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The Inverse of Psychopathology: A Loreta EEG and Cortisol Examination

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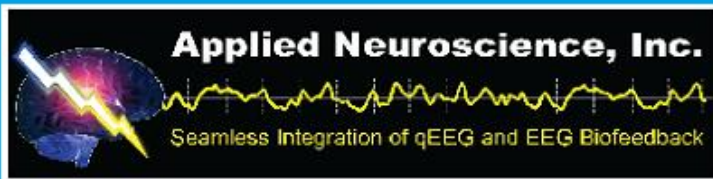
Low resolution electromagnetic tomography (LORETA) electroencephalogram (EEG) was recorded from 63 nonclinical adults (34 female and 29 male) while they completed inventories on self-perception (Self-Perception and Experiential Schemata) and psychological well-being (The Brief Symptom Inventory–18). In addition, salivary samples were collected before and after the self-assessment tasks for cortisol analyses. The statistical analyses revealed a significant decrease in cortisol levels from pretest to posttest self-examination. This decline in salivary cortisol was inversely correlated with greater left-sided than right-sided hemisphere activation. Self-perception and self-in-relation to others predicted resting salivary cortisol levels. These data provide further evidence for the use of LORETA EEG, in particular, as a biological marker for emotional self-regulation.

INTRODUCTION

Under stressful conditions, the hypothalamic-pituitary-adrenal (HPA) axis is activated, and cortisol is an end-product. Cortisol performs a role in the regulation of metabolism by mobilizing energy resources, which helps the organism respond to a potential threat or danger (Dickerson & Kemeny, 2004). Moreover, cortisol aids survival, increases cardiovascular tone, and augments aspects of immunity (Sapolsky, 2000). Cortisol secretion operates in conjunction with the circadian rhythm in humans: Cortisol levels peak early in the morning and continuously decrease during the day (Engeland & Arnhold, 2005). However, metatoxic levels of cortisol can cause damage and death to hippocampal neurons (Bremner, 1999; Sapolsky, 2000; Wolkowitz, Reus, Canick, Levin, & Lupien, 1997), which can have long-lasting deleterious effects on memory consolidation and psychological well-being (for review, see Sapolsky, 2004).

Serum cortisol levels are obtained via blood samples. However, a noninvasive method that is highly positively correlated with serum levels is the examination of cortisol levels in saliva (Umeda et al., 1981). Subsequently, salivary cortisol is frequently used as a biomarker of psychological stress (Hellhammer, Wust, & Kudielka, 2009).

It is well documented that elevated levels of cortisol tend to be associated with increased prefrontal cortex asymmetry, as measured by electroencephalography (EEG) in both animal and human studies on emotional regulation (for review, see Davidson, 2004). For example, Kalin, Larson, Shelton, and Davidson (1998) were among the first neuroscientists to show that fearful temperament in nonhuman primates is associated with increased right frontal brain activity and cortisol levels. Moreover,

Wang et al. (2005) found greater right-sided hemispheric activation was associated with elevated levels of salivary cortisol in response to a mental stressor task. However, Tops, van Peer, Wester, Wijers, and Korf (2006) found cortisol-induction to reduce right frontal cortical activity in eight healthy volunteers. In a recent nonclinical sample, Putnam, Pizzagalli, Gooding, Kalin, and Davidson (2008) investigated the relationship between resting neural activity and diurnal cortisol slope in college students classified as either high or low in anhedonia. Using low-resolution electromagnetic tomography (LORETA), they found a significant negative association between cortisol slope and beta activity in the medial prefrontal cortex (MPFC) region of the left hemisphere. This relationship was found in the control group but absent for the anhedonic group. They concluded that disruptions in MPFC-mediated HPA axis functioning may be indicative of psychopathology.

NEURAL CORRELATES OF SELF-EXAMINATION

To our knowledge, research is scant regarding the neural correlates of brain activation, in particular, as a function of self-examination. A host of neuroimaging studies have investigated aspects of the self using face recognition (e.g., Platek et al., 2006; Uddin, Kaplan, Molnar-Szakac, Zaidel, & Iacoboni, 2005), agency experience (e.g., Farrer & Frith, 2002), and autobiographical memory (e.g., Spreng & Grady, 2010). These tasks tend to activate the cortical midline structures of the brain (for reviews, see Legrand & Ruby, 2009; Northoff & Bermpohl, 2004). However, studies that assess an individual's emotional well-being and perception of self across various life domains while neural activity is continuously recorded are for the most part absent from the literature. EEG recording during personality or cognitive assessments would yield real-time information regarding neural activity during a dynamic psychological phenomenon, thereby rendering a clearer picture of the mind–body connection. The present investigation aims to address this gap in the literature.

From an EEG perspective, resting alpha activity tends to be the focus of many behavioral, cognitive, and personality investigations (Domino et al., 2009; Hewig, Hagemann, Seifert, Naumann, & Bartussek, 2006; Schneider, Graham, Grant, King, & Cooper, 2009; Urry et al., 2004). According to Shagass (1972), EEG alpha activity (8–12 Hz) has been found to be inversely related to cortical activity. Thus, high alpha activity is associated with inhibition or neural deactivation (Worden, Foxe, Wang, & Simpson, 2000). However, the assessment of frequencies across the EEG spectral bands (i.e., 1–30 Hz) would provide a clear picture of brain activation and functional connectivity of cortical structures in reference to a given task or trait. For example, Wacker, Chavanon, and Stemmler (2010) recently reported that increased delta (.05–3.5 Hz) and theta (3.5–7.5 Hz) activity in the anterior cingulate cortex was associated with the personality trait of extroversion. It is becoming clearer that the oscillations between frequency bands play a vital role in cognitive and behavioral processes (Knyazev, 2009). We aim to investigate the phenomenon of self-examination across the EEG spectral power.

We posit that self-examination can be a psychological stressor and a potential threat to one's self-esteem or identity. According to Benschop and Schedlowski (1999), psychological stressors are characterized as having a predominant emotional component. The process of self-examination and reflection often yields emotional fruits of sadness, anxiety, fear, and occasionally joy. According to the integrated specificity model (Dickerson, Gruenewald, & Kemeny, 2004; Sapolsky, 2004), distinct emotions produced distinct physiological outcomes that are influenced by cognitive appraisals. Neuroimaging studies have shown that the brain activation pattern differs based on emotional appraisal (Sutton & Davidson, 1997; Wang et al., 2005). Emerging evidence tends to indicate that the left and right frontal regions of the brain are heavily involved in approach-related and withdrawal-related affect, respectively (for review, see Harmon-Jones, Gable, & Peterson, 2010). For example, Krompinger and Simons (2009), reported that

participants high on depressive symptoma-tology exhibited larger P300 amplitudes in response to negative compared to positive emotional stimuli.

THE PRESENT STUDY

In this present investigation, LORETA EEG (Pascual-Marqui, Michel, & Lehmann, 1994) was used to measure brain activity during the self-examination tasks. LORETA EEG is an inverse solution for estimating cortical electrical current density produced on the scalp. This method provides optimal smoothing to estimate a direct 3D solution for the electrical activity distribution across the cortex (Congedo, Lubar, & Joffe, 2004; Pascual-Marqui et al., 1999). LORETA has received considerable validation from studies combining it with localization methods such as functional magnetic resonance imaging (fMRI; Cannon et al., 2011; Mulert et al., 2004) and positron emission tomography (Oakes et al., 2004).

The goals of the present study were two-fold: (a) to clarify the association between brain activity and salivary cortisol levels as a function of self-examination, and (b) to document the extent to which self-examination (via survey and self-image tasks) produced physiological signs of stress in a nonclinical sample. In an exploratory study (Cannon, Thatcher, Baldwin, & Lubar, 2009), we reported on the utility of LORETA EEG in measuring the 12 brain regions of interest associated with the processing of self-referential information. The present study addresses the neuroendocrine associations with self-examination in a broader context of the stress phenomenon. It was hypothesized that an increased cortisol response (post-self-examination) would be positively associated with greater right-sided hemisphere activation in a nonclinical sample.

METHOD

Participants

Sixty-three college students (34 female, 29 male: M age = 19.28, SD = 2.0, range = 18–31) took part in this investigation. This was a nonclinical sample, and all of the participants were right-handed. The majority of the sample was Caucasian ($n = 52$), and 11 participants were non-White. Data inclusion was based on the length of usable EEG for each file to be analyzed at or greater than 60 s. All participants were recruited from undergraduate psychology classes, and each individual received extra credit for their participation. Exclusion criteria (e.g., head trauma, psychiatric disorder, neurological disorder, substance abuse) were assessed with the standard inventory used in our laboratory. All participants were asked to read and sign the informed consent document, which was approved by the university Institutional Review Board.

Measures

EEG Apparatus. EEG was monitored and stored using Deymed Diagnostics Truscan EEG Acquisition system (Payette, ID) with a band pass set at 0.5–64.0 Hz at a rate of 256 samples per second. During the recordings, real-time impedance for electrodes and reference leads were available on the screen. The Truscan system utilizes fiber optics for the EEG recordings. Electro-Caps (Electro-Cap International, Eaton, OH; see Blom & Anneveldt, 1982) were used for the positioning of the electrodes, according to the International 10–20 method of electrode placement (Jasper, 1958). After fitting the caps, each electrode site was injected with electrogel. The impedances between individual electrodes and each ear were less than 10 KΩ. Using a linked-ear reference, EEG was recorded from the following locations: frontopolar (Fp1, Fp2), medial frontal (F3, F4), frontolateral (F7, F8), frontocentral (FC3, FC4), central (C3, C4), centroparietal (CP3, CP4), parietal (P3, P4), anterior temporal (T3, T4), posterior temporal (T5, T6), and occipital (O1, O2). To minimize eye-movement during the EEG data acquisition, a 15.4-in. monitor (Dell, Nashville, TN) was placed in a position so that the participant could look in a downward direction at the monitor.

Self-Perception and Experiential Schemata Assessment (SPESA). The SPESA was design-ed to detect negative, average or positive

perceptions of self and self-in-experience (ES) across three life domains: childhood, adolescence, and adulthood (Cannon, Lubar & Baldwin, 2008). This instrument taps into endogenous and exogenous experiences of an individual with respect to emotional abuse, self-efficacy, self-image, and self in relation to others. There are 45 items, and each domain consists of 15 items. Respondents were asked to indicate which of the four response options (A–Happy to D–Traumatic) best described their feelings with respect to each of the items (e.g., ''I feel that my childhood was'' or ''I feel that my adult life is''). The items were scored (2, 1, −1, and −2) and summed for each life domain. The SPESA possesses additive properties such that the sum of the three life domain equates to a total score representing negative, average to positive perception of self, and self-in-experience. Higher scores indicate a more positive perception of self. The reliability analysis yielded significant interitem correlations between domains tested (child/adol = .798; child/adult =.516; adol/adult =.590) in cohorts of 56 and 136 nonclinical adults. The results of the two-way random effects model with an internal consistency definition provided an intraclass correlation coefficient of .81 for average measures (Cannon et al., 2008).

Brief Symptom Inventory–18 (BSI–18). The BSI–18 (Derogatis, 2000) is a brief, highly sensitive self-report system inventory designed to screen for psychological distress and psychiatric disorders in medical and community populations. This is an 18-item survey in which respondents were asked to indicate on a 5-point scale, ranging 0 (*not at all*) to 4 (*extremely*), to what degree they have been troubled by symptoms (e.g., ''Feeling tense or keyed up,'' ''Feeling fearful'') during the past week. The BSI–18 includes three subscales: Anxiety, Depression, and Somatization. Scores for each subscale are summed, and a Global Symptom Index is derived by summing across scales. Higher scores indicate higher levels of symptom severity. Cronbach's alphas for the BSI–18 range from .74 to .89, respectively (Derogatis, 2000).

Salivary Cortisol and Analysis. Participants were instructed to rinse their mouths with water prior to the collection of saliva samples, in order to avoid possible contamination from food or drink. All participants expectorated into a sanitized 50 ml collection tube once per minute over a 3-min period (Navazesh, 1993). The samples were centrifuged for 5 min. Each sample was then alloquated into a microtube and stored at − 70°C for subsequent analysis. The total time between pretest and posttest salivary cortisol collection was approximately 40 min.

The supernatant was analyzed for total cortisol concentration using the High Sensitivity Salivary Cortisol Enzyme Immunoassay Kit (Salimetrics Inc., State College, PA). This assay can detect cortisol levels from 0.003 μg/dl to 3.0 μg/dl. The samples were run in duplicate, and cortisol concentrations were read from a standard curve generated by the Ascent Software program (Thermo Labsystems, Vantaa, Finland) for microplate readers.

Procedures

Each participant entered the laboratory at their scheduled time, and they signed the informed consent document prior to data collection. The participants were asked to render a saliva sample for cortisol analysis while sitting in a comfortable chair. Once the sample was collected, the participant was escorted to the experimental room. A digital photograph was taken of each participant's face and then transferred to the computer image interface. After sitting in the comfortable chair, participants were informed that they would be asked to give a verbal response to survey items on the monitor during EEG recording. Participants were then prepared for EEG data collection. After capping, the participants were instructed to limit their eye, tongue, neck, and jaw movements, in order to reduce artifacts in the recording. All participants were encouraged to relax as much as possible during the recordings. The EEG preparation took approximately 10 min.

For all participants, 4-min eyes-closed baselines (ECB) and eyes-opened baselines

(EOB) were obtained. During the EEG recording, they completed the assessment instruments and viewed their digital photograph of self. This process took approximately 12 min to complete. The instruments were presented in Microsoft PowerPoint presentation software via the computer with dual monitors. All participants were asked to make a verbal response to each item that best reflected their experiences. The slide exposure lasted 8 s for each survey item and 1.5 min for the photograph. Participant responses were marked within the EEG record by the research assistant using the computer function keys. Occasionally, the EEG recording was stopped due to excessive bodily movement. At that point, the participant was admonished to relax and refocus. These segments were removed from the statistical analyses.

Upon completion of all EEG measures and the removal of electrodes, participants were asked to complete the open-ended subjective report regarding their thoughts during the self-image condition. Finally, the second saliva sample was collected after the completion of the subjective report. All measures were collected between the hours of 10:00 a.m. and 1:00 p.m. during the week. On average, the total time for the completion of this study was 45 min.

Data Reduction and Analyses

The EEG data were cleaned for gross artifacts (e.g., eye blinks, teeth clenching, and neck movements) using the Truscan Explorer, and the EEG stream was edited using Eureka 3 software (Nova Tech EEG, Inc., Mesa, AZ). Only 60 s or more of useable EEG data were included in the statistical analyses for all conditions (EOB, ECB, and self-referential tasks). Four to 6 s of EEG prior to the participant's response to the survey items were extrapolated. Fourier cross-spectral matrices were then computed and averaged over 75% of the overlapping 4-s artifact-free epochs. This resulted in one cross-spectral matrix for each participant per discrete frequency. These cross-spectral matrices constitute the input for LORETA estimation in the frequency domain. More

specifically, LORETA was used to compute the intracerebral electrical sources underlying EEG activity recorded at the scalp (Pascual-Marqui et al., 1999). The EEG data were analyzed utilizing the following frequency domains: Delta (0.5–3.5 Hz), Theta (3.5–7.5 Hz), Alpha 1 (7.5–10.0 Hz), Alpha 2 (10.0–12.0 Hz), and Beta (12.0–32.0 Hz).

The LORETA solution space is restricted to the cortical gray matter in the digitized Montreal Neurological Institute atlas with 6,239 voxels at 5 mm spatial resolution (Pascual-Marqui, 2002). The average common reference was computed prior to the LORETA estimations. LORETA generates statistical maps modeling distribution currents of brain activity (Frei et al., 2001; Holmes, Brown, & Tucker, 2004). This procedure generates a 3D LORETA image for each participant for each frequency.

To compare the current source density amplitude between conditions (e.g., EOB and ECB), voxel-by-voxel t tests were computed for each frequency band-pass region. A threshold of significance was then computed by the t-sum method. A linear mixed model with repeated measures was then utilized to assess the differences in current source density levels in the brain as a function of EEG conditions. A log transformed file was generated, which contained the average current source density across multiple EEG segments for all participants for each region of interest. This normalization procedure removes participant-to-participant global variations and facilitates mean regional differences within the brain (Sherlin et al., 2007).

A randomization procedure was utilized to evaluate the correlations between the cortisol change scores (differences between pretest and posttest measures) and the estimated neural generators of EEG. The cortisol change scores were entered into a text file. This file was regressed onto the difference between the activation tasks (survey completion and image assessment) and EOB across the entire neocortical volume of 6,329 voxels. From this procedure, tomographic maps of the significant correlations between EEG frequencies and

TABLE 1. Means and Standard Deviations for Study Variables

Variables	M	SD
Som	2.03	2.32
Dep	3.35	3.00
Anx	2.91	2.44
GSI	8.30	5.81
SPESA-Child	21.00	10.08
SPESA-Adol	18.06	5.86
SPESA-Adult	20.92	7.46
SPESA-Tot	59.98	19.19
Pre-Cort	0.18**	0.11
Post-Cort	0.14**	0.07

Note. $N = 63$. Som = Somatization subscale; Dep = Depres-Depression subscale; Anx = Anxiety subscale; GSI = Global Severity Index; SPESA = Self-Perception and Experiential Schemata Assessment; Pre-Cort = Pretest cortisol; Post-Cort = Post-test cortisol.
$^{**}p < .01$.

cortisol levels were generated. The data were then subjected to randomization and permutation test to control for the family-wise error rate in multiple hypothesis testing (Edgington, 1987; Good, 1993).

RESULTS

The data were analyzed using the SAS 9.13 (SAS Institute Inc., Cary, NC) and SPSS 16.0 for Windows (SPSS Inc., Chicago, IL). The significance level was set at .05 for all data except the EEG voxel-by-voxel comparisons. Statistical significance was set at .01 for these comparisons in order to reduce error from multiple testing. Table 1 shows the means and standard deviations for the study variables in this investigation. Salivary cortisol changes from pretest to posttest were assessed using a student t-test analysis. A Pearson product moment correlation was

TABLE 2. Correlation Matrix for Study Variables

Variables	SPESA	BSI	Pre-Cort	Post-Cort
SPESA	—	−.097	−.260*	−.103
BSI	—	—	−.078	−.029
Pre-Cort	—	—	—	.699**
Post-Cort	—	—	—	—

Note. $N = 63$. SPESA = Self-Perception and Experiential Schemata Assessment; BSI = Brief Symptom Inventory–18; Pre-Cort = Pretest cortisol; Post-Cort = Posttest cortisol.
$^*p < .05$. $^{**}p < .01$.

TABLE 3. Regression Analyses for Cortisol Change Levels Predicted by Self-Perception Variables

Variables	B	SE (B)	β	R^2
SPESA child	.003	.001	.363**	.298**
SPESA adol	−.007	.002	−.482**	
SPESA adult	−.003	.002	−.283*	
BSI soma	−.002	.006	−.045	
BSI dep	−.002	.003	−.078	
BSI anx	−.002	.005	−.074	

Note. $N = 63$. SPESA = Self-Perception and Experiential Schemata; adol = Adolescence; BSI = Brief Symptom Inventory–18; soma = Somatatization; dep = Depression; anx = Anxiety.
$^*p < .05$. $^{**}p < .01$.

performed on the data to determine relationships between self-perception and psychological distress measures (see Table 2). Regression analyses were used to examine the predictive power of our self-examination tasks (SPESA, BSI-18, and self-image) on cortisol levels (see Table 3). Table 4 represents the voxel-by-voxel comparisions for each self-examination task to EOB.

Self-Examination and Cortisol Levels

It was hypothesized that self-examination was stressful and that participants would show an increased salivary cortisol response to these task. The analysis yielded an unexpected but significant decrease in salivary cortisol from pretest to posttest, $t(61) = 3.94$, $p < .01$, measures. Therefore, our hypothesis was not confirmed. The self-specific examination tasks were not stressful for this nonclinical sample. However, there was a significant inverse relationship between pretest resting cortisol levels and overall self-perception as measured by SPESA ($r = −.260$, $p < .05$). Thus, a more negative self-perception was associated with higher resting cortisol levels.

EEG and Cortisol Levels

To examine the relationship between EEG and salivary cortisol as a function of self-examination, these data were subjected to a Spearman's rank correlation (rho). Figures 1 to 3 reflect the horizontal view of the brain with the significant correlation analyses of the cortisol decrease with their

TABLE 4. Results for Voxel-by-Voxel Comparisons for Each Task Condition to Eyes-Open Baseline

| Frequency	Brodmann area	Hemisphere	t Value	p
SPESA > EOB				
Delta	BA 6, middle frontal gyrus	R	3.15	.002
Alpha 1	BA 13, insular cortex	L	3.19	.002
	BA 7, precuneus	R	2.29	.025
Alpha 2	BA 8, superior frontal gyrus	R	2.86	.005
Beta	BA 46, middle frontal gyrus	L	4.15	.000
BSI > EOB				
Delta	BA 32, anterior cingulated	R	3.32	.001
Theta	BA 10, middle frontal gyrus	R	2.25	.028
Alpha 1	BA 19, cuneus	R	2.68	.009
Alpha 2	BA 40, inferior parietal lobe	R	2.77	.007
	BA 11, superior frontal gyru	R	3.23	.001
Beta	BA 9, middle frontal gyrus	R	3.24	.001
Self-image > EOB				
Delta	BA 39, superior temporal gyrus	R	2.56	.012
	BA 20, uncus	R	2.65	.010
Theta	BA 11, middle frontal gyrus	L	2.11	.038
	BA 6, middle frontal gyrus	L	3.04	.003
Alpha 1	BA 9, middle frontal gyrus	R	2.35	.022
	BA 23, precuneus	M	2.42	.018
Alpha 2	BA 19, fusiform gyrus	L	2.79	.007
Beta	BA 30, posterior cingulated	M	3.11	.002
	BA 11, superior frontal gyrus	L	3.30	.001

Note. $N = 63$.
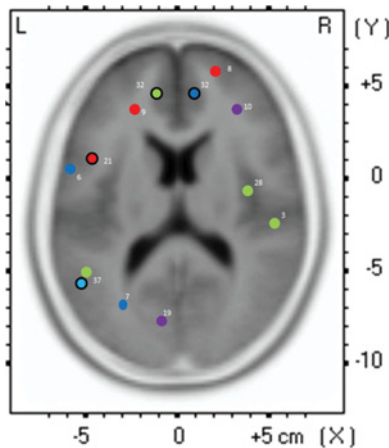
FIGURE 1. Self-Perception and Experiential Schemata Assessment and cortisol map. *Note.* This is a horizontal view of the brain at z-plane = 15. In the image are regions showing a positive or negative association with the postassessment/EEG cortisol decrease. The colors represent the frequency domains: blue = delta, red = theta, green = alpha 1, purple = alpha 2 and aquamarine = beta. The black circular enclosure = negative association with cortisol decrease. The numbers represent Brodmann area. The regions are approximated for 2-D rendering. The regions shown in the map are the results of the correlation analysis of the cortisol decrease with the respective activation map with $p < .05$. (Color figure available online.)

FIGURE 2. Brief Symptom Inventory and cortisol map. *Note.* This is a horizontal view of the brain at z-plane = 15. In the image are regions showing a positive or negative association with the postassessment/EEG cortisol decrease. The colors represent the frequency domains: blue = delta, red = theta, green = alpha 1, purple = alpha 2 and aquamarine = beta. The black circular enclosure = negative association with cortisol decrease. The numbers represent Brodmann area. The regions are approximated for 2-D rendering. The regions shown in the map are the results of the correlation analysis of the cortisol decrease with the respective activation map with $p < .05$. (Color figure available online.)
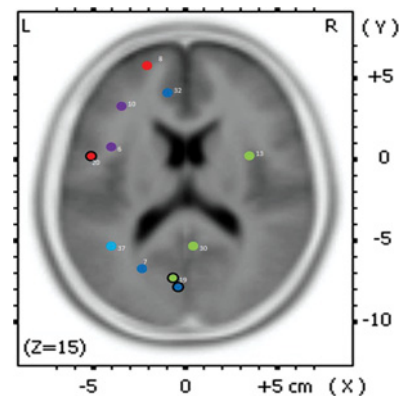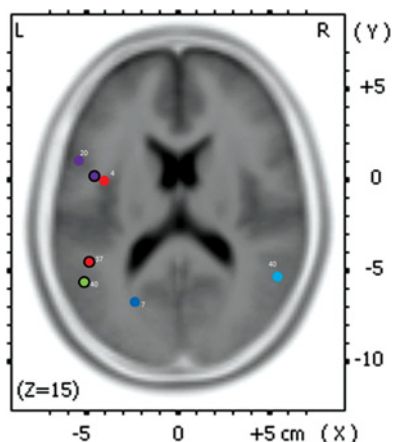
FIGURE 3. Self-image and cortisol map. *Note.* This is a horizontal view of the brain at z-plane = 15. In the image are regions showing a positive or negative association with the postassessment/EEG cortisol decrease. The colors represent the frequency domains: blue = delta, red = theta, green = alpha 1, purple = alpha 2 and aquamarine = beta. The black circular enclosure = negative association with cortisol decrease. The numbers represent Brodmann area. The regions are approximated for 2-D rendering. The regions shown in the map are the results of the correlation analysis of the cortisol decrease with the respective activation map with $p < .05$. (Color figure available online.)

respective activation map for each EEG condition and frequency ($p < .01$, $\rho > .40$). With regard to the self and self-in-experience (SPESA) examination task, increased activation in the left hemisphere was correlated with cortisol decline at the following sites: premotor cortex (BA 6, delta), precuneus (BA 7, delta), dorsolateral prefrontal cortex (BA 9, theta), fusiform gyrus (BA 37, alpha 1), and cuneus (BA 19, alpha 2). For the right hemisphere, increased activation was correlated with cortisol decline at the frontal eye field region (BA 8, theta), primary somatosensory cortex (BA 3, alpha 1), posterior cingulate (PC; BA 28, alpha 1), and frontopolar area (BA 10, alpha 2).

With regard to psychological distress, cortical excitability in the left hemisphere was correlated with cortisol decline at the following sites: precuneus (BA 7, delta), anterior cingulate (BA 32, delta), frontal eye field (BA 8, theta), part of the cingulate cortex (BA 30, alpha 1), premotor cortex (BA 6, alpha 2), frontopolar area (BA 10, alpha 2), and fusiform gyrus (BA 37, beta). For the right hemisphere, increased activation was correlated with

cortisol decline at the insular cortex (BA 13, alpha 1).

For the self-image condition, where participants viewed a digital photograph of themselves, cortical excitability in the left hemisphere was correlated with cortisol decline at the precuneus (BA 7, delta), primary motor cortex (BA 4, theta), and inferior temporal gyrus (BA 20, alpha 2). With regard to the right hemisphere, cortisol decline was correlated with increased activation in the beta frequency at BA 40 (supramarginal gyrus).

Regression Analysis and Subjective Report

Results of the regression analysis are displayed in Table 3. Self-perception as measured by SPESA was a significant predictor of salivary cortisol decline across all three life domains: childhood ($\beta = 0.36$, $t = 2.60$, $p = .01$), adolescence ($\beta = -.48$, $t = -3.05$, $p = .03$), and adulthood ($\beta = -.28$, $t = -1.93$, $p = .05$). However, psychological distress as measured by somatization, depression, and anxiety did not explain any additional variance in cortisol levels.

The subjective reports were open-ended responses to gauge participants' thought while viewing their own image on the screen. All reports were rated by three independent raters for positive/neutral or negative content. Agreement between raters was assessed using a two-way random effects model with an absolute agreement definition. Differences regarding the frequency of positive or negative responses were assessed using a chi-square analysis. Ninety percent ($n = 57$) of the participants viewed themselves in a positive/neutral manner, whereas 10% of participants ($n = 6$) endorsed a negative self-image. This difference was significant, $\chi^2 = 41.49$, $p < .01$.

DISCUSSION

Self-referential processing has garnished substantial interest within the neuroimaging field (Damasio, 2003; Gusnard, 2005; Northoff & Bermpohl, 2004). In the present study, we investigated the effects of self-examination

regarding perception of self, self-in-relation to others, and emotional well-being on brain activation and salivary cortisol levels in a nonclinical college student sample. EEG was continuously recorded during the self-examination tasks (SPESA, BSI-18, & self-image) in order to better assess the relationships between cortical excitability and self-perception. We posit that self-examination is a stressor that can produce elevated levels of cortisol. It was hypothesized that an increased salivary cortisol response (posttask) would be positively associated with greater right-sided hemisphere activation. We found greater activation in the left hemisphere of the brain, and it was inversely related to salivary cortisol levels. Moreover, the self-examination tasks did not produce an elevated cortisol response. Salivary cortisol levels were significantly lower at posttest compared to pretest resting values. Therefore, our hypothesis was partially confirmed.

Self-Examination as Stress

It is well documented that the evaluation of oneself across social and emotional constructs may harbor stressful connotations (e.g., Denson, Spanovic, & Miller, 2009). Participants in the current study were asked to make judgments about their perception of self, psychological well-being, and self in relation to others. It was hypothesized that self-examination would generate a stress response as measured by salivary cortisol. This hypothesis, however, was not supported in the present study. The active tasks were associated with a significant decrease in salivary cortisol levels from pretest to posttest assessment. This was an unexpected finding. One could argue that the decrease in cortisol was due to sampling time. According to Polk, Cohen, Doyle, Skoner, and Kirshbaum (2005), there are several features of the diurnal cortisol pattern (e.g., linear slope of the decrease over the course of the day or amplitude of the increase on wakening), but the different rhythm parameters have not been established. We sampled resting cortisol levels within a 3-hr window and on the same day of EEG recording. There were no gender differences found with regard to this

dependent variable. Moreover, the women in our sample were all young adults with similar reproductive cycles. This manipulation reduces the influence of differing estrogen levels on cortisol (Putnam et al., 2008). It is plausible that the instructions to remain still and relaxed during the EEG recording session down regulated the HPA axis in our participants.

Our findings suggest that the self-examination tasks did not elicit an emotional response that would be consistent with the cognitive appraisal of threat. Stressful situations that contain a social threat or rejection element have been repeatedly associated with elevated cortisol levels (Denson et al., 2009). According to Dickerson et al., (2004) integrated specificity model, distinct physiological responses are associated with specific emotions.

There was a significant negative correlation, however, between self-perception and resting salivary cortisol levels. In other words, individuals who endorsed a more negative self-perception tended to display higher resting cortisol levels than those individuals who endorsed a more positive self-perception. In addition, self-perception was a predictor of salivary cortisol decline across all three life domains of the SPESA. These findings are consistent with previous studies that found a positive association between negative mood and cortisol levels (Dettling, Gunnar, & Donzella, 1999; Holsboer, 2001; Holsboer & Barden, 1996). Moreover, our finding supports the use of cortisol as a biological marker for psychopathology. It must be noted that Clark, Iversen, and Goodwin (2001) found no significant differential effects on salivary cortisol levels as a function of positive or negative mood in a nonclinical adult population.

EEG and Cortisol Associations

The decline in salivary cortisol levels were significantly correlated with increased activation in both hemispheres of the brain. However, the self-examination tasks produced greater cortical excitability across the EEG spectral power in the left hemisphere (primary motor cortex, precuneus, frontal eye field, prefrontal

cortex, visual association cortex, anterior cingulate, and PC), as opposed to the right hemisphere (primary sensory cortex, middle frontal gyrus, insular cortex, and supramarginal gyrus). Upon closer examination of the data, the participants in our study reported minimum symptomatogy (anxiety, depression, and somatization) and negative emotional experiences (e.g., abuse). According to Cannon et al. (2008), clinical populations (e.g., recovering substance abusers) tend to hold a more negative self-perception across the three life domains (childhood, adolescent, and adulthood) as measured by the SPESA. Collectively, our findings are consistent with previous studies (e.g., Davidson, 2004; Hewig et al., 2008; Putnam et al., 2008) that reported an inverse relationship between cortisol levels and greater left-sided prefrontal activity as an indicator of a positive psychological profile.

The decline in salivary cortisol was associated with delta excitability in the left precuneus across all self-examination tasks. This finding, in particular, is of interest. The precuneus processes information regarding self-awareness, first-person perspectives, and memory (Fransson & Marrelec, 2008). According to Sajonz et al. (2010), the precuneus has strong reciprocal connections with the occipital and parietal areas of the brain. This finding suggest that our participants were engaged in the self-examination process, and it supports previous studies regarding core aspects of self residing in the midline cortical structures of the brain (Northoff & Bermpohl, 2004; Panksepp & Northoff, 2009).

In addition, cortisol decline was associated with higher alpha activity at the PC, uncus and premotor association cortical regions in the left hemisphere with self-examination. The PC is primarily associated with attention and mediates the interaction between emotional and memory-related processes (Fransson & Marrelec, 2008). High alpha activity in this region may indicate processing problems regarding the self-referential information. The items were presented in 8-s intervals, and the digital photograph was displayed for 1.5 min. Unlike the paper-and-pencil survey

administration, participants could not go back or change their responses. Thus the processing time was somewhat constrained. The uncus or inferior portion of the temporal lobe showed alpha excitability during the self-image condition only. The uncus is part of the visual-spatial processing area of the brain, and it is involved in object recognition (Nobre, Allison, & McCarthy, 1994). The participants were not given any instructions regarding their picture, and this task was not language based. It is plausible that our participants experienced cognitive dissonance when examining their own self-image or disregarded the image as not being representative of their being. In other words, it was a bad picture. During the assessment of psychological well-being (BSI–18), high alpha activity occurred in the premotor association cortex in the left hemisphere. Participants were asked to limit body movement as much as possible to reduce EEG artifacts. Research shows that high alpha activity inhibits motor evoked potentials (Sauseng, Klimesch, Gerloff, & Hummel, 2009). In the present study, it is plausible that our participants were actively engaged in the suppression of bodily movement.

Although the cortical excitability occurred primarily at the lower EEG spectral power bands, significant beta activity was found at BA 37 (fusiform gyrus) during the BSI–18 task. This cortical region is part of the inferior temporal lobe, and it is associated with word processing. This survey in particular assesses psychological well-being in a simple, brief, and straightforward manner. Therefore, increased beta activity at this cortical region within the left hemisphere is not surprising. However, the lack of significant beta activity across the cortical regions as a function of self-examination was unexpected. Putnam et al. (2008) found increased beta activation of the midline prefrontal cortex in college students who were classified into the low anhedonia group. Resting EEG was assessed after participants completed a number of psychological surveys. In the present study, EEG was continuously recorded during the self-examination tasks. In a previous study, we

recorded brain activity during the assessment of humor in a nonclinical sample (Cannon, Lubar, Clements, Harvey, & Baldwin, 2007). Participants rated pranking behaviors as good or bad, and verbal responses were given. We found the beta frequency to show maximum excitability in both the left (inferior temporal gyrus) and right (somatosensory cortex) hemispheres. Future studies are warranted to clarify the role of beta activity during self-specific tasks.

Limitations and Conclusions

There are a few limitations with the present study. First, a convenient sample was obtained from the university setting, and this may not adequately represent the general population. Second, EEG source localization techniques have less spatial resolution than fMRI and PET. However, EEG source localization does provide enhanced temporal resolution, which is very important in task dependent neuroimaging studies (Little, Lubar, & Cannon, 2010). Regular occurrences in the EEG record can be readily categorized, quantified, and correlated with cognition, affect, and behavior (Little et al., 2010). Moreover, the examination of frequency analyses adds another level of complexity to our understanding of functional connectivity and behavior. Although 63 participants had useable EEG data, a number of records (20) were not useable due to artifacts. Participants were asked to remain still and to limit bodily movement for a considerable time. Moreover, the responses to the survey items were verbal in nature. It is plausible that individuals who followed the experimental demands were less anxious in general from those who were unable to remain still during the data collection session. Recently, Muehlhan, Lueken, Wittchen, and Kirshbaum (2011) examined the effects of undergoing an fMRI on neuroendocrine responses. They found participants to be most nervous immediately after entering the scanner. Clearly, further studies are warranted regarding the influence of neuroimaging techniques on physiological outcomes. Finally, cortisol levels are higher in the morning. The present study did not examine the cortisol awakening response in regard to the self-examination tasks. Moreover, cortisol levels were assessed pre- and posttask only. Multiple assessments of this hormone over time would yield greater insights regarding the inverse of psychopathology from a cortical excitability perspective.

To our knowledge, this present study is the first to examine the relationship between brain activation and salivary cortisol levels as a function of self-perception and psychological well-being in a nonclinical sample. The present study addresses a gap in the literature regarding real-time assessment of neural activity and self-perception. Using LORETA EEG, we found that greater left-sided hemisphere activation was associated with a more positive psychological profile. More important, LORETA EEG is a useful tool for measuring brain activity and differentiating levels of psychopathology.

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