The Interaction Between Endogenous Cortisol and Salivary Alpha-Amylase Predicts Implicit Cognitive Bias in Young Women

THE INTERACTION BETWEEN ENDOGENOUS CORTISOL AND SALIVARY ALPHA-AMYLASE PREDICTS IMPLICIT COGNITIVE BIAS IN YOUNG WOMEN

A Dissertation Presented

by

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Submitted to the Graduate School of the

University of Massachusetts Amherst in partial fulfillment

of the requirements for the degree of

DOCTOR OF PHILOSOPHY

September 2011

Clinical Psychology

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ACKNOWLEDGEMENTS

This research would not have been possible without the dedication, guidance and support of my advisor, Sally I. Powers, to whom I am forever grateful. I want to thank Douglas Granger for his belief in my work and his assistance in conceptualizing and analyzing the alpha-amylase data. I would also like to thank the other members of my committee, Jerrold Meyer, Melinda Novak and M. Christine King, for their helpful comments and suggestions throughout this project.

This work was supported by an American Psychological Foundation/Council of Graduate Departments of Psychology Graduate Research Scholarship, and an Elizabeth Munsterberg Koppitz Child Psychology Graduate Student Fellowship.

I am grateful to numerous research assistants for their help with data collection, to Jennifer Jacobsen for her assistance with data entry, to Gina Kuperberg for providing helpful feedback on earlier versions of this manuscript, and to all the individuals who participated in this project.

A special thank you to my friends and family who supported me throughout this process, and provided the encouragement I needed to keep going.

ABSTRACT

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SEPTEMBER 2011

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Both animal and human studies suggest that cognitive bias toward negative information, such as that observed in major depression, may arise through the interaction of cortisol (CORT) and norepinephrine (NE) within the amygdala. To date, there is no published account of the relationship between endogenous NE and CORT levels and cognitive bias. The present study examined salivary CORT and salivary alpha-amylase (sAA), an indirect measure of NE, in relation to masked affective priming of words in young female participants. Women with higher salivary CORT showed increased priming to negative word pairs only when sAA was also high; when sAA was low, no effect of CORT on priming was observed. These results are in line with previous research indicating that increased CORT is linked to enhanced processing of negative information. However, our findings extend this literature in providing evidence that CORT predicts enhanced processing of negatively valenced information only in the presence of higher sAA.

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CHAPTER 1

INTRODUCTION

It has long been observed in humans that response to stress occurs via two distinct systems: the locus cereleus–norepinephrine/sympathetic nervous system (LC–NE/SNS) and the hypothalamic–pituitary–adrenal (HPA) axis (Chrousos & Gold, 1992). Traditionally, these two components have been described as being responsible for the immediate and longer term effects of stress, respectively. In the presence of an acute threat, the SNS responds within seconds, preparing the body to engage in "fight or flight" through the release of NE (Cannon, 1914). The HPA response is much slower, taking minutes to achieve its end-product: increased circulating glucocorticoids such as cortisol (CORT). Given this lagged response, the HPA axis is believed to play a crucial role in helping the body cope with future consequences of the stressor. However, the function of glucocorticoids within the stress response is far from simple, and there is evidence that glucocorticoids can play permissive, suppressive, stimulatory, and preparative roles (Sapolsky, Romero, & Munck, 2000), alternately enhancing or dampening the effects of NE depending on the precise physiological system being observed. Hence, the physiological consequences of NE or glucocorticoids such as CORT can only be fully understood in relation to one another. The present study adds to a growing body of literature suggesting that the psychological consequences of the stress response are also best understood by examining the interactions between SNS and HPA activity.

In addition to numerous effects throughout the body, the stress response influences cognitive functioning via the action of NE and glucocorticoids within the brain. One well-described and clearly adaptive cognitive effect of stress is enhanced learning and memory (see Roozendaal, McEwen, & Chattarji, 2009 for a review), particularly of emotional material (Buchanan & Lovallo, 2001; Jelici, Geraerts, Merckelbach & Guerrieri, 2004; Putman, van Honk, Kessels, Muldera, & Koppeschaar, 2004; Segal & Cahill, 2009). Some research has also suggested that higher levels of CORT may result in a more subtle effect: cognitive bias. Tops et al. (2003) found that participants given glucocorticoids showed poorer memory for pleasant words, but not unpleasant or neutral words, compared with a placebo group. Similarly, van Honk et al. (2003) reported that participants with higher endogenous CORT levels showed reduced spatial working memory for happy faces relative to angry or neutral faces. Putman, Hermans, and van Honk (2007) observed that healthy males given exogenous glucocorticoids demonstrated increased accuracy in spatial working memory for angry faces, but not happy faces. Taken together, these findings suggest that increased levels of CORT - either occurring naturally or artificially induced - result in increased cognitive resources allocated to negatively valenced information. Thus, individuals with higher CORT become more facile at processing negative information, and less adept at processing positive information.

Stress is known to increase corticotrophin-releasing hormone (CRH) mRNA in both the central amygdala and the bed nucleus of the stria terminalis (Makino, Gold, & Schulkin, 1994; Makino et al., 1995; Mamalaki, Kvetnansky, Brady, Gold, & Herkenham, 1992), areas that have been linked to sensitivity and response to specific fear cues and overall context, respectively (Lee & Davis, 1997). Higher levels of CORT may be associated with increased activation of these limbic affective appraisal systems which may, in turn, result in bias toward negatively valenced information. Indeed, heightened amygdala activation has been linked to implicit negative cognitive bias (Dannlowski, Ohrmann, Bauer, Kugel, Arolt, Heindel, & Suslow, 2007; Dannlowski, Ohrmann, Bauer, Kugel, Arolt, Heindel, Kersting, et al., 2007), suggesting that increased CORT may induce cognitive bias via amygdala hyper-responsivity.

Although much research on negative cognitive bias and the stress response has focused exclusively on the HPA axis, there is a wealth of evidence from animal models indicating that interactions between the two branches of the stress response system are critical to understanding the effects of stress on cognition. In particular, the memory-enhancing effects of glucocorticoids, partially mediated via the amygdala, appear to depend on the presence of NE (Quirarte, Roozendaal, & McGaugh, 1997; Roozendaal, Hui, et al., 2006; Roozendaal, Okuda, et al., 2006). Similarly, it is likely that the relationship between increased CORT, amygdala activation, and negative cognitive bias is at least partially dependent on levels of NE. Kukolja et al. (2008) examined this hypothesis through exogenous manipulations of NE, CORT, or both within healthy participants, who then viewed emotional faces within an fMRI scanner. The authors reported a decrease in amygdala activation to positive facial emotion and a concomitant increase in amygdala activation to negative facial emotion within the combined NE-CORT elevated group only. These results provide compelling evidence for the relationship between the stress response, amygdala activation, and negative cognitive bias, and highlight the importance of examining both SNS and HPA activity with regard to cognition.

Through the use of salivary cortisol, it has been relatively easy to assess HPA activity in relation to multiple psychological variables of interest; assessment of SNS activity has been historically more burdensome. The emergence of salivary alpha-amylase (sAA) as a reliable, non-invasive marker of SNS activity (Granger, Kivlighan, El-Sheikh, Gordis, & Stroud, 2007; Nater & Rohleder, 2009) has made it possible to explore resting SNS and HPA activity, as well as their interactions, within the same individuals. There is strong evidence that sAA reflects central NE levels: alpha- and beta-adrenergic agonists significantly increase sAA (Ehlert, Erni, Hebisch, & Nater, 2006; Speirs, Herring, Cooper, Hardy, & Hind, 1974), while beta-adrenergic antagonists significantly decrease sAA (Nederfors & Dahlof 1992; Nederfors, Dahlof & Twetman, 1994; Speirs, et. al. 1974; van Stegeren, Cahill Everaerd, Cahill, McGaugh, & Gooren, 2006). However, there is some debate as to whether sAA levels correlate with catecholamine activity specifically in response to psychological stress (Chatterton, Vogelsong, Lu, Ellman, & Hudgens, 1996; Ehlert, et. al. 2006; Nater et al., 2006).

The present study represents the first attempt of which we are aware to examine resting SNS and HPA activity (via sAA and salivary CORT, respectively) in relation to rapid, online affective information processing. Previous research examining the relation between endogenous stress hormones and cognition have utilized tasks that require conscious, effortful processing on the part of the participants, such as working memory and delayed recall paradigms. Thus, it is not possible to infer whether participants with higher CORT and/or NE levels are displaying an automatic negative cognitive bias, or whether they are consciously allocating their attentional resources toward negative information (or away from positive information). A measure of implicit cognitive bias could provide key insights as to how sAA and CORT relate to rapid emotional evaluations such as those mediated by the amygdala and related cortical regions.

Some of the strongest evidence for unconscious, involuntary emotion appraisal processes in healthy adults derives from the affective priming paradigm. In the paradigm originally developed by Fazio, Sanbonmatsu, Powell, and Kardes (1986), positive, negative or neutral prime words are followed by affectively polarized target words, and participants are asked to evaluate the valence (i.e. positive or negative) of the target words only. Participants respond faster and more accurately to target words (e.g. friendship) when they are preceded by affectively congruent primes (e.g. love) relative to neutral primes (e.g. engine). Multiple cognitive mechanisms can contribute to this affective congruency or priming effect depending on experimental conditions (Spruyt, De Houwer, Hermans, & Eelen, 2007). Under conditions which bias toward more automatic processing, affective priming is thought to occur through spreading activation in semantic memory, similar to semantic priming (Rossell & Nobre, 2004): the presentation of an affectively polarized prime preactivates affectively related memory representations, and thus when a target corresponding to one of these preactivated representations is presented, it will be encoded more easily, resulting in faster and more accurate responses (De Houwer, Hermans & Spruyt, 2001; Spruyt, De Houwer, Hermans, & Eelen, 2007; Spruyt, Hermans, De Houwer & Eelen, 2002; Spruyt, Hermans, De Houwer, Vandromme & Eelen, 2007).

One method of assessing automatic, or implicit, priming is masked priming. In masked priming, the prime stimulus is presented for a very brief duration, and is then immediately obscured by either a pattern mask (e.g., a series of letters or symbols occupying the same location on the screen as the prime) or the target word itself. Under these conditions, participants generally report having had no awareness of the prime stimuli. Affective priming can be achieved even when prime words are masked (Greenwald, Draine, & Abrams 1989; Greenwald, Klinger, & Liu, 1996), confirming that the spread of activation based on affective valence does not depend on conscious awareness of the primes.

Through the use of a masked affective priming paradigm, we assessed both explicit and implicit cognitive bias: the former via response bias in participants' affective categorization of target words (i.e. the proportion of words categorized as "positive" and "negative"), and the latter via priming effects. Increased priming effects for negatively valenced words might reflect the fact that negatively valenced memory representations are already preactivated, or are activated more easily, due to a bias toward negatively valenced information. Consequently, we were particularly interested in the relationships among sAA, CORT and priming effects to negative congruent word pairs as an indicator of implicit cognitive bias.

CHAPTER 2

METHOD

<u>Participants</u>

One hundred and nine female University of Massachusetts-Amherst undergraduate students (mean age: 19) received course extra credit for completion of the study. All participants were native speakers of English, and had normal or corrected to-normal vision. Participants were demographically representative of the local community: the majority (83.5%) was White, with smaller numbers of Asian American (5.5%), African American (4.6%), Latina (4.6%), and Native American or Pacific Islander (.9%) races/ethnicities. Written informed consent was obtained from all participants according to the established guidelines of the UMass Institutional Review Board.

<u>Design and Procedures</u>

Participants completed three lab sessions on three consecutive days. During the first session, participants performed the affective priming task and provided a saliva sample for sAA and CORT analysis; participants provided two additional saliva samples during their second and third lab sessions.

Affective priming.

***<u>Stimuli</u>*.** A total of 120 negatively valenced targets, 120 positively valenced targets, 80 negatively valenced primes, 80 positively valenced primes and 80 neutral primes were taken from the Affective Norms for English Words (ANEW) database (Bradley & Lang, 1999). Word pairs were developed such that target words were paired with affectively congruent (e.g. prestige-affection), affectively incongruent (e.g. bomb-holiday) or neutral primes (e.g. engine-scared), and were counterbalanced across three lists such that each list contained 40 trials in each of the six conditions (240 total trials per list: negative-negative, neutral-negative, positive-negative, positive-positive, neutral-positive, and negative-positive). Participants saw each word only once per list, but across lists each prime word was paired with three different targets.

As would be expected, positive, negative, and neutral words all significantly differed from each other on valence ratings (see Table 1)[1]. Although positive and negative words both had significantly higher arousal ratings than did neutral words (see Table 1), they did not differ significantly from each other on ratings of arousal. Hence, any relationships observed between CORT, sAA and priming to negative words could be attributed to the effect of negative valence specifically rather than arousal generally.

Procedure. Participants were seated in front of a computer in a room separate from the experimenter. They were asked to classify each target word as either positive or negative by pressing one of two buttons on the computer keyboard. Participants were not given any information about the nature of the word stimuli, and were simply instructed to go with their first instincts and not to dwell on any single word. Each participant was given 12 practice trials at the start of the experiment and was randomly assigned to one of the three lists used for counterbalancing.

Linguistic stimuli were presented on a monitor set to a refresh rate of 100 Hz, allowing for 10 millisecond (ms) resolution of stimulus control. Stimuli were displayed at the center of the screen at high contrast as white letters on a black background in the Arial font. Each trial began with a fixation stimulus centrally presented for 500 ms, followed by a 500 ms blank screen. The blank screen was followed by a forward mask of

[1] Ratings of word valence and arousal were obtained via the ANEW database; ratings of word frequency (Kucera & Francis, 1967) and concreteness (Coltheart, 1981a) were obtained via the MRC Psycholinguistic Database (Coltheart, 1981b).

hash marks (#######) for 200 ms, which was replaced by a prime word for 30 ms, immediately followed by the presentation of the target word for 250 ms. Following target word presentation, a blank screen was displayed by 750 ms. Finally, a question mark was presented, and remained on the screen until participants pressed a button on the keyboard indicating their affective categorization (positive or negative) of target words only.

In line with previous research suggesting that this short prime duration would encourage entirely automatic processing (Holcomb & Grainger, 2006; Holcomb, Reder, Misra, & Grainger, 2005) a pilot study conducted with volunteers who did not participate in this experiment confirmed that primes were not consciously perceived.

Saliva collection and assay procedures.

Participants were scheduled based on their individual waking times, arriving at the lab between 8 and 10 hours after waking for each of the three lab sessions, in order to assess sAA and CORT levels during a relatively stable time point in their diurnal rhythms (Nater et al., 2007). By conducting all saliva collection within the lab, we aimed to increase compliance with desired CORT and sAA collection times. In vivo (in the natural environment) saliva collection has yielded poor compliance in experimental studies (Broderick, Arnold, Kudielka, & Kirschbaum, 2004; Kudielka, Broderick, & Kirschbaum, 2003). Furthermore, significant differences in measured cortisol levels have been observed between compliant and noncompliant participants (Kudielka et al., 2003).

Whole unstimulated saliva samples were collected by passive drool (Granger, Kivlighan, Fortunato, Harmon, Hibel, et al., 2007). Specimens were sealed in cryogenic vials and immediately placed in frozen storage (-20 °C) until shipped on dry ice to Penn State for analysis.

CORT. All samples were assayed for salivary cortisol by enzyme immunoassay (Salimetrics, State College, PA). The test used 25 ul of saliva, had a lower limit of sensitivity of .007 ug/dl, range of sensitivity from .007 to 3.0 ug/dl, and average intra-and inter-assay coefficients of variation of less than 5 percent and 10 percent.

sAA. Samples were assayed for sAA by kinetic reaction assay (Salimetrics, State College PA). The assay employs a chromagenic substrate, 2-chloro-p-nitrophenol, linked to maltotriose. The enzymatic action of sAA on this substrate yields 2-chloro-p-nitrophenol, which can be spectrophotometrically measured at 405 nm using a standard laboratory plate reader. The amount of sAA activity present in the sample is directly proportional to the increase (over a 2 minute period) in absorbance at 405 nm. Results are computed in U/mL of sAA. Intra-assay variation (CV) computed for the mean of 30 replicate tests was less than 7.5 percent. Inter-assay variation computed for the mean of average duplicates for 16 separate runs was less than 6 percent.

Controls. To ensure accuracy of sAA and CORT measurements, participants were instructed to refrain from drinking alcohol, using illegal drugs, or visiting the dentist within 24 hours prior to their lab sessions, and to not exercise, eat, smoke cigarettes, brush their teeth, or drink (except water) for 2 hours prior to their lab sessions. Participants received written instructions detailing these procedural controls prior to signing up for the study, and also received reminder emails containing these instructions the day before each of their lab sessions.

In addition, other variables that could potentially influence sAA and CORT levels were assessed (Granger, Hibel, Fortunato, & Kapelewski, 2009). At each lab session, participants completed a questionnaire noting any and all medications that they had taken in the past 24 hours, including psychotropic, allergy, oral contraceptives, and non-prescribed drugs. During the first lab session participants completed a questionnaire indicating the frequency with which they used nicotine, caffeine, alcohol, and various illegal substances.

CHAPTER 3

RESULTS

CORT and sAA

CORT and sAA levels were estimated by taking the arithmetic mean of the three CORT and SAA values generated by each participant. Mean CORT and sAA values were moderately skewed and were normalized with square root transformations. In all analyses reported, a total of 4 participants were excluded as outliers due to values more than three standard deviations from mean CORT or sAA values.

Within the present sample, CORT and sAA were significantly and positively correlated with one another ($r = .26$, $p < .01$). This is consistent with other research utilizing young adult samples (DeBuse, Pietromonaco, & Powers, 2010), although researchers sampling from a broader age range have reported no relationship between average sAA and CORT levels (Nater et al., 2006, 2007).

Affective Priming

Priming effects were calculated two ways: as the difference in reaction time (RT) between affectively congruent versus neutral trials, and as the difference in percentage of correct responses between affectively congruent and neutral trials. Overall, participants were quite accurate in their affective classifications (mean across all trial types: 92%); nevertheless, RT difference scores were computed for correct trials only. Trials with response times of less than 150 ms or greater than 1500 ms were excluded from all analyses reported.

Across the entire sample, a significant RT priming effect to positively congruent word pairs (relative to neutral-positive word pairs) was achieved [$t(108) = -2.25$, p <

.05], and a trend ($p = .08$) toward increased accuracy to positively congruent word pairs (relative to neutral-positive word pairs) was observed. When examining all participants without regard to other independent variables, no significant RT or accuracy priming effects were observed to word pairs congruent for negative valence relative to neutral-negative word pairs (see Table 2).

Relationship between CORT, sAA and affective information processing.

The relationships between SNS and HPA measures and dependent cognitive variables were examined via hierarchical multiple regression. In the first step of each analysis reported marijuana, Advil, and Tylenol usage were controlled, as each of these variables was found to correlate significantly ($p < .05$) with CORT or sAA. In the second step, mean-centered CORT and sAA values were entered into models; in the final step, a CORT X sAA interaction term was entered. Significant interactions were followed up by dividing participants by median split on SAA values, and repeating regression models within each group (high and low sAA) with CORT and control variables as predictors.

Implicit cognitive bias: priming. While there was no main effect of CORT or sAA on priming to negatively congruent word trials (as assessed by difference in accuracy between negatively congruent relative to neutral-negative trials), a significant CORT X sAA interaction was observed (see Table 3A). This interaction accounted for 11.5% of unique variance over and above main effects and control variables. Among participants with lower sAA, there was no significant relationship between CORT and priming to negative words ($\beta = -.15$, $p = .3$; see Figure 1A). In contrast, participants with higher sAA displayed a significant positive relationship between CORT and cognitive bias: as CORT increased, their priming to negative words also increased ($\beta = .35$, $p < .05$;

see Figure 1B). Thus, CORT predicted enhanced processing of negatively valenced information, but only in the presence of higher sAA.

No main effects of CORT, sAA, or CORT X sAA interactions were found for any other measure of implicit cognitive bias.

Explicit cognitive bias : response bias. Across the entire sample, there was a slightly higher proportion of “positive” than “negative” responses (55% versus 45%, respectively). There was a trend ($p = .08$, see Table 3B) toward a main effect of sAA in predicting the proportion of words classified as pleasant, with participants with higher salivary sAA categorizing more words as positive (see Figure 2). There was no significant main effect of CORT or a sAA X CORT interaction. In these models, sAA and CORT main effects accounted for 4% of unique variance over and above control variables, while the interaction term explained only an additional 2% of the variance.

CHAPTER 4

DISCUSSION

Using a task that allowed for the examination of automatic affective processing, we found that salivary CORT was associated with implicit negative cognitive bias (as indicated by enhanced priming to word pairs congruent for negative valence) only when there was a concomitant increase in sAA levels. Insofar as sAA levels reflect central NE, these results confirm that negative cognitive bias arises when both NE and CORT are elevated. Bias toward emotionally negative information appears to be linked to amygdala hyper-responsivity to negative stimuli (Dannlowski et al., 2007), an effect which can be induced through pharmacological elevations of central NE and CORT (Kukolja et al., 2008). Affective priming of words is dependent on the insular cortex (Liu et al., 2010), an area which is highly connected to the amygdala and is susceptible to stress-induced manipulations (Merz, Tabbert, Schweckendiek, Klucken & Vaitl, 2010). In our study, increased sAA and CORT may have been associated with amygdala hyper-responsivity to negative stimuli, and a concurrent facilitation in masked priming to negative words both behaviorally and within the insular cortex.

These results are broadly consistent with animal research as well as recent fMRI studies indicating that the stress response affects cognition via the interaction of NE and CORT within the amygdala (Kukolja et al., 2008; Quirarte et al., 1997; Roozendaal et al., 2006a, 2006b; van Stegeren, Wolf, Everaerd, Scheltens, Barkhof, & Rombouts, 2007). However, our findings extend this literature in two important ways. First, they represent the first evidence that the interaction between endogenous levels of sAA and CORT predicts automatic negative cognitive bias. Prior research on cognitive bias has either not included a measure of SNS activity (van Honk et al., 2003), or has focused on external manipulations of NE and CORT levels (Kukolja et al., 2008; Putman et al., 2007; Tops et al., 2003). The present results reveal an ecologically valid model of how the SNS and HPA axis interact to engender negative cognitive bias.

Second, our findings are the first demonstration that resting, non-stress levels of sAA and CORT together significantly influence affective processing. Given the correlational nature of the present research design, it is impossible to determine conclusively whether increases in sAA and CORT preceded cognitive bias within our sample or vice versa. Nevertheless, multiple studies have provided evidence that artificially enhancing CORT and/or NE can induce a cognitive bias, suggesting that acute increases in stress hormones result in more cognitive resources allocated to negative information. Within the context of responding to an immediate stressor, it would appear adaptive to devote more resources to negative (or threatening) stimuli. Indeed, both animal and human studies have demonstrated that stress reactivity to physiologically arousing stimuli results in a cognitive advantage: increased long-term memory for those stimuli (Putman et al., 2004; Roozendaal et al., 2009; Segal & Cahill, 2009). However, if NE and CORT levels remain somewhat elevated following the resolution of the stress response, this might lead to a more chronic, maladaptive negative cognitive bias.

A persistent bias toward negative information is thought to play a crucial role in the development of mood and anxiety disorders (Beck, 1967; Matthews & McLeod, 2005). Evidence supporting this theory derives from decades of research demonstrating bias toward negatively valenced (or mood congruent) information within depressed samples (Bradley, Mogg & Williams 1995; Burt, Zembar & Niederehe, 1995; Dozios &

Dobson, 2001; Gotlib & Cane, 1987; Gur et al., 1992; Hayward, Goodwin, Cowen & Harmer, 2005; Mathews, Ridgeway & Williamson, 1996). Depression has also been linked consistently with alterations in HPA activity (Burke et al., 2005) - including increased basal, salivary cortisol – as well as heightened amygdala activation (Abercrombie et al., 1998; Drevets et al., 1992, 2002; Sheline et al., 2001; Siegle, Steinhauer, Thase, Stenger & Carter, 2002, Siegle, Thompson, Carter, Steinhauer & Thase, 2007). Dannlowski et al. (2007) demonstrated that increased amygdala responsivity to negative stimuli was associated with implicit cognitive bias within a depressed sample, and that this bias, in turn, was associated with illness severity and duration. Our findings within a normative sample confirm that resting levels of CORT and NE (as assessed by sAA) are related to an automatic bias toward negative information, and suggest a potential mechanism through which chronically higher salivary levels of stress hormones might contribute to the development of affective disorders.

Within our sample, there was also a trend toward higher sAA levels predicting an explicit positive response bias. Specifically, participants with higher salivary sAA levels categorized more words as positive. This is consistent with other reports linking basal sAA to positive mood states (Nater, Rohleder, Schlotze, Ehlert, & Kirschbaum 2007; Fortunato, Dribin, Granger, & Buss, 2008; Adam & Granger, under review) as well as past research linking SNS activity to self-reported levels of effort in completing experimental tasks (Frankenhaeuser, Lundberg, & Forsman, 1980; Lundberg & Frankenhaeuser, 1980). Within the context of the present study, the relationship between sAA and positive response bias might have been driven by participants' conscious attempts to categorize words in a mood-congruent (i.e. positive) fashion. Further, these findings are in keeping with the notion that implicit and explicit affective processes are at least somewhat distinct on both a cognitive and neural level (Liu et al., 2010). Our measure of implicit cognitive bias, masked affective priming, revealed that higher sAA in combination with increased salivary CORT was associated with increased priming to negative congruent word pairs, indicating a greater ease of encoding negative information under automatic conditions. Simultaneously, higher levels of sAA irrespective of CORT levels contributed to a bias toward *consciously* labeling more stimuli as positive. This pattern of findings underscores the value of examining multiple levels of cognitive processing in relation to stress hormones, as the SNS and HPA axis may exert differential effects under implicit relative to explicit processing conditions.

Some limitations warrant comment. The present study focused exclusively on women as it was more likely that female participants would demonstrate a relationship between stress hormones and our measure of cognitive bias. There is recent evidence that CORT may enhance affective processing within the insular cortex for women, but not for men (Merz et al., 2010). As it was beyond the scope of this study to examine sex differences, we restricted our sample to female participants, and therefore our results may not extend to males. Future research should investigate whether males display a similar pattern of effects. Additionally, our findings are based solely on young adults and may not generalize to other developmental stages.

Conclusions

In sum, we have demonstrated that endogenous, resting levels of sAA and CORT are significantly related to cognitive bias. Specifically, we have provided evidence that the combination of higher endogenous levels of sAA and CORT is associated with implicit bias toward negative information within young females. In providing a more nuanced description of the interrelations between the SNS, the HPA axis, and online affective processes, these findings add to an expanding body of literature seeking to integrate neuroendocrine and cognitive methodologies.

Table 1. Mean (SD) Word Stimulus Characteristics as a Function of Affective Valence.

	Positive	*Negative*	*Neutral*
Valence	7.24 (0.68)^	2.98 (0.9)	5.00 (0.65)+
Arousal	5.42 (1.00)	5.49 (1.11)	4.4 (0.84)+
Frequency	39.79 (25.79)	39.39 (53.71)	94.18 (248.4)+
Length	6 (2)	6 (2)	6 (2)
Concreteness	439.54 (122.36)	435.61 (111.49)	442.25 (131.93)

Note. Unless indicated, there are no significant differences between conditions.
+differed from both positive and negative (all *t*s > 3.0, all ps <.01).
^differed from negative [$t(200) = 54.6$, $p < .01$].

Table 2. Mean Affective Priming Effects (APE) as a Function of Accuracy and Reaction Time.

	Positive congruent	*Neutral-positive*	*APE*	*Negative congruent*	*Neutral-negative*	*APE*
Reaction time (ms)	469	480	11*	512	507	-5
Accuracy	5.2	6.1	0.9†	9.5	10.0	0.5

†p < .1, *p < .05.

Table 3A. Summary of Hierarchical Regression Analysis for Variables Predicting Priming to Negative Congruent Words.

	Model 1			Model 2			Model 3		
Variable	*B*	*SE B*	*β*	*B*	*SE B*	*β*	*B*	*SE B*	*β*
Advil/Tylenol use	1.91	1.2	0.16	1.51	1.24	0.13	1.35	1.17	0.11
Marijuana use	0.2	0.37	0.06	0.21	0.38	0.06	0.49	0.36	0.13
sAA				0.09	0.18	0.05	0.06	0.17	0.03
CORT				6.75	7.05	0.1	8.38	6.66	0.13
sAA x CORT							8.04	2.24	.35**
R2		0.03			0.05			0.16	
F for change in R2		1.55			1.12			3.59**	

†p < .1, *p < .05, **p < .01.

Table 3B. Summary of Hierarchical Regression Analysis for Variables Predicting Proportion of Words Categorized as Positive.

	Model 1			Model 2			Model 3		
Variable	*B*	*SE B*	*β*	*B*	*SE B*	*β*	*B*	*SE B*	*β*
Advil/Tylenol use	0.02	0.01	0.15	0.01	0.01	0.11	0.01	0.01	0.1
Marijuana use	0.002	0.004	0.04	0.003	0.004	0.08	0.004	0.004	0.1
sAA				0.003	0.002	0.19†	0.003	0.002	0.18†
CORT				0.02	0.07	0.03	0.02	0.07	0.03
sAA x CORT							0.03	0.02	0.14
R2		0.02			0.06			0.08	
F for change in R2		1.26			1.58			1.69	

†p < .1, *p < .05, **p < .01.

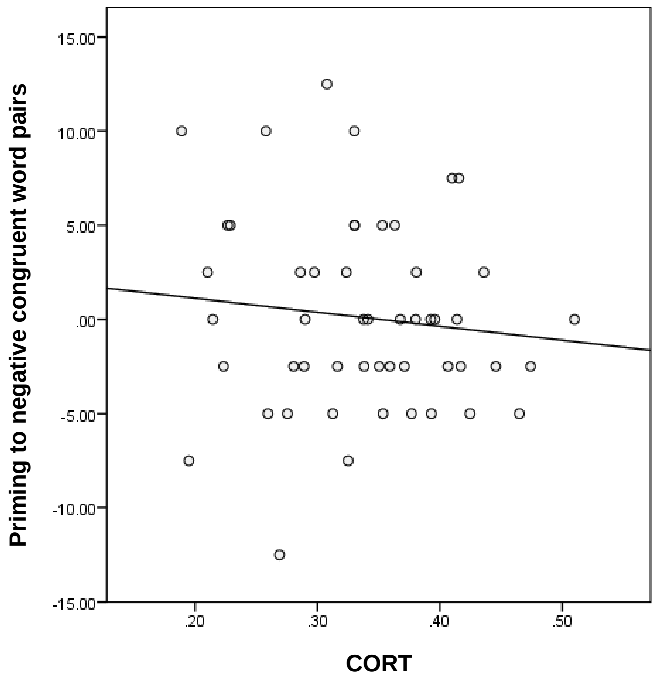

Figure 1A. Priming to negative congruent word pairs (as measured by the difference in accuracy between negative congruent and neutral-negative trials) as a function of salivary CORT when sAA levels are LOW.

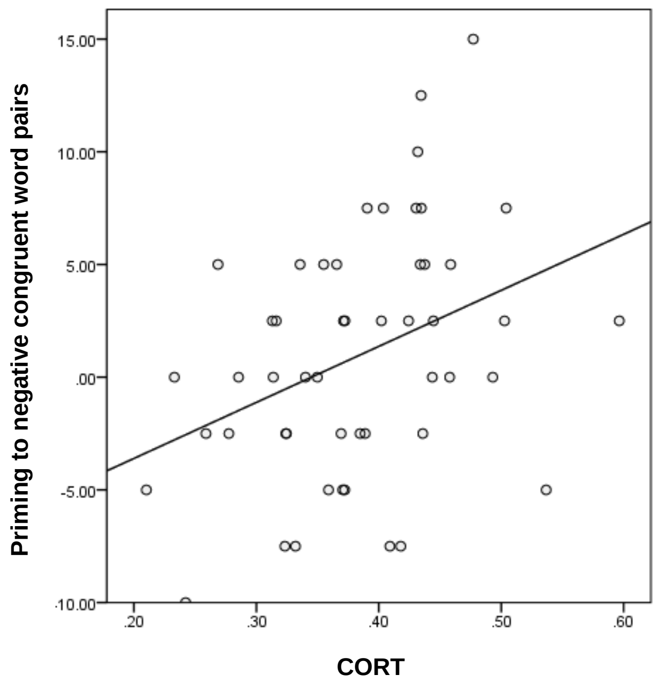

Figure 1B. Priming to negative congruent word pairs (as measured by the difference in accuracy between negative congruent and neutral-negative trials) as a function of salivary CORT when sAA levels are HIGH.

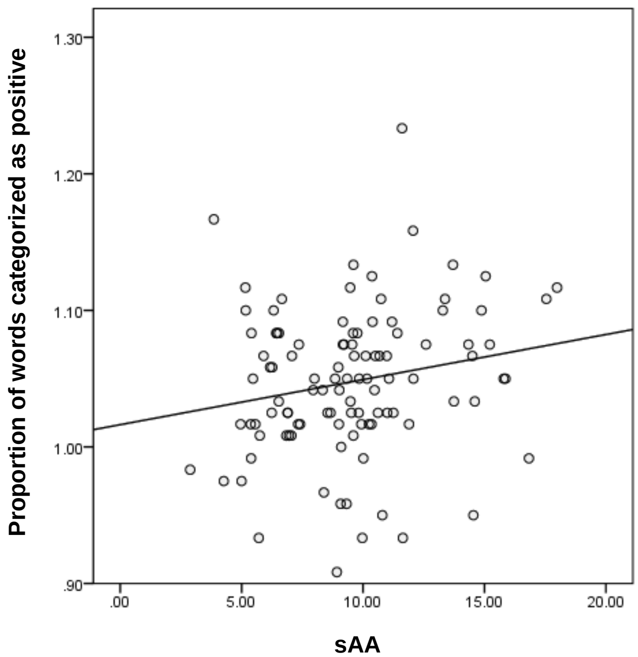

Figure 2. Proportion of words categorized as positive as a function of salivary sAA (1 = 100% accuracy in categorizing affective valence).

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