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Salivary cortisol changes in humans after winning or losing a dominance contest depend on implicit power motivation

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Abstract

In two studies, one with an all-male German sample and the other with a mixed-sex U.S. sample, subjects competed in pairs on reaction time-based cognitive tasks. Participants were not aware that contest outcome was experimentally varied. In both studies, implicit power motivation, defined as the non-conscious need to dominate or have impact on others, predicted changes in salivary cortisol from before to after the contest. Increased cortisol post-contest was associated with high levels of power motivation among losers but with low levels of power motivation among winners, suggesting that a dominance success is stressful for low-power individuals, whereas a social defeat is stressful for high-power individuals. These results emerged only in participants tested in the afternoon, possibly because of greater variability in cortisol in the morning due to the rapid decline after the morning peak. These studies add to the evidence that individual differences greatly influence whether a social stressor like losing a contest activates the HPA axis in humans.

Keywords: Implicit motives; Power motivation; Personality; Salivary cortisol; HPA axis; Social defeat; Humans

Introduction

The hypothalamic–pituitary–adrenal (HPA) axis responds to both physical and psychological stressors by increasing glucocorticoid release. In social species, social stressors can be potent elicitors of HPA activation. Social defeat, in particular, appears to be tied to alterations in HPA response. Generally, animals show a rise in glucocorticoids following social defeat and chronically higher glucocorticoid levels when in subordinate positions. For example, in rats, losing aggressive encounters leads to higher levels of corticosterone (Bhatnagar and Vining, 2003); in baboons, higher ranking males have lower basal cortisol levels than lower ranking males (Sapolsky et al., 1997). In humans as well, there is some evidence that lower social rank contributes to higher basal cortisol (Decker, 2000).

Social stressors are commonly used to elicit HPA activation in human studies, such as the Trier Social Stress Test (TSST; Kirschbaum et al., 1993), which reliably induces increased cortisol in human subjects (e.g., Pruessner et al., 1997). However, the relationship between social dominance and HPA responsiveness appears to be complex and has not been fully explored in humans. In particular, the question of how the HPA axis responds to social victory and defeat in humans has not been answered. In contrast to the animal research reviewed above, which reliably documents cortisol increases in the losers of aggressive or dominance-related encounters, studies with human subjects in which effects of naturally occurring or experimentally manipulated contest outcomes were examined have failed to find post-contest cortisol differences between winners and losers (e.g., Booth et al., 1989; Gladue et al., 1989; McCaul et al., 1992; Salvador, 2005). This null effect is particularly remarkable because in many of these studies, clear differences between winners and losers were obtained in other hormonal and behavioral variables, suggesting that dominance contests and their outcomes are important and consequential for humans; some actually document a post-contest cortisol increase in all participants (e.g., Booth et al., 1989; Gladue et al., 1989; Gonzalez-Bono et al., 1999). This suggests that dominance contests, both naturally occurring or staged in the

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laboratory, can engage the HPA axis, but that the contest outcome (victory or defeat) per se does not determine whose cortisol levels increase and whose do not. In the present research, we therefore proceed on the assumption that individuals differ in the extent to which they experience a defeat as stressful or a victory as soothing and that differential effects of dominance contest outcomes on cortisol cannot be found unless such individual differences are taken into account.

Consistent with the notion that individual differences moderate the physiological stress response, studies on primates show that individual differences in personality and behavioral style predict differences in HPA axis functioning. In baboons, Sapolsky and colleagues have reported that lower ranking males who displace aggression onto a third party after a conflict have lower basal cortisol levels, more similar to dominants (Virgin and Sapolsky, 1997). In humans, aside from the well-known HPA axis alterations found in clinical populations, such as patients with depression and post-traumatic stress disorder, a number of studies with healthy subjects have demonstrated that individual differences related to coping style and perceived control over one's environment can predict levels of cortisol (e.g., Brown et al., 1996; Pruessner et al., 1997). A person's interpretation of a stressful situation or stimulus determines how the HPA axis responds to that stimulus. For example, in a study of teachers, perceived stress predicted higher basal cortisol levels, while "burnout" predicted lower cortisol (Pruessner et al., 1999). Other personality and individual difference variables also modify HPA axis function: to name several examples, temperament in children has been related to HPA axis responses to stressors (e.g., Davis et al., 1999); a harm-avoidant disposition predicted cortisol response to a pharmacological challenge in adults (Gerra et al., 2000); extraversion and openness were related to greater ACTH response to the TSST (Oswald et al., 2004); selective attention to angry face stimuli correlated with cortisol response to those stimuli (Van Honk et al., 2000); and men from different American subcultures have different cortisol responses to an identical insult (Cohen et al., 1996).

The present research further extends the notion that individual difference variables are crucial for understanding variations in the cortisol response to stress and examines the idea that the degree to which individuals seek dominance could influence their cortisol response to victory or defeat in a dominance contest. This drive for dominance is reflected in individual differences in implicit power motivation; that is, in the non-conscious need to have impact on others (McClelland, 1975; Winter, 1973). Past research shows that those high in power motivation respond to power-related stressors (such as oral exams) with greater release of epinephrine and norepinephrine (for a review, see McClelland, 1989). However, the effect of power motivation on HPA axis function has not been examined so far. Likewise, it is unclear how the outcome of dominance challenges (i.e., victory or defeat) affects the stress response in power-motivated individuals. We hypothesized that power motivation would be a crucial personality factor in predicting the HPA axis response to a social victory or defeat. Individuals who are high in power motivation, and therefore desire to have impact on others, should be more invested in the outcome of a dominance challenge than people who are low in this dispositional variable. Therefore, we hypothesized that losing a contest against another person would be more stressful for and hence lead to greater cortisol release in high-power motivation individuals relative to low-power motivation individuals. Consistent with the lack of significant cortisol differences between contest winners and losers in past research, we did not expect to find a main effect of contest outcome on cortisol changes. We tested these hypotheses in both a German (all male; Study 1) and a U.S. (male and female; Study 2) sample, each using a different type of reaction time-based cognitive task for the contest. In order not to conflate the experience of winning or losing with actual performance, contest outcome was experimentally manipulated. While effects of circadian changes in cortisol on the results were held relatively constant in Study 1 by running sessions only in the afternoon, we used Study 2 to explore whether circadian differences in HPA activation moderated our predicted effects.

Study 1: Materials and methods

Subjects

Sixty-six male students of a vocational college in Potsdam, Germany (mean age 23.8 ± 0.4 years) participated in this study in pairs (one randomly pre-designated winner and one loser); participants within the pairs were not previously acquainted with one another. Participants had refrained from eating and oral hygiene for at least 1 h prior to the start of the study. Sessions were scheduled either at 1:45 pm or 4:00 pm, in an effort to minimize cortisol variations due to circadian rhythmicity. Sessions lasted approximately an hour and a half, for which participants were paid 35 Deutschemark (~$15 U.S.). Results for contest-induced testosterone changes in this sample have been reported previously (Schultheiss and Rohde, 2002).

Design

Experimentally varied contest outcome (win versus lose) and individual differences in power motivation were the independent variables, and cortisol change from before to after the contest was the dependent variable in this study.

Procedure

Each session was run by a male experimenter and consisted of a pre-contest, a contest, and a post-contest phase. In the pre-contest phase, participants provided a saliva sample (T1, at 0 min) and then completed a picture story exercise (PSE; 25-min duration) for assessment of implicit motives. Participants provided a second saliva sample (T2, at 60 min) and then listened to a 12-min tape-recorded goal imagery exercise vividly describing the course of the ensuing contest from the winner's perspective (cf. Schultheiss, 2001), and provided a third saliva sample (T3, at 75 min). During the contest phase, participants competed against each other on 12 forms of a Number Tracking Task (NTT), a speed-based cognitive task requiring participants to trace a line with a pen to make a continuous path through consecutive numbers on a grid filled with distractor numbers (contest duration: 10 min). The outcome of the contest was rigged so that the designated winner won eight times and the designated loser only four times (for details, see Schultheiss and Rohde, 2002). In the post-contest phase, participants collected three additional saliva samples (T4 at 95 min, T5 at 110 min, and T6 at 130 min) while working on additional materials and tasks. Suspicion checks indicated that participants were not aware that contest outcome was rigged. Afterward, participants were fully debriefed about the hypotheses underlying the study and the manipulations employed.

Picture story exercise (PSE)

The PSE was administered to participants using standard instructions described in Smith (1992). It consisted of five pictures that have been widely used in research on implicit motives. Participants had 5 min to write each story. Stories were later coded for power motive imagery according to Winter's (1994) Manual for Scoring Motive Imagery in Running Text. Two trained scorers, who had previously attained at least 85% agreement with training materials pre-scored by experts and contained in the Manual, independently coded each participant's stories. Their inter-rater reliability across all stories was 84%, as estimated by the index of concordance. Participants wrote, on average, 388 ± 10 words, with an average of 3.67 ± 0.25 power images. Participants' power scores were corrected by regression for total word count, which correlated significantly with power scores ($P < 0.05$), and the residuals were converted to z scores. These standardized scores were used in subsequent data analyses.

Salivary cortisol assay

At each sampling point, participants used a fresh sugar-free chewing gum to collect between 2 and 10 ml saliva in a sterile polypropylene vial and then removed the chewing gum (Dabbs, 1991). Vials were closed and frozen immediately at the end of each data collection session. Samples were freed from mucopolysaccarides and other residuals by three freeze–thaw cycles with subsequent centrifugation. Salivary cortisol levels were determined by solid-phase ^{125}I radioimmunoassays (Coat-A-Count, Diagnostic Products Corp. Biermann, Bad Nauheim, Germany). Cortisol was measured using 400 µl saliva samples in combination with water-diluted standards (analytical range: 0.5 to 50 ng/ml) and overnight incubation at room temperature. Saliva samples obtained at 7 am and at 9 pm from a male participant showed the expected diurnal variation, with 13.76 ng/ml at 7 am and 2.18 ng/ml at 9 pm. Averaged across three assays, intra-assay coefficients of variation for these samples were 5.0% and 9.4% and inter-assay coefficients of variation were 8.6% and 22.2%. Overall intra-assay coefficient of variation for participant samples was 11.6%. Sensitivity of the assay (B0-3 SD) was at 0.37 ng/ml. Parallelism checks indicated that relative to water or serum standards, saliva as a matrix did not affect the measurement of known amounts of cortisol.

Data analysis

All analyses for this and the second study were conducted with SYSTAT 10 and involved regression and correlation analysis. When higher order effects were tested for significance, all lower order effects were controlled for first. Descriptive statistics are given as mean ± SEM unless otherwise indicated. All tests were conducted two tailed.

Study 1: Results

Descriptive statistics for power motivation and raw cortisol data are presented in Table 1. Salivary cortisol data at all six time points were not normally distributed (skewed towards zero); therefore, log-transformed cortisol levels are used for all analyses.

Table 1
Descriptive statistics for participants' power motivation (z scores) and untransformed salivary cortisol levels (in ng/ml) in Study 1

	Winners	Losers
Power motive (M, SD)	−0.09 (0.99)	0.09 (1.00)
Cortisol T1 (Md, range)	4.81 (1.59–10.34)	4.75 (1.75–44.24)
Cortisol T2 (Md, range)	3.14 (1.06–19.14)	3.98 (1.05–37.89)
Cortisol T3 (Md, range)	3.19 (0.72–19.35)	2.92 (0.86–29.34)
Cortisol T4 (Md, range)	3.20 (1.16–18.50)	3.18 (0.85–21.88)
Cortisol T5 (Md, range)	2.95 (0.96–16.58)	2.36 (0.95–30.51)
Cortisol T6 (Md, range)	2.29 (0.85–13.71)	2.22 (0.44–11.25)

Measurements T1–T3 are pre-contest.

A repeated measures regression of win/lose condition (WIN) and word-corrected power motivation scores (POWER) on the six log-transformed cortisol variables revealed a significant interaction between WIN, POWER, and the repeated measure variable before versus after the contest, $F(1,62) = 5.33$, $P = 0.024$. This interaction effect was not moderated by session starting time. Also, variation of cortisol within the three measurements before or after the contest was not a significant factor, allowing aggregation by averaging together the three pre-contest cortisol values ($M = 1.33$, SD = 0.58) and the three post-contest cortisol values ($M = 1.08$, SD = 0.70). Subsequent analyses were performed on the resulting aggregated cortisol variables. There was no effect of POWER, WIN, or the WIN × POWER interaction on pre-contest cortisol. Next, a regression analysis was performed on post-contest cortisol using WIN and POWER as factors and pre-contest cortisol as a covariate. A significant main effect of WIN emerged, $F(1,63) = 4.18$, $P = 0.045$, indicating that winners ($M = 1.19$) had higher adjusted post-contest cortisol levels than losers ($M = 0.98$). However, this main effect was superseded by a WIN × POWER interaction on post-contest cortisol, $T(61) = -2.30$, $P = 0.025$.

Investigating this interaction further, we found a positive correlation between POWER and the cortisol residuals (variance in post-contest cortisol after controlling for pre-contest cortisol), among losers, $R = 0.411$, $P = 0.017$. This relationship was not present among winners, $R = -0.158$, $P = 0.380$ (Fig. 1). Thus, implicit power motivation predicted cortisol increases in losers, but not in winners of the contest.

Study 2: Materials and methods

Subjects

One hundred sixteen undergraduate and graduate students of the University of Michigan (mean age 20.3 ± 0.3 years) participated in this study in same-sex pairs (one randomly pre-designated winner and loser); again, participants within the pairs were not previously acquainted with one another. Psychology majors were not admitted to the study. Five participants had missing data and were discarded from analysis, and three had recently participated in a similar study with false contest feedback and so were excluded, leaving data from a total of 108 participants (53 women and 55 men). For women, an average of 18.5 days had elapsed since the onset of the last menstruation, and 14 women reported currently using birth-control pills. Participants had refrained from eating and oral hygiene for at least 1 h prior to the start of the study. In order to explore effects of circadian changes in cortisol release on cortisol changes induced by victory and defeat, we scheduled sessions to start between 10:30 am and 4:30 pm, with a duration of 2.5 h. Participants were paid a total of $35 for their participation. The study had received prior approval by the University of Michigan Institutional Review Board.

Design

Experimentally varied contest outcome (win *versus* lose), individual differences in power motivation, and time of day were the independent variables and cortisol change from before to after the contest was the dependent variable in this study.

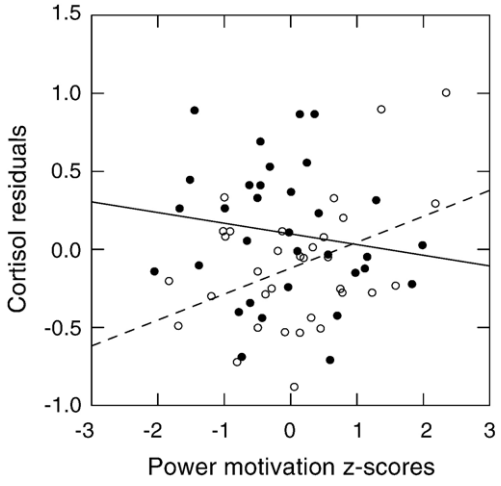

Fig. 1. Study 1 (all-male, German sample): cortisol residuals (post-contest log-corrected cortisol adjusted for pre-contest log-corrected cortisol) as a function of implicit power motivation (*z* scores), for contest winners (closed circles, solid line) and losers (open circles, dashed line).

Procedure

Sessions were run by a single male or female experimenter. As part of hypotheses unrelated to those reported here, participants were administered, in a double-blind fashion, 200 mg caffeine or placebo (vitamin C) at the beginning of the study. In the pre-contest phase, participants provided a saliva sample (T1, at 0 min), then completed a PSE (25 min duration) and other tasks. Next, the experimenter announced that participants would compete against each other in a contest based on the serial response task (SRT), described below. Participants then provided a second saliva sample (T2, at 52 min), listened to a 10-min tape-recorded goal imagery exercise vividly describing the course of the ensuing contest from the winner's perspective (cf. Schultheiss, 2001) and provided a third saliva sample (T3, at 64 min) while working on another task.

During the contest phase, participants competed against each other on 10 rounds of the SRT, with a total duration of 10 min. The SRT required participants to quickly and accurately respond to asterisks (*) presented sequentially in four different screen positions by pressing one of four response keys mapped to those screen positions. The experimenter explained to participants that after each round, the computers would calculate their performance scores based on their speed and accuracy on the SRT and then compare their results to determine the winner of a round. Each round started with a screen announcing the round number, followed by a countdown. Participants then worked on the SRT for 50 s. After that, they saw a black screen featuring the words "Calculating and comparing scores..." for 2 s, followed by either a green screen with the words "You have won this round" and accompanied by a jubilant jingle or a red screen with the words "You have lost this round" and accompanied by a low-frequency snarling tone for 2 s, followed by a blank screen that retained the color of the feedback screen (3 s). Participants in the winning condition "won" all rounds except for the second and the fifth, and participants in the losing condition correspondingly "lost" all rounds except for the second and the fifth.

In the post-contest phase, participants collected fourth, fifth, and sixth saliva samples (T4, at 78 min, 0 min post-contest; T5, at 93 min, 15 min post-contest; T6, at 108 min, 30 min post-contest) while completing other tasks unrelated to the results reported here. Finally, they completed a background-data questionnaire, and a suspicion check in the form of an open-ended questionnaire asking for anything they had noted about the study. No included participants demonstrated awareness that the contest outcome was rigged. Participants were fully debriefed about the hypotheses underlying the study and the manipulations employed at the end of the session.

Picture story exercise (PSE)

The PSE was administered to participants and scored by a trained scorer for power motive imagery as described in Study 1. The PSE consisted of 5 pictures: boxer (from McClelland and Steele, 1972); women in the laboratory; man talking to ship captain (both from Smith, 1992); a protester throwing a stone; and two bicyclists racing in front of an enthusiastic crowd (the latter two pictures were selected for their aggressive and competitive character and used here for the first time.) A trained scorer coded PSE protocols for power motive imagery as described in Study 1. The scorer had previously exceeded 85% agreement with training materials pre-scored by experts and contained in the Manual. Participants wrote, on average, 527 ± 11 words, with an average of 5.86 ± 0.24 power images. Participants' power scores were corrected by regression for PSE protocol length, which correlated significantly with power scores ($P < 0.05$), and the residuals were converted to *z* scores. These standardized scores were then used in further analyses.

Salivary cortisol assay

Collection and processing of saliva and radioimmunoassay for cortisol were performed as in Study 1. Low- and high-concentration saliva pools yielded averages of 2.30 and 9.31 ng/ml cortisol. Average inter-assay coefficient of variation for these pools was 9.8%. Average intra-assay coefficient of variation was 5.5%. Average lower limit of detection (B0-3 SD) of the assays was 0.023 ng/ml.

Study 2: Results

Descriptive statistics for power motivation and raw cortisol data are presented in Table 2. Salivary cortisol data at all six time points were not normally distributed; therefore, log-transformed cortisol levels are used for all analyses.

Table 2
Descriptive statistics for participants' power motivation (*z* scores) and untransformed salivary cortisol levels (in ng/ml) in Study 2

	Before 2:00 p.m.		After 2:00 p.m.	
	Winners	Losers	Winners	Losers
N	32	31	22	23
Men/women	14/18	14/17	14/8	13/10
Power motive (M, SD)	0.02 (0.88)	−0.00 (0.81)	0.06 (1.42)	−0.08 (0.96)
Cortisol T1 (Md, range)	3.38 (1.08–15.92)	2.85 (0.76–7.32)	1.85 (0.85–13.83)	2.16 (0.77–8.47)
Cortisol T2 (Md, range)	2.61 (0.59–8.30)	1.76 (0.51–9.08)	1.66 (0.74–4.31)	1.52 (0.82–5.46)
Cortisol T3 (Md, range)	2.29 (0.58–8.58)	1.53 (0.53–4.55)	1.67 (0.72–4.34)	1.81 (0.69–3.95)
Cortisol T4 (Md, range)	2.43 (0.47–8.28)	1.90 (0.47–6.10)	2.13 (0.97–6.74)	1.68 (0.61–4.82)
Cortisol T5 (Md, range)	2.60 (0.43–10.68)	1.95 (0.45–9.54)	1.88 (0.74–6.31)	1.50 (0.62–5.75)
Cortisol T6 (Md, range)	2.31 (0.53–8.48)	1.91 (0.48–7.12)	1.56 (0.67–4.78)	1.29 (0.52–4.45)

Measurements T1–T3 are pre-contest.

Repeated measures regression of caffeine condition on the six log-transformed cortisol variables revealed a marginally significant positive effect of caffeine on cortisol, $F(1,103) = 3.83$, $P = 0.053$. Therefore, caffeine condition was controlled for in subsequent analyses. There was no effect of participant sex on cortisol.

We first regressed power motivation (POWER), contest outcome (WIN) and time of day (TIME) on the six cortisol measures. We found a significant four-way interaction between these three factors and the repeated-measure variable before versus after the contest, $F(1,96) = 4.30$, $P = 0.041$, which was not significantly moderated by caffeine condition, sex of participant or, in women, use of birth-control pills or menstrual cycle day. The effect of WIN × TIME was not significant, indicating that winners' and losers' cortisol levels were not differentially affected by time of day. In follow-up analyses, we were able to trace the 4-way interaction effect back to a significant interaction between WIN (contest outcome), POWER (word-corrected power motivation scores), and the before/after contest factor on cortisol in participants tested after 2:00 pm ($N = 45$), $F(1,40) = 5.25$, $P = 0.027$. In a regression performed on participants tested prior to 2:00 pm ($N = 63$), the WIN by POWER by before/after interaction was not significant, $P > 0.1$. (There is a precedent for lesser effects of acute stressors on cortisol release in humans in the morning; see Discussion and Dickerson and Kemeny, 2004).

In the post-2:00 pm analysis, variation of cortisol within the three measurements before or after the contest was not a significant factor, allowing aggregation by averaging together the three pre-contest cortisol values ($M = 0.64$, SD = 0.43) and the three post-contest cortisol values ($M = 0.51$, SD = 0.54). A regression analysis was performed on post-contest cortisol using WIN and POWER as factors and pre-contest cortisol as a covariate. This revealed a significant WIN by POWER interaction on post-contest cortisol, controlling for pre-contest cortisol, $T(41) = -2.19$; $P = 0.034$. Again, this interaction was not moderated by caffeine condition, sex, or women's hormonal status. The correlation between power motivation and cortisol residuals did not reach significance in the losing condition, $R = 0.299$, $P = 0.166$. In the winning condition, a negative correlation between power motivation and cortisol residuals reached the level of a trend, $R = -0.386$, $P = 0.076$ (Fig. 2).

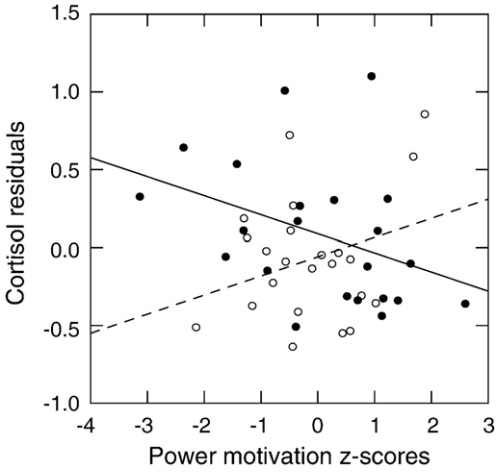

Fig. 2. Study 2 (mixed sex, American sample): cortisol residuals (post-contest log-corrected cortisol adjusted for caffeine condition and pre-contest log-corrected cortisol) as a function of implicit power motivation (z scores), for contest winners (closed circles, solid line) and losers (open circles, dashed line). Only data from subjects tested after 2:00 pm are shown here.

Study 2 replicates the WIN by POWER interaction on post-contest cortisol, controlling for pre-contest cortisol, found in Study 1. In addition, according to a comparison between Fisher's Z transformations of correlation coefficients, the correlation coefficients among losers in the two studies are not significantly different, $Z = 0.447$, $P = 0.326$, and neither are they different among winners, $Z = 0.843$, $P = 0.198$. Thus, Study 2 replicates Study 1's positive relationship between power motivation and cortisol residuals in contest losers. Though they are non-significant, the relationships between power motivation and cortisol residuals in winners are also similar in size and direction across the two studies.

Meta-analysis

Since the WIN by POWER interaction was found in both studies, and correlation coefficients for power motivation and cortisol residuals are similar in size and direction between the two studies, we conducted an internal meta-analysis. After conversion of log-corrected pre-contest and post-contest cortisol scores and power motive levels to z scores separately within each study (from Study 2, only data from participants tested after 2:00 pm were standardized and included), we combined data from both studies to test the reliability of the conjoint effect of contest outcome and power motivation on cortisol changes ($N = 111$). A regression analysis on post-contest cortisol, with WIN and POWER as factors and pre-contest cortisol as a covariate, revealed a highly significant interaction of WIN and POWER on post-contest cortisol, $T(110) = -3.33$; $P = 0.001$. The correlation between POWER and the cortisol residuals (variance in post-contest cortisol after controlling for pre-contest cortisol) was significant and positive among contest losers, $R = 0.343$, $P = 0.009$. In addition, there was a negative correlation between POWER and cortisol residuals among contest winners, $R = -0.272$, $P = 0.044$. Thus, both contest losers highest in power motivation and contest winners lowest in power motivation had an increase in cortisol post-contest.

Discussion

In an all-male German sample tested in the afternoon (Study 1), we found that cortisol changes after a contest depended on desire for dominance, as measured by implicit power motivation. Among contest losers, those higher in power motivation had increased cortisol after the contest, whereas power motivation and cortisol increases showed a non-significant negative relationship in winners. In a mixed-sex, U.

S. sample (Study 2), a similar pattern of results held for participants tested in the afternoon: power motivation was a marginally significant negative predictor of cortisol increases among winners, and it had a non-significant positive relationship with cortisol increases among losers. When data from Study 1 and Study 2 were combined in a meta-analysis, both the positive relationship between power motivation and cortisol increase among contest losers and the negative relationship between power motivation and cortisol change among contest winners were significant.

These findings support our hypothesis predicting a greater cortisol increase in response to social defeat in individuals high in power motivation, a disposition characterized by a desire to have impact on others, compared to individuals low in this motive. Furthermore, this effect was found in two studies, each with a different nationality of participants, and each using a slightly different task on which participants "competed". Thus, the dependence of cortisol changes in losers of a contest on power motivation does not seem to be task- or culture-specific, although a wider range of cultures and types of competition could be tested in the future. The effect also appeared to be the same in both sexes; in Study 2, which employed both male and female participants, sex was not a moderator of the effect. However, more controlled studies directly comparing men and women would have to be conducted to verify this.

An intriguing finding that we had not directly predicted was that in contrast to high-power individuals, participants low in power motivation had *increased* cortisol after winning the contest and *decreased* cortisol after losing the contest. This finding suggests that low-power motivation scores may not so much reflect indifference towards dominance but to actually indicate a tendency to find dominance aversive and avoid it (see Schultheiss, in press; Schultheiss et al., 2005). Indeed, developmental research has demonstrated that severity of parental punishment for aggressive behaviors during childhood predicts low levels of power motivation on the PSE measure in adulthood (McClelland and Pilon, 1983). Thus, individuals low in power motivation may have learned at an early age to avoid exercising dominance over others. Regardless of its origin, however, such a "fear of power" would be reflected not only in an avoidance of themes of dominance and power when telling stories in response to PSE picture cues suggesting power and aggression but also in a greater HPA activation in response to successful exertion of power (such as winning a contest) and perhaps greater HPA axis deactivation in response to successful avoidance of a dominant position (such as losing a contest) (see Newman et al., 2005, and Schultheiss et al., 2005, for related arguments regarding testosterone and dominance). The fact that the cortisol responses of low-power participants were the exact reverse of the cortisol responses of high-power participants may explain why we did not observe any net cortisol increase at the end of the contest, and why differential effects of winning and losing on cortisol have remained elusive in many previous studies.

It is important to note that the interaction between change in cortisol and power motivation was only found in the afternoon. In Study 1, all testing was performed in the afternoon; in Study 2, the relationship only held for participants tested in the afternoon. It could be the case that rapidly dropping cortisol levels in the few hours following the circadian rhythm-driven morning peak "drown out" the cortisol response to a moderate stressor, such as losing a contest. This idea gains support from an extensive meta-analysis of studies examining changes in cortisol in humans after various acute stressors; overall, a greater effect of acute stressors on cortisol is seen in the afternoon (Dickerson and Kemeny, 2004).

The present findings dovetail with our previously reported research on testosterone responses to contest outcomes in the same participants. It was found in the German study that implicit power motivation predicted testosterone increases among contest winners low in activity inhibition (Schultheiss and Rohde, 2002). In separate studies using U.S. samples, implicit power motivation again predicted testosterone increases in male winners, as well as testosterone decreases in male losers. The relationship between contest outcome, power motivation and testosterone in women was quite different (Schultheiss et al., 2005). In men, at least, it would seem that high-power motivation leads to a testosterone increase and a cortisol decrease after victory, and a testosterone decrease and cortisol increase after a defeat. This pattern of opposite effects on testosterone and cortisol fits with a large body of literature on inhibitory effects of the HPA axis on the hypothalamic–pituitary–gonadal (HPG) axis, as well as evidence of inhibitory effects of testosterone on the HPA axis (e.g., Viau, 2002). It is possible that, in male participants, the testosterone decrease we observed in high-power losers could be due in part to the increased cortisol in these individuals, and/or that the decreased cortisol in high-power winners was due in part to increased testosterone. For a more extensive discussion of inter-relationships between cortisol and testosterone in these contest studies, see Schultheiss (in press).

Importantly, a main effect of contest outcome on cortisol in Study 1 was superseded by the interaction between contest outcome and power motivation, and in Study 2, there was no main effect of contest outcome. This is as predicted. If subjects high and low in power motivation respond in opposite ways to each contest outcome, we should not expect main effects of contest outcome on cortisol when these two groups are combined. Other studies of neuroendocrine responses to competition, such as those reviewed by Salvador (2005), have concluded that increased cortisol to competition, regardless of outcome, is seen only when an "active" rather than "passive" coping strategy to competition is adopted. This conclusion is in line with ours in that the individual's interpretation of a dominance challenge is an important factor in determining HPA axis response, but different in that contest outcome does not emerge as important in Salvador's review. These studies differ from ours, however, in two respects. First, ability levels and victory are conflated in the physical contests covered in Salvador's review, whereas in our studies we de-coupled these factors by artificially manipulating contest outcome. Second, our competitions were non-strenuous, whereas those covered in Salvador (2005) and many others in the literature are athletic in nature. Such physically taxing competitions would presumably

have very different effects on stress hormones like cortisol whose function is to mobilize energy. Therefore, it is difficult to compare findings from this body of research to the present studies.

In conclusion, losing a contest against a stranger in a laboratory setting does not appear to be a uniformly stressful experience in terms of HPA axis response; it increased cortisol only in people who strive for dominance. In fact, for those who do not strive for dominance, winning may actually be more stressful than losing. In addition to highlighting the importance of implicit power motivation as a personality variable which plays a role in determining physiological responses to social stimuli, our findings suggest that caution should be exercised in assuming a given social stressor will be uniformly stressful to all individuals, or likewise that a social success is rewarding and non-stressful for all people. This conclusion is also underscored by our failure to find a main effect of contest outcome on cortisol changes in Study 2, as well as a large body of literature documenting null effects of dominance contest outcomes on cortisol responses. As our present research shows, such null effects of situational variables on hormonal changes may actually mask complex person-by-situation interactions.

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References

Bhatnagar, S., Vining, C., 2003. Facilitation of hypothalamic–pituitary–adrenal responses to novel stress following repeated social stress using the resident/intruder paradigm. Horm. Behav. 43 (1), 158–165.

Booth, A., Shelley, G., Mazur, A., Tharp, G., Kittok, R., 1989. Testosterone, and winning and losing in human competition. Horm. Behav. 23 (4), 556–571.

Brown, L.L., Tomarken, A.J., Orth, D.N., Loosen, P.T., Kalin, N.H., Davidson, R.J., 1996. Individual differences in repressive–defensiveness predict basal salivary cortisol levels. J. Pers. Soc. Psychol. 70 (2), 362–371.

Cohen, D., Nisbett, R.E., Bowdle, B.F., Schwartz, N., 1996. Insult, aggression, and the southern culture of honor: an "experimental ethnography". J. Pers. Soc. Psychol. 70 (5), 945–960.

Dabbs, J.M., 1991. Salivary testosterone measurements: collecting, storing, and mailing saliva samples. Physiol. Behav. 49, 815–817.

Davis, E.P., Donzella, B., Krueger, W.K., Gunnar, M.R., 1999. The start of a new school year: individual differences in salivary cortisol response in relation to child temperament. Dev. Psychobiol. 35 (3), 188–196.

Decker, S.A., 2000. Salivary cortisol and social status among Dominican men. Horm. Behav. 38 (1), 29–38.

Dickerson, S.S., Kemeny, M.E., 2004. Acute stressors and cortisol responses: a theoretical integration and synthesis of laboratory research. Psychol. Bull. 130 (3), 355–391.

Gerra, G., Zaimovic, A., Timpano, M., Zambelli, U., Delsignore, R., Brambilla, F., 2000. Neuroendocrine correlates of temperamental traits in humans. Psychoneuroendocrinology 25 (5), 479–496.

Gladue, B.A., Boechler, M., McCaul, K.D., 1989. Hormonal response to competition in human males. Aggress. Behav. 15, 409–422.

Gonzalez-Bono, E., Salvador, A., Serrano, M.A., Ricarte, J., 1999. Testosterone, cortisol, and mood in a sports team competition. Horm. Behav. 35 (1), 55–62.

Kirschbaum, C., Pirke, K.-M., Hellhammer, D.H., 1993. The 'Trier Social Stress Test'—a tool for investigating psychological stress responses in a laboratory setting. Neuropsychobiology 28, 76–81.

McCaul, K.D., Gladue, B.A., Joppa, M., 1992. Winning, losing, mood, and testosterone. Horm. Behav. 26, 486–504.

McClelland, D.C., 1975. Power: The Inner Experience. Irvington Publishers, New York.

McClelland, D.C., 1989. Motivational factors in health and disease. Am. Psychol. 44, 675–683.

McClelland, D.C., Pilon, D.A., 1983. Sources of adult motives in patterns of parent behavior in early childhood. J. Pers. Soc. Psychol. 44 (3), 564–574.

McClelland, D.C., Steele, R.S., 1972. Motivational Workshops. General Learning Press, New York.

Newman, M.L., Sellers, J.G., Josephs, R.A., 2005. Testosterone, cognition, and social status. Horm. Behav. 47 (2), 205–211.

Oswald, L.M., Mathena, J.R., Wand, G.S., 2004. Comparison of HPA axis hormonal responses to naloxone vs psychologically-induced stress. Psychoneuroendocrinology 29 (3), 371–388.

Pruessner, J.C., Gaab, J., Hellhammer, D.H., Lintz, D., Schommer, N., Kirschbaum, C., 1997. Increasing correlations between personality traits and cortisol stress responses obtained by data aggregation. Psychoneuroendocrinology 22, 615–625.

Pruessner, J.C., Hellhammer, D.H., Kirschbaum, C., 1999. Burnout, perceived stress, and cortisol responses to awakening. Psychosom. Med. 61, 197–204.

Salvador, A., 2005. Coping with competitive situations in humans. Neurosci. Biobehav. Rev. 29, 195–205.

Sapolsky, R.M., Alberts, S.C., Altmann, J., 1997. Hypercortisolism associated with social subordinance or social isolation among wild baboons. Arch. Gen. Psychiatry 54, 1137–1143.

Schultheiss, O.C., 2001. An information processing account of implicit motive arousal. In: Pintrich, P.R., Maehr, M.L. (Eds.), Advances in Motivation and Achievement, vol 12. New Directions in Measures and Methods. JAT/Elsevier, Amsterdam, pp. 1–41.

Schultheiss, O.C., in press. A biobehavioral model of implicit power motivation arousal, reward and frustration. In: Harmon-Jones, E., Winkielman, P. (Eds.), Fundamentals of Social Neuroscience. Guilford, New York.

Schultheiss, O.C., Rohde, W., 2002. Implicit power motivation predicts men's testosterone changes and implicit learning in a contest situation. Horm. Behav. 41 (2), 195–202.

Schultheiss, O.C., Wirth, M.M., Torges, C.M., Pang, J.S., Villacorta, M.A., Welsh, K.M., 2005. Effects of implicit power motivation on men's and women's implicit learning and testosterone changes after social victory or defeat. J. Pers. Soc. Psychol. 88 (1), 174–188.

Smith, C.P., 1992. Motivation and Personality: Handbook of Thematic Content Analysis. Cambridge Univ. Press, New York.

Van Honk, J., Tuiten, A., van den Hout, M., Koppeschaar, H., Thijssen, J., de Haan, E., Verbaten, R., 2000. Conscious and preconscious selective attention to social threat: different neuroendocrine response patterns. Psychoneuroendocrinology 25 (6), 577–591.

Viau, V., 2002. Functional cross-talk between the hypothalamic–pituitary–gonadal and –adrenal axes. J. Neuroendocrinol. 14 (6), 506–513.

Virgin Jr., C.E., Sapolsky, R.M., 1997. Styles of male social behavior and their endocrine correlates among low-ranking baboons. Am. J. Primatol. 42, 25–39.

Winter, D.G., 1973. The Power Motive. Free Press, New York.

Winter, D.G., 1994. Manual for Scoring Motive Imagery in Running Text, 4th ed. Department of Psychology, University of Michigan, Ann Arbor. (Unpublished manuscript).