$, $p = 0.0002$; RMSEA = 0.028, 90% CI = 0.020–0.036; CFI = 0.973, TLI = 0.963, SRMR = 0.042). Latent E/PA was derived from self- and informant-reported extraversion and positive affect, N/NA from self-and informant reported neuroticism and negative affect, and slope, CAR and AUC were derived from respective individual measures of each on the three days of measurement. Factor loadings for all latent variables were significant ($p < 0.001$) and are displayed in Table 2. Residual variances from E/PA and N/NA indicators were permitted to correlate within informant type, as were within-day correlations of cortisol metrics (Table 3).

3.3. Structural model

As shown in Fig. 1, greater latent E/PA associated with a steeper diurnal cortisol slope ($\beta = -0.19$, $p = 0.02$) and smaller awakening

Table 1
Descriptive characteristics of study variables.

Affect Measures				
	Negative affect		Positive affect	
	Mean ± SD	Min; Max	Mean ± SD	Min; Max
Self-report	15.45 ± 5.92	10.00; 39.00	34.05 ± 5.92	15.00; 50.00
Informant-report 1	16.89 ± 6.30	10.00; 42.00	37.73 ± 6.24	14.00; 50.00
Informant-report 2	15.83 ± 5.68	10.00; 43.00	38.26 ± 5.78	19.00; 50.00

Personality Measures				
	Neuroticism		Extraversion	
	Mean ± SD	Min; Max	Mean ± SD	Min; Max
Self-report	74.98 ± 22.31	24.00; 147.00	114.31 ± 19.68	40.00; 162.00
Informant-report 1	16.22 ± 9.09	0.00; 45.00	30.59 ± 6.95	6.00; 48.00
Informant-report 2	15.06 ± 7.51	0.00; 42.00	31.49 ± 6.82	11.00; 45.00

Cortisol Indices						
	CAR (Δ from awakening)		Slope (Δ nmol/hour)		AUC (nmol/L)	
	Mean ± SD	Min; Max	Mean ± SD	Min; Max	Mean ± SD	Min; Max
Day 1	0.63 ±.0.83	−0.61; 4.20	−0.04 ± 0.02	−0.08;0.03	7.21 ± 2.52	1.13; 16.16
Day 2	0.63 ± 0.88	−0.87; 4.32	−0.04 ± 0.02	−0.08;0.04	7.40 ± 2.45	2.02; 15.70
Day 3	0.60 ± 0.90	−0.92; 4.60	−0.04 ± .04	−0.08;0.02	7.70 ± 2.91	0.53; 19.99

CAR: cortisol awakening response, AUC: area under the curve.

Table 2
Standardized factor loadings and standard errors (SE) for latent variables.

Positive Emotionality			Negative Emotionality			Slope			CAR			AUC		
Variable	Estimate	SE	Variable	Estimate	SE	Variable	Estimate	SE	Variable	Estimate	SE	Variable	Estimate	SE
PA_{self}	0.40	0.05	NA_{self}	0.46	0.05	$Slope_{Day1}$	0.56	0.05	CAR_{Day1}	0.48	0.07	AUC_{Day1}	0.66	0.04
PA_{inf1}	0.47	0.05	NA_{inf1}	0.52	0.05	$Slope_{Day2}$	0.58	0.05	CAR_{Day2}	0.60	0.07	AUC_{Day2}	0.70	0.04
PA_{inf2}	0.47	0.05	NA_{inf2}	0.50	0.06	$Slope_{Day3}$	0.63	0.05	CAR_{Day3}	0.54	0.06	AUC_{Day3}	0.72	0.04
E_{self}	0.74	0.04	N_{self}	0.68	0.05									
E_{inf1}	0.71	0.04	N_{inf1}	0.58	0.05									
E_{inf2}	0.65	0.04	N_{inf2}	0.67	0.05									

PA: positive affect; E: extraversion, NA: negative affect; N: neuroticism, INF: informant, CAR: cortisol awakening response, AUC: area under the curve.

response ($\beta = -0.26$, $p = 0.004$), but was unrelated to AUC ($\beta = 0.14$, $p = 0.08$). In contrast, no indices of cortisol activity associated significantly with the latent N/NA factor (β's = −0.12 to 0.13; p's = 0.10 to 0.53). In order to test whether the effects of E/PA on slope and CAR differed significantly from the modest, but null effects of N/NA on these same indices, we compared the fit of additional models where the paths of E/PA and N/NA to slope and CAR were either fixed to equality or allowed to vary freely. Chi-square difference tests showed effects on the diurnal slope to differ significantly (difference $\chi^2_{(1)} = 8.38$ $p = 0.004$) indicating that E/PA associated more strongly with slope than did N/NA. However, the test for difference was not significant for CAR ($\chi^2_{(1)} = 2.06$ $p = 0.15$).

3.4. Additional self and informant models

We next examined the effects of E/PA on diurnal slope and CAR for self- and informant-reported traits separately, to determine if patterns of association varied by informant type. As a result of collinearity between the E/PA factors ($r = 0.78$), a model estimating self-and informant-reported E/PA simultane-

Table 3
Residual error correlations.

Personality and affect variables (within-informant)											
Self-Report				Informant-report 1				Informant-report 2			
	NA	E	PA		NA	E	PA		NA	E	PA
N	0.55***	−0.24***	−0.26***	N	0.58***	−0.42***	−0.39***	N	0.48***	−0.29***	−0.35***
NA	1.00	−0.12*	−0.04	NA	1.00	−0.32***	−0.25***	NA	1.00	−0.24***	−0.21***
E	–	1.00	0.43***	E	–	1.00	0.42***	E	–	1.00	0.47***

Cortisol indices (within-day)								
Day 1			Day 2			Day 3		
	Slope	AUC		Slope	AUC		Slope	AUC
CAR	0.24***	−0.28***	CAR	0.33***	−0.31***	CAR	0.29***	−0.34***
Slope	1.00	−0.03	Slope	1.00	0.04	Slope	1.00	−0.03

PA: positive affect, E: extraversion, NA: negative affect, N: neuroticism, CAR: cortisol awakening response, AUC: area under the curve ***$p < 0.001$ *$p < 0.05$.

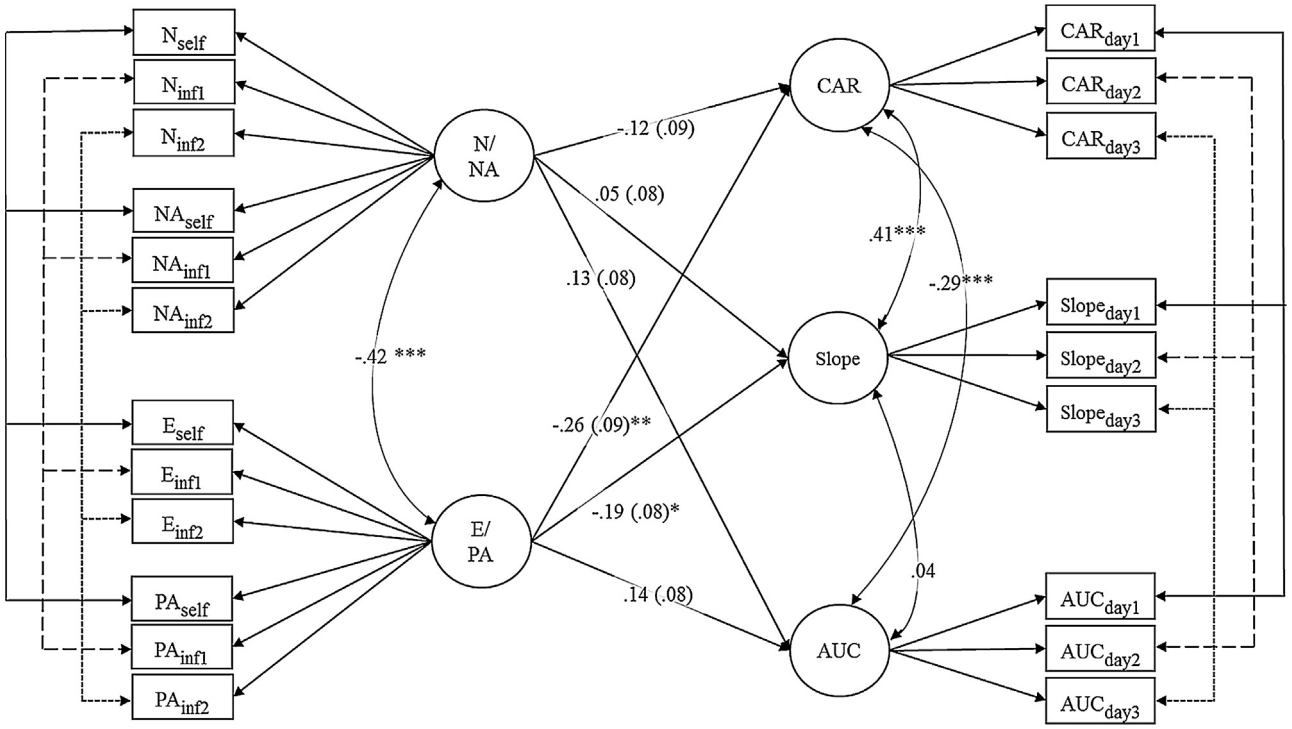

Fig. 1. Regression model predicting cortisol indices from emotionality factors.
Note: Standardized path coefficients (standard errors) reported ***$p < 0.001$ **$p < 0.01$ *$p < 0.05$. Covariates and error variances not displayed to simplify model. N = Neuroticism, NA = Negative Affect, E = Extraversion, PA = Positive Affect, Inf = Informant, CAR = Cortisol Awakening Response, AUC = Area Under the Curve.

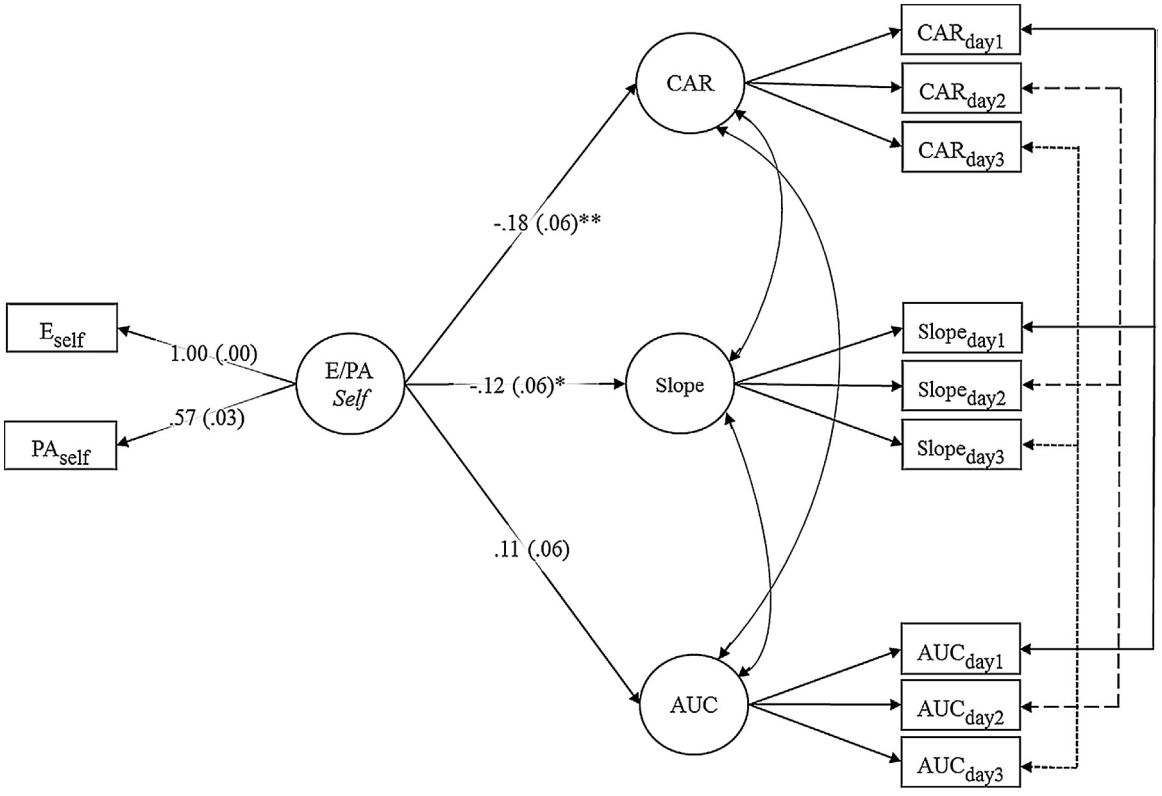

Fig. 2. Regression model predicting cortisol indices from self-reported positive emotionality.
Note: Standardized path coefficients (standard errors) reported **$p < 0.01$ *$p < 0.05$. Covariates and error variances not displayed to simplify model. E = Extraversion, PA = Positive Affect, CAR = Cortisol Awakening Response, AUC = Area Under the Curve.

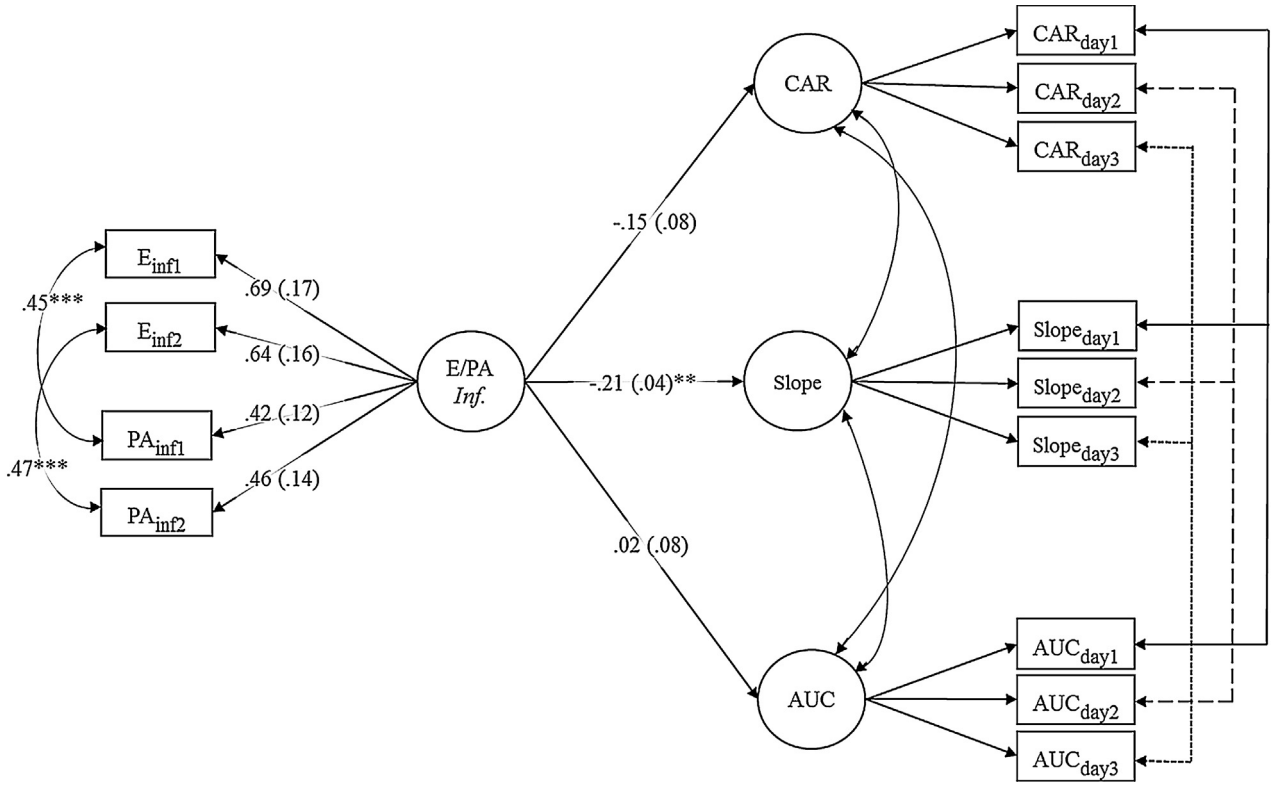

Fig. 3. Regression model predicting cortisol indices from informant-reported positive emotionality.
Note: Standardized path coefficients (standard errors) reported ***$p < 0.01$ **$p < 0.01$. Covariates and error variances not displayed to simplify model. E = Extraversion, PA = Positive Affect, Inf = Informant, CAR = Cortisol Awakening Response, AUC = Area Under the Curve.

ously posed problems with estimation and therefore the two were examined independently. Models reflecting associations of self- and informant-reported E/PA with diurnal slope and CAR are shown in Figs. 2 and 3, respectively. Each model exhibited good fit to the data (self-report $\chi^2_{(54)} = 77.95$, $p = 0.018$; RMSEA = 0.03, 90% CI = 0.01–0.04; CFI = 0.98, TLI = 0.96, SRMR = 0.04; informant-report $\chi^2_{(78)} = 103.61$, $p = 0.028$; RMSEA = 0.026, 90% CI = 0.01–0.04; CFI = 0.98 TLI = 0.97, SRMR = 0.045). Estimates of self- and informant-reported E/PA were similar for both the diurnal slope (self-report $\beta = -0.12$, $p = 0.027$; informant-report $\beta = -0.21$, $p = 0.007$) and CAR (self-report $\beta = -0.18$, $p = 0.005$; informant-report $\beta = -0.15$, $p = 0.083$), suggesting that our results are robust to variation in informant source.[1]

3.5. Secondary analyses

In order to examine possible moderation of our significant results by sex, we used a multi-group model establishing strong measurement invariance with factor loadings and intercepts constrained to equality across the two groups. We then compared models with fixed and free regression paths across groups. These analyses showed that there were no significant differences in model fit for associations of E/PA with diurnal slope or CAR ($\Delta\chi^2_{(2)} = 1.36$, $p = 0.51$). We then tested whether there were any sex differences for all other (non-significant) paths and similarly found that results did not differ by sex ($\Delta\chi^2_{(4)} = 6.33$, $p = 0.18$).

With respect to behaviors proximal to cortisol sampling, the majority of successful collections were not preceded within one hour by intake of food (75%), beverages (88%), or over-the-counter medications (99%). Preliminary analyses showed these variables largely unrelated to subsequent cortisol levels on a sample-by-sample basis (r's −0.09 to 0.13) or to same-day cortisol metrics (i.e. slope, CAR, AUC; r's −0.09 to 0.11). In addition, entering these variables as further covariates in secondary analyses did not alter study findings. Although time of awakening can affect cortisol measurements, including a latent wake time covariate (derived from the three days of measurement) also did not alter findings reported in any of the preceding analyses.

4. Discussion

The current study examined associations of latent dispositional emotionality with common indices of aggregated HPA activity. Results showed greater E/PA related to a steeper decline in cortisol levels across the day, as well as a larger cortisol awakening response, whereas N/NA did not associate with HPA activity. While previous investigations have reported mixed associations of trait affect and these personality dimensions with various cortisol assessments, the majority of these studies utilized limited cortisol sampling protocols that entailed few (often single) cortisol samples or days of measurement (e.g. Dettling et al., 1999; Gerritsen et al., 2009; Polk et al., 2005; Portella et al., 2005; Schommer et al., 1999; Turner-Cobb et al., 2008; van Santen et al., 2011). Diurnal variation can significantly influence cortisol values obtained at single points in time, and variance estimates from multilevel models suggest that at least four samples per day are needed to optimize estimation of total output and diurnal slope (Hruschka et al., 2005). In addition, significant day-to-day variation argues against measurements restricted to a single day, with results of some studies suggesting that at least 3 sampling days are needed to estimate cortisol activity reliably (e.g. Kraemer et al., 2006). Here, HPA indices were derived from cortisol samples obtained at five times on each

[1] Restricting all analyses to the self-reported NEO-PI-R items corresponding to the informant-reported NEO-FFI did not significantly alter results.

of three days, and our results are largely in line with the few prior investigations employing more thorough cortisol sampling procedures that showed: (a) greater happiness (a dimension of positive affect) associated with a smaller CAR (Steptoe et al., 2007); and (b) an absence of association of negative affect with AUC (Nater et al., 2010) or of neuroticism with AUC or CAR (Hauner et al., 2008). On the other hand, inconsistencies among studies with more robust cortisol sampling procedures remain, with three studies reporting results contrary to ours [i.e., directionally opposite associations of extraversion with CAR (Hauner et al., 2008), associations of neuroticism with diurnal slope (Hauner et al., 2008) and AUC (Nater et al., 2010), and of positive affect with AUC (Steptoe and Wardle, 2005)]. These differences of outcome in relation to CAR and AUC could conceivably be attributed to other methodological discrepancies. For instance, Steptoe and Wardle (2005), and Nater et al. (2010) aggregated momentary measures of state affect across the day to derive a generalized index, whereas we measured E/PA and N/NA using standard dispositional trait instruments. In addition, Hauner et al. (2008) examined associations of personality and cortisol in adolescents, and while it is unclear how developmental processes might influence these particular associations (Dockray and Steptoe, 2010), some evidence suggests that associations of affect and cortisol activity may vary over the life course (e.g. Kudielka et al., 2004). Thus, our findings are generally consistent with the few studies that have examined associations of HPA metrics with trait affect and personality measured in adulthood and used multiday cortisol sampling.

4.1. Positive emotionality

Our results showed that higher latent E/PA associated with a steeper diurnal slope and smaller cortisol awakening response. Regarding the former, a steep decline in cortisol levels over the day is thought to reflect normative HPA activity, whereas a flatter diurnal slope is considered maladaptive, associating with a number of negative health outcomes such as coronary artery calcification, mortality among cancer patients, and all-cause cardiovascular mortality (Kumari et al., 2010; Matthews et al., 2006; Sephton et al., 2000). Moreover, greater positive affect is increasingly recognized as conducive to good health (e.g. Chida and Steptoe, 2008), and together, these relationships suggest that as an indicator of HPA activity, the diurnal slope may link greater positive emotionality to better health outcomes. Interpreting E/PA associations with the cortisol awakening response is more ambiguous, however, as less is known about the mechanisms that modulate the cortisol response to awakening (see Fries et al., 2009). Thus, future studies are needed to better inform interpretation of the inverse association of E/PA with the awakening response. Additionally, there is some evidence that affective states associate more consistently with flexibility of the awakening response (e.g. workday/non-workday differences in CAR) than with magnitude, suggesting that traditional metrics of the awakening response may not fully capture its true association with affect (Mikolajczak et al., 2010).

4.2. Negative emotionality

That we did not find associations between negative emotionality and HPA activity was unexpected given that neuroticism underlies a major portion of trait liability to depression (e.g. Kendler et al., 1993) and the extensive literature on altered HPA functioning in this disorder. It may be noted, however, that associations of depression with indices of daily cortisol activity like ours are not always consistent (see Pariante and Lightman, 2008). Reduced feedback inhibition of cortisol release, as indexed by a diminished sensitivity to acute administration of dexamethasone or of dexamethasone plus corticotrophin releasing hormone (CRH), on the other hand, is fairly consistently related to depression. These associations appear to be stronger in more severe forms of depression (e.g. Nelson and Davis, 1997; Zobel et al., 2001), and improvement of depressive symptoms has been accompanied by a normalization of response to dexamethasone challenges (Ribeiro et al., 1993). There is also evidence that higher neuroticism associates with greater cortisol release following dexamethasone administration, suggesting that negative affectivity may be more closely tied to decreased glucocorticoid receptor sensitivity than to indices of diurnal cortisol release (Zobel et al., 2001; but see also McCleery and Goodwin, 2001). At the same time, structural models of psychopathology suggest that depression is differentiated from other affective disorders by its association with low positive affect (Brown et al., 1998), which would, in turn, tend to reconcile our findings with reported evidence linking depression with HPA activity. Alternatively, like cortisol, positive (but not negative) affect has a diurnal pattern, raising the possibility that diurnal variation in PA may be entrained to diurnal variation in cortisol (Miller et al., 2015).

4.3. Conclusion

The results of this study should be interpreted in light of several limitations. First, although HPA activity was treated as the predicted variable in this study, it is at least conceivable that variation in the diurnal slope of daytime cortisol decline or in the awakening response might instead influence positive or negative emotionality. In addition, our sample is relatively homogeneous (i.e. middle-aged, predominantly white, well-educated), thus limiting the generalizability of our findings to a broader population. Despite these limitations, this study is the first to examine associations of HPA activity with multi-informant assessments of emotionality using both trait affect and related personality constructs. We also used more extensive sampling of cortisol than much of the prior literature in order to obtain a more reliable estimate of HPA activity, and with a relatively large sample, were better powered to detect associations of emotionality with cortisol metrics. Our results confirm an association of positive (but not negative) emotionality with two prominent indices of aggregated HPA activity – the diurnal cortisol slope and the cortisol awakening response (Dockray and Steptoe, 2010). These results suggest that positive emotionality may be more closely associated with indices of diurnal cortisol dynamics than negative emotionality.

Conflicts of interest

None.

Authors' contributions

K.G.M., A.G.C.W., L.M.P., and C.K. analyzed the data; S.B.M., T.W.K., A.L.M., M.F.M., and B.A.A. designed and performed the research; K.G.M., A.G.C.W., and S.B.M wrote the paper.

All authors have reviewed and approved this manuscript.

Role of the funding source

The funders of this study (NIH grant P01HL040962) had no further role in the study design; data collection, analysis, or interpretation; writing of the manuscript; or in decision to submit for publication.

Acknowledgement

This research was generously supported by NIH grant P01HL040962.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.psyneuen.2016.03.004.

References

Atkinson, B.M., Thomas, S., Fernandez-Enright, F., 2015. The dark triad of personality traits diurnal cortisol variations and sleep-wake cycles. Front. Hum. Neurosci. 53, http://dx.doi.org/10.3389/conf.fnhum, Conference Abstract: ASP2015—25th Annual Conference of the Australasian Society for Psychophysiology.

Brown, T.A., Chorpita, B.F., Barlow, D.H., 1998. Structural relationships among dimensions of the DSM-IV anxiety and mood disorders and dimensions of negative affect, positive affect, and autonomic arousal. J. Abnorm. Psychol. 107, 179–192.

Brown, T.A., 2014. Confirmatory Factor Analysis for Applied Research, 2 ed. Guilford Publishers, New York.

Brummett, B.H., Boyle, S.H., Kuhn, C.M., Siegler, I.C., Williams, R.B., 2009. Positive affect is associated with cardiovascular reactivity, norepinephrine level, and morning rise in salivary cortisol. Psychophysiology 46, 862–869.

Burns, R.A., Machin, M.A., 2010. Identifying gender differences in the independent effects of personality and psychological well-being on two broad affect components of subjective well-being. Pers. Individ. Dif. 48, 22–27.

Chida, Y., Steptoe, A., 2008. Positive psychological well-being and mortality: a quantitative review of prospective observational studies. Psychosom. Med. 70, 741–756.

Clark, L.A., Watson, D., 2008. An Organizing Paradigm for Trait Psychology Handbook of Personality: Theory and Research., pp. 265–286.

Connelly, B.S., Ones, D.S., 2010. An other perspective on personality: meta-analytic integration of observers' accuracy and predictive validity. Psychol. Bull. 136, 1092–1122.

Costa Jr., P.T., McCrae, R.R., 1992. Revised NEO Personality Inventory (NEO-PI-R) and NEO Five-Factor Inventory (NEO-FFI) Professional Manual. Psychological Assessment Resources, Odessa, FL.

Costa, P.T., McCrae, R.R., 2008. The revised NEO personality inventory (NEO-PI-R), The Sage handbook of personality theory and assessment. Personality Measurement and Testing, vol. 2. Sage Publications Ltd., London, pp. 179–199.

Dettling, A.C., Gunnar, M.R., Donzella, B., 1999. Cortisol levels of young children in full-day childcare centers: relations with age and temperament. Psychoneuroendocrinology 24, 519–536.

Doane, L.D., Franz, C.E., Prom-Wormley, E., Eaves, L.J., Mendoza, S.P., Hellhammer, D.H., Lupien, S., Xian, H., Lyons, M.J., Kremen, W., Jacobson, K.C., 2011. Negative emotionality, depressive symptoms and cortisol diurnal rhythms: analysis of a community sample of middle-aged males. Horm. Behav. 60, 202–209.

Dockray, S., Steptoe, A., 2010. Positive affect and psychobiological processes. Neurosci. Biobehav. Rev. 35, 69–75.

Ellenbogen, M.A., Hodgins, S., Walker, C.D., Couture, S., Adam, S., 2006. Daytime cortisol and stress reactivity in the offspring of parents with bipolar disorder. Psychoneuroendocrinology 31, 1164–1180.

Fries, E., Dettenborn, L., Kirschbaum, C., 2009. The cortisol awakening response (CAR): facts and future directions. Int. J. Psychophysiol. 72, 67–73.

Garcia-Banda, G., Chellew, K., Fornes, J., Perez, G., Servera, M., Evans, P., 2014. Neuroticism and cortisol: pinning down an expected effect. Int. J. Psychophysiol. 91, 132–138.

Gerritsen, L., Geerlings, M.I., Bremmer, M.A., Beekman, A.T., Deeg, D.J., Penninx, B.W., Comijs, H.C., 2009. Personality characteristics and hypothalamic-pituitary-adrenal axis regulation in older persons. Am. J. Geriatr. Psychiatry 17, 1077–1084.

Hauner, K.K., Adam, E.K., Mineka, S., Doane, L.D., DeSantis, A.S., Zinbarg, R., Craske, M., Griffith, J.W., 2008. Neuroticism and introversion are associated with salivary cortisol patterns in adolescents. Psychoneuroendocrinology 33, 1344–1356.

Hoyt, L.T., Craske, M.G., Mineka, S., Adam, E.K., 2015. Positive and negative affect and arousal: cross-sectional and longitudinal associations with adolescent cortisol diurnal rhythms. Psychosom. Med. 77, 392–401.

Hruschka, D.J., Kohrt, B.A., Worthman, C.M., 2005. Estimating between- and within-individual variation in cortisol levels using multilevel models. Psychoneuroendocrinology 30, 698–714.

Kendler, K.S., Neale, M.C., Kessler, R.C., Heath, A.C., Eaves, L.J., 1993. A longitudinal twin study of personality and major depression in women. Arch. Gen. Psychiatry 50, 853–862.

Kraemer, H.C., Giese-Davis, J., Yutsis, M., O'Hara, R., Neri, E., Gallagher-Thompson, D., Taylor, C.B., Spiegel, D., 2006. Design decisions to optimize reliability of daytime cortisol slopes in an older population. Am. J. Geriatr. Psychiatry 14, 325–333.

Kudielka, B.M., Buske-Kirschbaum, A., Hellhammer, D.H., Kirschbaum, C., 2004. HPA axis responses to laboratory psychosocial stress in healthy elderly adults, younger adults, and children: impact of age and gender. Psychoneuroendocrinology 29, 83–98.

Kumari, M., Badrick, E., Sacker, A., Kirschbaum, C., Marmot, M., Chandola, T., 2010. Identifying patterns in cortisol secretion in an older population. Findings from the Whitehall II study. Psychoneuroendocrinology 35, 1091–1099.

Kunz-Ebrecht, S.R., Kirschbaum, C., Marmot, M., Steptoe, A., 2004. Differences in cortisol awakening response on work days and weekends in women and men from the Whitehall II cohort. Psychoneuroendocrinology 29, 516–528.

Laceulle, O.M., Nederhof, E., Aken, M.A., Ormel, J., 2015. Adolescent personality: associations with basal, awakening, and stress-induced cortisol responses. J. Pers. 83, 262–273.

Lai, J.C., Evans, P.D., Ng, S.H., Chong, A.M., Siu, O.T., Chan, C.L., Ho, S.M., Ho, R.T., Chan, P., Chan, C.C., 2005. Optimism, positive affectivity, and salivary cortisol. Br. J. Health Psychol. 10, 467–484.

Matthews, K., Schwartz, J., Cohen, S., Seeman, T., 2006. Diurnal cortisol decline is related to coronary calcification: cARDIA study. Psychosom. Med. 68, 657–661.

McCleery, J.M., Goodwin, G.M., 2001. High and low neuroticism predict different cortisol responses to the combined dexamethasone–CRH test. Biol. Psychiatry 49, 410–415.

McCrae, R.R., Costa Jr., P.T., 2003. Personality in Adult- Hood: A Five-factor Theory Perspective, 2nd ed. Guilford Press, New York, NY.

McDonald, J.D., 2008. Measuring personality constructs: the advantages and disadvantages of self-reports, informant reports and behavioral assessments. Enquire 1, 1–18.

Mikolajczak, M., Quoidbach, J., Vanootighem, V., Lambert, F., Lahaye, M., Fillee, C., de Timary, P., 2010. Cortisol awakening response (CAR)'s flexibility leads to larger and more consistent associations with psychological factors than CAR magnitude. Psychoneuroendocrinology 35, 752–757.

Miller, M.A., Rothenberger, S.D., Hasler, B.P., Donofry, S.D., Wong, P.M., Manuck, S.B., Kamarck, T.W., Roecklein, K.A., 2015. Chronotype predicts positive affect rhythms measured by ecological momentary assessment. Chronobiol. Int. 32, 376–384.

Munafo, M.R., Lee, L., Ayres, R., Flint, J., Goodwin, G., Harmer, C.J., 2006. Early morning salivary cortisol is not associated with extraversion. Pers. Individ. Dif. 40, 395–400.

Muthén, L.K., Muthén, B.O., 2012. Mplus User's Guide, 7th. Muthén and Muthén, Los Angeles, CA.

Nater, U.M., Hoppmann, C., Klumb, P.L., 2010. Neuroticism and conscientiousness are associated with cortisol diurnal profiles in adults-role of positive and negative affect. Psychoneuroendocrinology 35, 1573–1577.

Nelson, J.C., Davis, J.M., 1997. DST studies in psychotic depression: a meta-analysis. Am. J. Psychiatry 154, 1497–1503.

Oishi, S., Krochik, M., Roth, D., Sherman, G.D., 2012. Residential mobility, personality, and subjective and physical well-being an analysis fo cortsiol secretion. Soc. Psychol. Personal. Sci. 3, 153–161.

Pariante, C.M., Lightman, S.L., 2008. The HPA axis in major depression: classical theories and new developments. Trends Neurosci. 31, 464–468.

Polk, D.E., Cohen, S., Doyle, W.J., Skoner, D.P., Kirschbaum, C., 2005. State and trait affect as predictors of salivary cortisol in healthy adults. Psychoneuroendocrinology 30, 261–272.

Portella, M.J., Harmer, C.J., Flint, J., Cowen, P., Goodwin, G.M., 2005. Enhanced early morning salivary cortisol in neuroticism. Am. J. Psychiatry 162, 807–809.

Pruessner, J.C., Kirschbaum, C., Meinlschmid, G., Hellhammer, D.H., 2003. Two formulas for computation of the area under the curve represent measures of total hormone concentration versus time-dependent change. Psychoneuroendocrinology 28, 916–931.

Ribeiro, S.C., Tandon, R., Grunhaus, L., Greden, J.F., 1993. The DST as a predictor of outcome in depression: a meta-analysis. Am. J. Psychiatry 150, 1618–1629.

Schommer, N.C., Kudielka, B.M., Hellhammer, D.H., Kirschbaum, C., 1999. No evidence for a close relationship between personality traits and circadian cortisol rhythm or a single cortisol stress response. Psychol. Rep. 84, 840–842.

Sephton, S.E., Sapolsky, R.M., Kraemer, H.C., Spiegel, D., 2000. Diurnal cortisol rhythm as a predictor of breast cancer survival. J. Natl. Cancer Inst. 92, 994–1000.

Sheehan, David V., Lecrubier, Yves, Harnett Sheehan, K., Amorim, Patricia, Janavs, Juris, Weiller, Emmanuelle, Hergueta, Thierry, Baker, Roxy, Dunbar, Geoffrey C., 1998. "The Mini-International Neuropsychiatric Interview (MINI): the development and validation of a structured diagnostic psychiatric interview for DSM-IV and ICD-10.". J. Clin Psychiatry 59, 22–33.

Smyth, J., Ockenfels, M.C., Porter, L., Kirschbaum, C., Hellhammer, D.H., Stone, A.A., 1998. Stressors and mood measured on a momentary basis are associated with salivary cortisol secretion. Psychoneuroendocrinology 23, 353–370.

Steptoe, A., Wardle, J., 2005. Positive affect and biological function in everyday life. Neurobiol. Aging 26 (Suppl. 1), 108–112.

Steptoe, A., Wardle, J., Marmot, M., 2005. Positive affect and health-related neuroendocrine, cardiovascular, and inflammatory processes. Proc. Natl. Acad. Sci. U. S. A. 102, 6508–6512.

Steptoe, A., Gibson, E.L., Hamer, M., Wardle, J., 2007. Neuroendocrine and cardiovascular correlates of positive affect measured by ecological momentary assessment and by questionnaire. Psychoneuroendocrinology 32, 56–64.

Steptoe, A., O'Donnell, K., Badrick, E., Kumari, M., Marmot, M., 2008. Neuroendocrine and inflammatory factors associated with positive affect in healthy men and women: the Whitehall II study. Am. J. Epidemiol. 167, 96–102.

Turner-Cobb, J.M., Rixon, L., Jessop, D.S., 2008. A prospective study of diurnal cortisol responses to the social experience of school transition in four-year-old children: anticipation, exposure, and adaptation. Dev. Psychobiol. 50, 377–389.

Vazire, S., 2010. Who knows what about a Person? The self-other knowledge asymmetry (SOKA) model. J. Pers. Soc. Psychol. 98, 281–300.

Vedhara, K., Tuinstra, J., Miles, J.N., Sanderman, R., Ranchor, A.V., 2006. Psychosocial factors associated with indices of cortisol production in women with breast cancer and controls. Psychoneuroendocrinology 31, 299–311.

Watson, D., Clark, L.A., Tellegen, A., 1988. Development and validation of Brief measures of positive and negative affect: the PANAS scales. J. Pers. Soc. Psychol. 54, 1063–1070.
Watson, D., 2000. Mood and Temperament. Guildford Press, New York.
Weisberg, Y.J., Deyoung, C.G., Hirsh, J.B., 2011. Gender differences in personality across the ten aspects of the big five. Front. Psychol. 2, 178.
Zobel, A.W., Nickel, T., Sonntag, A., Uhr, M., Holsboer, F., Ising, M., 2001. Cortisol response in the combined dexamethasone/CRH test as predictor of relapse in patients with remitted depression. a prospective study. J. Psychiatr. Res. 35, 83–94.
van Eck, M., Berkhof, H., Nicholson, N., Sulon, J., 1996. The effects of perceived stress, traits, mood states, and stressful daily events on salivary cortisol. Psychosom. Med. 58, 447–458.
van Santen, A., Vreeburg, S.A., Van der Does, A.W., Spinhoven, P., Zitman, F.G., Pennix, B.W., 2011. Psychological traits and the cortsiol awakening response: results from the Netherlands Study of Depression and Anxiety. Psychoneuroendocrinology 36, 240–248.