# State and trait affect as predictors of salivary cortisol in healthy adults

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(Sheridan et al., 1994). Although there is evidence that circulating cortisol is higher with greater NA (Rose et al., 1982; Schaeffer and Baum, 1984; Hubert and de Jong-Meyer, 1992; van Eck et al., 1996; Smyth et al., 1998; Hanson et al., 2000), the degree to which this association is due to stable individual differences in affect (i.e. traits) or transient fluctuations in mood (i.e. states) remains unclear. Moreover, the possible association of cortisol level with PA is relatively unexplored. The primary purpose of the present study was to determine if cortisol level is related to the trait and state components of both NA and PA.

### 1.1. Cortisol

Cortisol has a characteristic daily rhythm, peaking shortly after an individual wakens and then falling throughout the day. This rhythm can be disrupted by psychological and environmental influences such as low socio-economic status (Steptoe et al., 2003), stressful work or home environments (Adam and Gunnar, 2001), or chronic stress (McEwen, 1998). Cortisol levels that are either higher or lower than normal for any given time of day may set the stage for pathogenic processes that predispose an individual to illness (McEwen, 1998). Cortisol dysregulation has also been proposed as a possible contributor to morbidity, mortality, and severity of disease (McEwen, 1998). An initial study provides evidence of a role for cortisol dysregulation in the progression of breast cancer (Sephaton et al., 2000).

To characterize cortisol rhythm in humans, several features of the diurnal cortisol pattern are commonly extracted, including the overall level of circulating cortisol over the waking day, the amplitude of the increase on wakening, and the linear slope of the decrease over the course of the day. In one study, total daily cortisol level and morning rise area under the curve (AUC) were found to be negatively correlated (Schmidt-Reinwald et al., 1999), but, in general, the independence or redundancy of the information contained in the different rhythm parameters is not established. Additionally, in several studies sex differences in these parameters have been reported (Van Cauter et al., 1996; Wust et al., 2000).

### 1.2. Affect

State affect represents transient fluctuations in mood, and trait affect represents stable individual predispositions to certain states. Trait affect is measured either as the respondent's report of how he or she 'typically' feels or as an average of multiple measures of state affect (Diener and Emmons, 1984). State affect is measured either as the respondent's report of how he or she feels over a short period of time, such as a day or moment, or as the deviation of the short-term measure from the respondent's trait (mean) affect (Diener and Emmons, 1984). Affective responses can also be categorized as having either a negative or positive valence. Whether NA and PA are bipolar opposites or are independent is a source of controversy (Feldman et al., 1999). Measures based on the bipolar approach place negative and positive valence on opposite ends of the same scale of emotion. Measures assuming independence assess the degree to which each particular valence is experienced. Finally, that affect differs in men and women may not be completely implausible. One recent review argued that men and women handle stressful situations differently (Taylor et al., 2000) and have evolved differently to support these different behaviors.

### 1.3. Associations between affect and cortisol

Most research on cortisol and affect has focused on trait NA. In one community sample, depression and

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shyness—generally find that children low in surgency or both high in surgency and low in effortful control experience higher cortisol levels in response to new social situations (Gunnar et al., 2003). However, the conceptual relationship between trait PA and surgency remains unclear.

With respect to state NA and PA, the association between the depression, fatigue, and vigor scales of the POMS assessed at the start of each of 5 days and plasma cortisol drawn using an in-dwelling catheter throughout those same days was examined in a group of air traffic controllers. Within subjects, there was a positive relationship between depression and increased cortisol levels (Rose et al., 1982). A similar relationship with cortisol was observed for fatigue, and there was a tendency for cortisol to be higher with greater vigor, but these associations were marginally significant. In other studies, multi-item scales were used to

(Cohen et al., 2003). All data reported in this article were part of the baseline data collection (before viral exposure) of the larger study. Institutional Review Board approval was obtained from both the University of Pittsburgh and Carnegie Mellon University. All participants provided written informed consent.

## 2.2. Procedure

Participants underwent medical screenings and were excluded if they had a history of psychiatric illness, nasal or otologic surgery, asthma, or cardiovascular disease; if they had abnormal clinical profiles on urinalysis, CBC, or blood enzymes; if they were pregnant, lactating, or seropositive for HIV; or if they were on a regular medical regimen other than oral contraceptives or hormone replacement therapy. Demographic variables were obtained during the medical screening. Measures of state affect were obtained during six telephone interviews on evenings during a 6-week baseline period. All interviewers were women. A final state affect measure and samples of cortisol were collected during a 24-h baseline (before viral exposure) period at a hotel, where the participants were quarantined as a part of the larger study.

## 2.3. Measures

### 2.3.1. Affect measures

Over 2 weeks during the 6 week baseline period, participants were phone interviewed on three evenings (two weekdays and one weekend day) per week. In the evening 24 h after entering the hotel, they completed a questionnaire with the same adjectives. Each evening they were asked how accurately (0=not at all accurate to 4=extremely accurate) each of nine positive and nine negative mood adjectives described how they felt in the previous 24 h (Usala and Hertzog, 1989; Benyamini, et al., 2000; Cohen et al., 2003). The positive adjectives were representative of three subcategories of positive emotion: vigor (i.e. lively, full-of-pep, energetic), well-being (i.e. happy, pleased, cheerful), and calm (i.e. at ease, calm, relaxed). The nine negative adjectives were representative of three subcategories of negative emotion: depression (i.e. sad, depressed, unhappy), anxiety (i.e. on edge, nervous, tense), and hostility (i.e. hostile, resentful, angry). Daily positive mood scor69ve
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the amplitude of the morning rise, and the linear slope of the decrease over the waking day. To calculate AUC for the waking day, we first removed the observations at 06:15 h (i.e. 30 min after waking) and 14:00 h (i.e. peak lunch rise 1 h after lunch) and treated the 18:30 and 22:30 h observations from day 1 as if they had been collected on

examined correlations among the different measures of cortisol. Morning rise and waking day cortisol concentration were moderately correlated, $r=0.31$, $p<0.01$; but slope was not correlated with either waking day cortisol concentration, $r=0.05$; or morning rise, $r=-0.12$. Table 4 presents the correlations between the affect and cortisol measures.

Because the cortisol measures were obtained when the participants were in the hotel, the associated change from a normal routine could have disrupted health behaviors known to influence

cortisol. Sleep quality was somewhat affected, with 35% of the participants reporting decreased quality, 52% reporting the same quality, and 13% reporting improved quality compared with sleep at home. However, the relationships between cortisol and affect are not attributable to average sleep quality, hotel sleep quality, or change in sleep quality influencing both cortisol and affect. Smoking behavior during quarantine was essentially unchanged from the baseline period, with a coefficient $\kappa$ of 0.91.

In analyses with only the five covariates in the models, sex was associated with both waking day cortisol concentration, B=0.04 (SE=0.02, 95% CI=0.00, 0.08), t(305)=2.03, p<0.04, and morning rise, B=−3.52 (SE=1.12, 95% CI=−5.72, −1.32), t(305)=−3.15, p<0.01. Compared with men, women had lower waking day cortisol concentration but higher morning rise. Month was associated with waking day cortisol concentration but not morning rise. Compared with December, cortisol levels were higher in May, B=0.08 (SE=0.03, 95% CI=0.02, 0.14), t(305)=2.78, p<0.01. Race was associated with waking day cortisol concentration, such that Caucasians had higher levels than non-Caucasians, B=−0.06 (SE=0.02, 95% CI=−0.11, −0.02), t(305)=−2.96, p<0.01. Neither age nor average morning wake up time was associated with any variable.

## 3.2. Are trait and state affect associated with cortisol?

### 3.2.1. PA

There was a state PA by sex interaction for waking day cortisol concentration, B=0.09 (SE=0.04, 95% CI=0.02, 0.16), F(1,296)=6.86, p<0.01. Simple effects analyses revealed that higher state PA was associated with lower waking day cortisol concentration in women only, B=−0.07 (SE=0.02, 95% CI=−0.11, −0.02), t(153)=−2.95, p<0.01 (see Fig. 1).

In the multilevel model used to analyze cortisol slope, there was an interaction of trait PA by sex by time, B=−0.02 (SE=0.01, 95% CI=−0.04, −0.01), F(1,2127)=6.62, p<0.01. Cortisol levels for men low in trait PA did not decrease in the afternoon, resulting in a relatively high, flat rhythm. In contrast, women high in trait PA had low morning cortisol resulting in a low flat rhythm (see Fig. 2). In pairwise comparisons comparing men and women high in trait PA, the women were significantly lower than the men at every time point until 16:00 h, B=0.18–0.16, (SE=0.08–0.07, 95% CI=0.04–0.31, 0.01–0.31), t(2141)=Fig. i1(than)-597.9(t3.2(t

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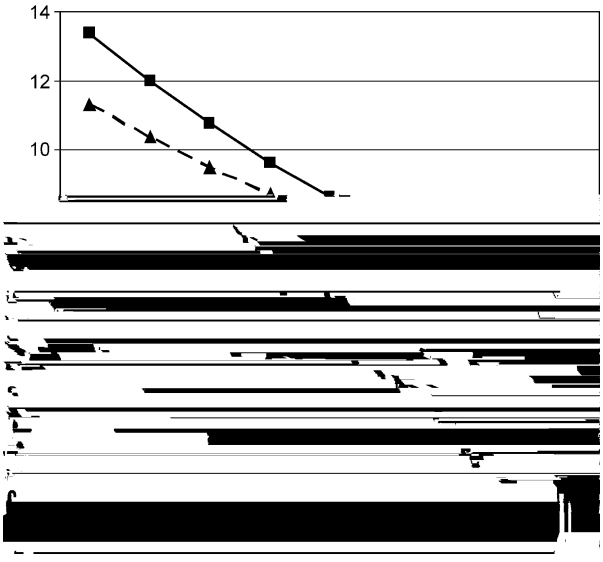


Figure 3 Cortisol as a function of state PA and time.

0.03), F(1,2132)=6.29, p<0.01, such that higher state PA was associated with a flatter slope through lower morning values (see Fig. 3).

Neither trait nor state PA was associated with morning rise.

#### 3.2.2. NA

Higher trait NA was associated with higher waking day cortisol concentration, B=0.04 (SE=0.01; 95% CI=0.01, 0.06), F(1,300)=9.01, p<0.01.

In morning rise, there was an interaction of trait NA by sex, B=3.44 (SE=1.37, 95% CI=0.75, 6.13) F(1,299)=6.36, p<0.01. Lower trait NA was associated with lower morning rise among men, B=2.01 (SE=0.62, 95% CI=0.79, 3.23), t(142)=3.26, p<0.01, (see Fig. 4). This association remained when controlling for the cortisol level at awakening (i.e. 5:45 a.m.).

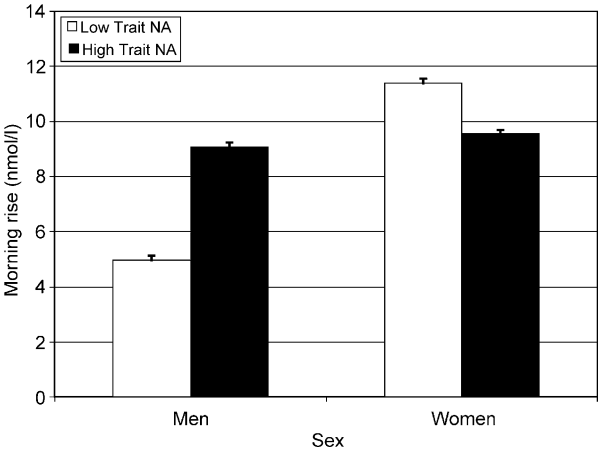


Figure 4 Morning rise amplitude as a function of trait NA and sex.

State NA was not associated with any measure of cortisol.

### 3.3. Do different measures of cortisol provide separate components of explanatory power in affect?

The degree to which different measures of cortisol provide separate components of explanatory power in affect can be examined for trait NA, with which both waking day cortisol concentration and morning rise were associated. To address this question, we regressed trait NA on each cortisol variable controlling for the other cortisol variable and the standard covariates. Regardless of the order of entry, each cortisol measure and its interaction with sex were significantly associated with higher trait NA. In either model, the estimates were quite similar. Trait NA was associated with waking day cortisol concentration, B=1.01 (SE=0.47, 95% CI=0.09, 1.92), t(300)=2.15, p<0.03; waking day cortisol concentration by sex, B=−0.11 (SE=0.68, 95% CI=−1.46, 1.23), t(300)=−0.17, p>0.05; morning rise, B=0.02 (SE=0.01, 95% CI=0.00, 0.05), t(300)=2.08, p<0.04; morning rise by sex, B=−0.04 (SE=0.01, 95% CI=−0.06, −0.01), t(300)=−2.63, p<0.01.

### 3.4. Are there cross-valence affect interactions?

We examined cross-valence affect interactions for their effects on the cortisol responses. There was no evidence for cortisol moderation by trait–trait, state–state, or trait–state cross-valence interactions.

## 4. Discussion

### 4.1. Are trait and state affect associated with cortisol response?

#### 4.1.1. Waking day cortisol concentration

In general, PA was associated with lower concentrations of cortisol and NA with higher concentrations. However, one association was moderated by sex. Waking day cortisol concentration was associated with state PA only in women. It is not clear why PA's biggest association was in women. Because men and women did not differ in mean levels or variances of state PA, neither the magnitude nor variation in the affective responses can account for the sex differences. It may be that men and women have different biological responses to PA

that in turn mediate the cortisol response. For example, oxytocin is thought to increase (especially in females) in response to positive affiliative

sizes we obtained are smaller than the true magnitude of the associations.

### 4.2. Do different measures of cortisol provide separate components of explanatory power in affect?

In analyses predicting trait NA, waking day cortisol concentration and morning rise each contributed separate components of explanatory power, which suggests that these relationships are attributable to different mechanisms.

### 4.3. Are there cross-valence affect interactions?

There was no evidence for cortisol moderation by trait–trait, state–state, or trait–state cross-valence interactions. Recently it has been proposed that PA might have the ability to 'undo' the effects of NA on physiological responses (Fredrickson, 2001). Our failure to document such an interaction is inconsistent with that hypothesis.

### 4.4. Which is more closely associated with cortisol, state or trait affect?

Most of the associations were obtained with trait affect measures and not state affect measures. This suggests that deviations may be less important than overall level. On the other hand, the associations obtained with trait affect were not also obtained with state affect and vice versa. We conclude from this that although trait affect may be more closely associated with cortisol in general, when state affect is associated with cortisol, it accounts for a unique portion of the variance. Additionally, we note that the deviations we obtained were small. If data were collected under conditions resulting in

based on measures from only 1 day; thus the reliability of the results for state affect may be less than that of results in studies that employed multiple assessments of state affect and cortisol. This could have lessened our power to detect significant associations in these analyses. Third, although we examined the association of cortisol with affect varying in tonic-phasic and valence distinctions, there are additional affective distinctions such as activation that we did not examine.

Finally, the generalizability of the findings must be considered. For example, the participants in the present study were carefully screened for good health; hence extrapolation of our findings may be limited to healthy people. Additionally, generalizability may be limited because some of the data were collected when participants were under quarantine. With respect to affect, however, when the state affect scores are standardized (i.e. in standard deviation units), each of the state affect scores is well within one standard deviation of each person's mean (i.e. zero), suggesting that the quarantine did not markedly disrupt affect. As reported above, smoking was similarly unaffected, and sleep was only moderately affected. Because we assessed cortisol only on the day of quarantine, we have no non-quarantine day with which to compare it.

In conclusion, although most research to date has conceptualized cortisol as a physiological measure of stress and NA, our results suggest that it may af(-)i

McCarthy, M.M., 1995. Estrogen modulation of oxytocin and its relation to behavior, in: Ivell, R., Russell, J. (Eds.), Oxytocin: Cellular and Molecular Approaches in Medicine and Research. Plenum Press, New York, pp. 235–242.