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ScienceDirect
Hormones and Behavior 50 (2006) 393 – 400
Hormones and Behavior
www.elsevier.com/locate/yhbeh

Interspecies hormonal interactions between man and the domestic dog (*Canis familiaris*)

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Received 6 March 2006; revised 20 April 2006; accepted 28 April 2006
Available online 19 June 2006

Abstract

To date, hormonal influence in interspecies interaction has not been examined. In a study of a dog agility competition among human/dog teams, men's pre-competition basal testosterone (T) levels were positively related to changes in dogs' cortisol levels from pre- to post-competition, but only among losing teams. Furthermore, pre-competition basal T in men on losing teams predicted more than half of the variance in dogs' cortisol change. This relationship was mediated through men's punitive and affiliative behaviors towards their dogs immediately after competition. Men's T change was also a significant predictor of dogs' change in cortisol such that men who experienced greater decreases in T after a loss were associated with dogs that experienced greater increases in cortisol. In winning teams, men's pre-competition T and T changes were unrelated to dogs' cortisol changes. These results are discussed in light of T as a proxy for dominance motivation as well as T's relation to stress across the species boundary.

Keywords: Competition; Testosterone; Cortisol; Dog; *Canis familiaris*; Men; Interspecies interaction

Hormones have been shown to regulate social behavior within a species. In many species, testosterone (T) activity is associated with frequency of behaviors aimed at obtaining high status (Beaver and Amoss, 1982; Cavigelli and Pereira, 2000; Oliveira et al., 1996). The typical response to a status threat among animals with higher T is an aggressive response, whether direct physical fighting or ritualized postural displays.

Cortisol may also be associated with changes in the frequency of social behaviors. High cortisol levels mark elevated stress and can occur when an individual, for example, loses a competition (DeVries et al., 2003; Pottinger and Carrick, 2001; Rosal et al., 2004; Ruis et al., 2001; Vedhara et al., 2000; see Dickerson and Kemeny, 2004 for a meta-analysis of laboratory studies). Elevation in cortisol may deter a losing individual from competing again. Social conditions such as support, avoidance, and antagonism exacerbate or dampen hormonal changes, especially in such stressful situations (DeVries et al., 2003; Heinrichs et al., 2003; Kaiser et al., 2003; Rosal et al., 2004; Ruis et al., 2001; Stoney and Finney, 2000; Vedhara et al., 2000).

Of course, social interactions are not limited to within-species interactions. Many different types of interspecies social interactions, from predation to cooperation, occur frequently (Alcock, 2005; Drickamer et al., 1996). Humans interact with many species in contrived situations (e.g., zoos) and situations similar to those found in nature (e.g., hunting, pets). However, these interactions are not always positive (i.e., people often abuse pets, wildlife).

Hormones play powerful roles in within-species interactions (e.g., mating, aggression) by influencing behavior and behavior frequency; they seem likely to play a role in interspecies interaction. This issue has received little empirical attention. People have the potential to influence stress in other animals, but very little research has examined how people's hormone levels influence their behavior and, in turn, hormonal changes in other animals. In one study to examine this link, Dreschel and Granger (2005) found a non-significant relationship between owners' behavior during a simulated thunderstorm and thunderstorm phobic dogs' cortisol change.

In the current study, we investigated the existence of a relationship between hormones, social behavior, and another species' hormone change in a stressful situation. Specifically, we examined the relationship between men's T levels and their

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0018-506X/$ - see front matter © 2006 Elsevier Inc. All rights reserved.
doi:10.1016/j.yhbeh.2006.04.007

behavior towards their dogs after a competition between human/dog teams, then we examined whether men's behavior related to their dogs' cortisol changes.

A small-but-growing literature suggests, in addition to a link between T change and behavior, a link between basal T and status-linked behavior. A recent review (Archer, 2006) showed basal and pre-competition T mark an individual difference in tendency towards aggressive and dominant behaviors but that pre-competition T is a stronger predictor (e.g., Salvador et al., 1999; Berman et al., 1993). Single measures of T have been shown to reliably predict status-related behaviors across a variety of situations (e.g., prison, Dabbs et al., 1995; Dabbs and Hargrove, 1997; and the laboratory, Grant and France, 2001; van Honk et al., 1999). More recently, Josephs and his colleagues (e.g., Josephs et al., 2003, in press; Newman et al., 2005) showed that basal T significantly predicted status-related behaviors, but only when status was seen as uncertain. As a whole, these studies suggest basal T as a strong predictor of behavior both within and outside the confines of the laboratory.

Relative to T, the roles of cortisol are better understood. The release of cortisol is adaptive and healthy when the stressor is an immediate challenge (e.g., being chased by a predator) because it helps energize the body (Sapolsky, 2004; Selye, 1978). Consistently, high levels of cortisol, however, have been linked to illness. Changes in cortisol secretion may also be a consequence of illness, but an important current hypothesis is that the activation of the stress system could contribute to the onset of illness (e.g., McEwen, 1998).

Attempts to link testosterone activity with cortisol activity have not been reported. However, a useful analogue exists among individuals with high implicit power motives. For these individuals, who are argued to encode competitive loss as a dominance threat (see Josephs et al., in press; Schultheiss et al., 2005; Wirth et al., 2006), reaction to loss can be especially stressful (e.g., DeVries et al., 2003; Wirth et al., 2006). Wirth et al. (2006) found, for example, that high implicit power motivation was positively related to cortisol increases in losers, but not in winners. Losers high in implicit power motivation might transfer this elevation in stress to others, especially if others are seen as responsible for the loss.

In this study, we examined the question of whether the frustration and stress of a competitive loss presumably experienced by a subset of male dog handlers would be transferred onto others. Our study was in the context of a dog agility competition, allowing us to investigate species that commonly interact. We examined handlers' pre-competition T, their T after they learned the outcome of the competition, and their post-competition social behavior towards their dogs. We also examined dogs' cortisol levels before the competition and following a period of post-competition interaction with the handlers.

Materials and methods

In a dog agility competition, people ("handlers") work closely with their dogs, guiding the dogs through an obstacle course without a leash or physical contact. To win the competition, teams complete the course quickly and with minimal faults (e.g., deviations or improper manoeuvres). Teams are disqualified if they fail to complete the course and for aberrant behaviors. Teams that earn a minimum of 85 (of 100) points by completing the agility course in minimal time, with minimal faults, earn qualifying scores. Qualifying scores must be earned three times at each of three levels of competition before a team advances to the next level. In the current study, teams that earn qualifying scores were considered to have won the competition. Teams that did not earn qualifying scores were considered to have lost the competition. Teams that were disqualified were excluded from analyses. All protocols for recruitment and treatment of subjects in this study exceeded the safety and ethical guidelines put forth by the University of Texas's Internal Review Board, Institutional Animal Care and Use Committees, and were further overseen by the North American Dog Agility Council, Inc.

Subjects

A total of 184 handler/dog teams volunteered to take part in this study. Winning and losing male handlers (N = 83) and their dogs (56 males, 27 females) were examined; disqualified teams were excluded from further analyses. Handlers varied in age from 20 to 65 years old (mean = 44.45, SD = 9.99) and their dogs from 2 to 7 years old (mean = 3.64, SD = 1.37).

Questionnaire information

After completing their run of the agility course, but before receiving results about the outcome of the competition, handlers filled out a series of questionnaires. The questions included inquiries about their and their dogs' health (e.g., were they on any medications?), their dogs' breed information, basic demographic information, the number of competitions they had competed in as a team, in how many of those competitions they had performed well, and various ratings of how they felt about the agility run they had just completed.

Saliva sampling

Pre-competition saliva samples were taken from the 83 handler/dog teams an hour and a half (mean = 93.28 min, SD = 3.66) before the teams competed. After all teams at a given level of competition had finished, results of the competition were publicly posted. Post-competition salivary samples were collected approximately 20 min (mean = 20.35, SD = 2.84) after each team had received these results. All salivary samples were taken between 12 p.m. and 3 p.m. to control for circadian declines in T (Granger et al., 1999).

For both pre- and post-competition saliva sampling, human subjects chewed sugar-free gum to stimulate salivation; they then drooled 2.5 mL of saliva into a sterile polypropylene microtubule. Dogs' saliva samples were collected by having dogs chew on sterile polypropylene gauze. Prior to analysis, the dogs' saliva was extracted from the gauze by centrifuge. Although non-invasive canine hormone sampling has rarely been used, salivary cortisol values in dogs are highly correlated with plasma cortisol values (Vincent and Michell, 1992) and have the benefits of being easily done outside the laboratory and being minimally stressful for the dogs (e.g., Dreschel and Granger, 2005).

Immunoassay

All saliva samples were closed and frozen immediately after collection to avoid hormone degradation and to precipitate mucins. Saliva was separated from residuals (e.g., mucins) by thorough mixing by vortex followed by centrifugation at 3000 rpm for 15 mins.

For purpose of the current investigation, T in humans' samples was measured through enzyme immunoassay of salivary samples using assay kits produced by Salimetrics (State College, Pennsylvania) and cortisol in dogs' samples using assay kits produced by Diagnostic Systems Laboratory, Inc. (Webster, Texas). We also assayed humans' saliva samples for cortisol levels and dogs' saliva samples for T levels. These measures will be used to address research questions that are outside the scope of the current paper and will, as a consequence, not be discussed further in this paper. The assay kits produced by Diagnostic Systems Laboratory, Inc. were validated for assay of canine salivary cortisol by comparing in-house canine salivary and blood serum cortisol levels. In every assay, for both species, seven known control concentrations were included, in addition to two samples of unknown concentrations from in-house salivary samples.

For both species and both hormones assessed, every salivary sample was assayed at least twice to establish test–retest reliability. Inter-assay CVs for assays conducted in our laboratory average is 8.7%. For the salivary samples in this study, intra-assay coefficient of variation (CV) across paired control samples of known concentration was never more than 4.57%. Intra-assay CV across paired control samples of unknown concentration never exceeded 5.06%. If intra-assay CV across paired test samples varied more than 7.5%, the samples were assayed again. This occurred for only 7 of 184 humans' samples, and 3 of 184 dogs' samples.

Computing hormone change scores

We controlled for pre-competition levels when computing change scores for both handlers' T and dogs' cortisol levels. To compute handlers' change in T scores, we saved the unstandardized residuals of a regression analysis with pre-competition T as the predictor and post-competition T as the dependent variable. To compute dogs' change in cortisol scores, we saved the unstandardized residuals of a regression analysis with pre-competition cortisol as the predictor and post-competition cortisol as the dependent variable. The saved unstandardized residuals of each computation were then used as change scores for that hormone. These hormone change scores have the benefit of being able to be interpreted in the original units (e.g., T in pg/mL). This method for calculating hormone change scores has been used in previous research on hormone changes in competition (e.g., Schultheiss et al., 2005); it is conceptually equivalent to conducting an analysis of covariance (ANCOVA) controlling for pre-competition hormone levels, which has also been used in previous studies (e.g., Gladue et al., 1989).

Results and discussion

We examined whether, in losing teams, men's pre-competition T and/or T change (controlling for pre-competition T levels) would predict their dogs' change in cortisol from pre- to post-competition. To gain a fuller understanding of the influence of T, we also looked at T as a predictor of competitive outcome as well as examining T's relationship to the men's behavior.

T as a predictor of competitive win or loss

The mean pre-competition T level among losers was 120.12 pg/mL, and the mean pre-competition T level among winners was 126.72 pg/mL. A logistic regression using handlers' pre-competition T to predict competitive outcome (win or loss) indicated that pre-competition T was a significant predictor of outcome such that higher levels of pre-competition T significantly predicted winning ($\beta = 0.001$, $P = 0.031$; $\chi^2 = 4.647$, $P = 0.031$).

T change in handlers

Controlling for pre-competition T levels, the average change in T (from pre- to post-competition) among the 40 losers in this competition was a decrease of 7.92 pg/mL. Changes ranged from a decrease of 82.99 pg/mL to an increase of 39.44 pg/mL. Losing handlers' change in T after a loss was significantly predicted by pre-competition T, even when controlling for pre-competition T levels ($t = -2.933$; $P = 0.006$; $R^2 = 0.185$). Among men who lost, higher pre-competition T predicted a larger decrease in T from pre- to post-competition.

The pattern was reversed among winners. Controlling for pre-competition T levels, the average change in T (from pre- to post-competition) among the 43 winners in this competition was an increase of 17.21 pg/mL. Changes ranged from a decrease of 26.67 pg/mL to an increase of 113.48 pg/mL. Handlers' change in T after a win was significantly predicted by pre-competition T, even controlling for pre-competition T levels ($t = 3.940$; $P < 0.001$; $R^2 = 0.275$). Among men who won, higher pre-competition T predicted a larger increase in T from pre- to post-competition.

Pre-competition T as a predictor of dogs' cortisol change

After a loss, handler pre-competition T was a significant predictor ($t = 6.273$, $P < 0.001$) of change in dogs' cortisol level from pre- to post-competition such that higher handler pre-competition T leads to a larger increase in the dogs' cortisol and predicted 50.9% ($R^2 = 0.509$) of the variance in change in dogs' cortisol. In contrast, after a win, handler pre-competition T was not a significant predictor ($t = 1.461$, $P = 0.152$; $R^2 = 0.0495$) of dogs' change in cortisol from pre- to post-competition (Fig. 1).

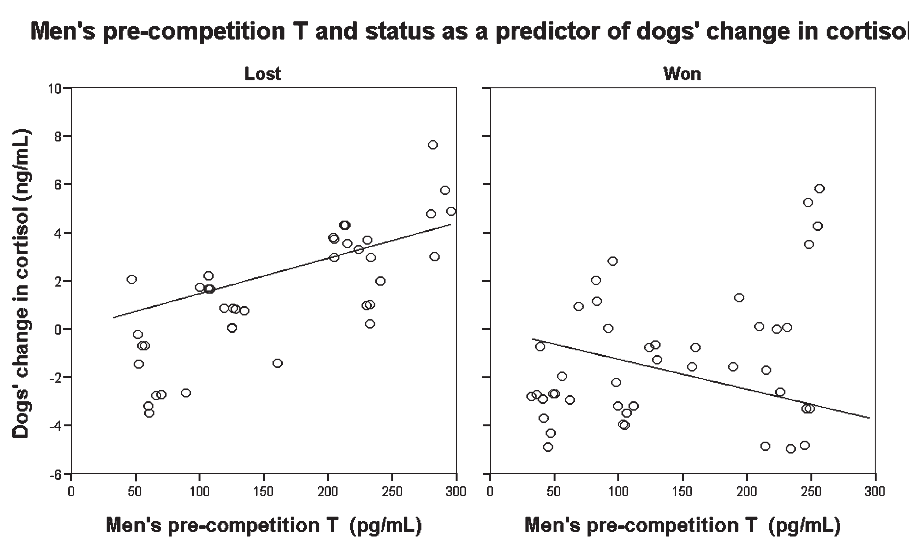

Fig. 1. Handler pre-competition T and status as predictors of dogs' change in cortisol.

Table 1
Fifteen behaviors most frequently shown by handlers towards their dogs after competition

Petting head, neck, chin	Person extends hand to touch and pet (not hit) dog above the collar
Petting body	Person extends hand to touch and pet (not hit) dog anywhere else on body
Yelling	Person speaks loudly (often using negative phrases) while looking towards dog
Making eye contact	Person looks into dog's face and eyes; dog may look away
Pushing	Person extends hand to push dog in a non-playful way; dog may or may not lose a step, be moved
Making large gestures	Person gestures (may or may not be speaking) with arms extended out from body at about 60° angle or greater
Making small gestures	Person makes small gestures (e.g., pointing) towards dog
Standing still	Person stands still and does not interact with dog
Pulling dog/leash	Person pulls on dog's leash (e.g., walking away, reprimanding)
Playing	Person actively attempts to play with dog; may include pushing playfully, large gestures, yelling but often accompanied by smiling, laughing, hugging, dog responding playfully
Holding/carrying	Person picks up and carries dog or holds/hugs dog
Greeting people	Person and/or dog approach and interact with other person or people
Praising	Person praises dog (e.g., good boy!) or speaks to dog in high-pitched or fluctuating voice
Crating	Person places dog in crate and leaves dog in crate
Giving treats	Person gives dog food treats

The relationship between pre-competition T and post-competition behavior

To test whether the effect found in losing teams was influenced by the handlers' behaviors towards their dogs, we systematically coded the handlers' behavior during the period immediately following the competition. The handlers and dogs all interacted for a few minutes after completing the agility course. This gave us the opportunity to videotape, for later analysis, the handlers' behavior towards their dogs immediately after completing the course before the handlers received official results about their team's performance.

Three trained researchers, blind to how well each team had performed, coded the length of time each handler engaged in each of the 15 most common behaviors, described in Table 1 (inter-rater reliability = 90.2%; in cases of disagreement, times were averaged).

Among winners, none of the behaviors was found to significantly correlate with both handlers' pre-competition T and dogs' change in cortisol. Furthermore, winners' pre-competition T did not significantly predict any of the behaviors.

In losing teams, four behaviors were found to significantly correlate with both handlers' pre-competition T and with dogs' change in cortisol. These behaviors–playing with the dog; petting the dog's head, ears, neck or chin; physically pushing the dog; and yelling at the dog–form two intuitively logical and meaningful pairs. We labeled the first pair "affiliative behaviors," composed of playing with the dog and petting the dog's head, ears, neck or chin; more time spent engaging in affiliative behaviors was associated with a lesser increase in dogs' cortisol. We labeled the second pair "punitive behaviors," composed of physically pushing the dog and yelling at the dog; more time spent engaging in punitive behaviors was and associated with a larger increase in dogs' cortisol. Among losing handlers, pre-competition T strongly negatively predicted time spent in affiliative behaviors ($t = -4.147$, $P<0.001$; $R^2 = 0.312$) and strongly positively predicted time spent in punitive behaviors ($t = 3.478$, $P = 0.001$; $R^2 = 0.242$). Thus, higher pre-com-

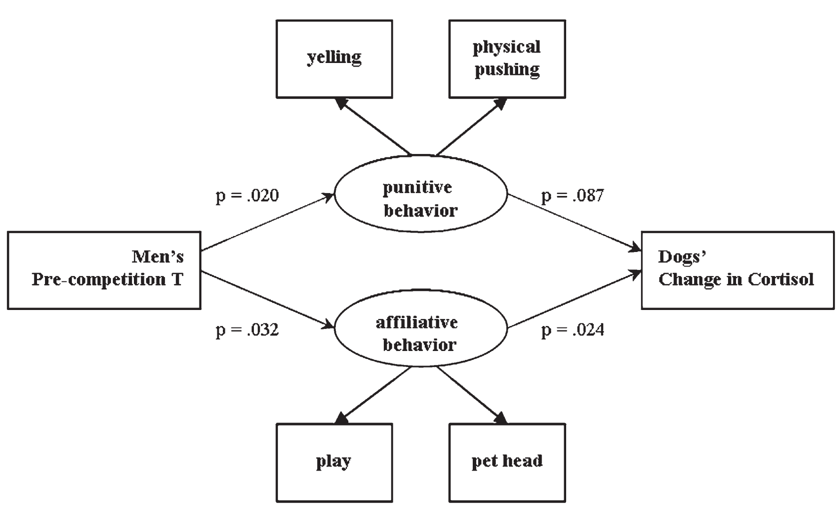

Fig. 2. Structure equation pathway model. Three of the four pathways are statistically significant at $P < 0.05$, and the fourth (Punitive behavior to dogs' change in cortisol) is marginally significant ($P = 0.087$).

petition T levels were associated with less time spent engaging in affiliative behaviors but more time spent engaging in punitive behaviors.

Structural equation modeling of the handlers' T–dogs' cortisol relationship

The organization of behaviors into clearly punitive and affiliative behaviors also implied a Structural Equation Model with two latent variables (affiliative and punitive behaviors; Fig. 2). The RMSEA fit statistic for this model was <0.001, indicating a superior fit (≤0.05 indicates a good fit; Browne and Cudeck, 1993). Similarly, the Goodness of Fit Index for this model indicates a close fit of 0.958 (a perfect fit is 1). Each of the two latent variables has two measured indicator variables, affiliative and punitive behaviors, as described above.

Men's T change as a predictor of dogs' cortisol change

In addition to pre-competition T, we also tested men's T change as a predictor of their dogs' cortisol changes. Handlers' change in T from pre- to post-competition (controlling for pre-competition T levels) was a significant predictor ($t = -2.349$, $P = 0.024$; $R^2 = 0.127$) of change in dogs' cortisol level from pre- to post-competition (see Fig. 3). The larger a decrease in T a handler experienced, the greater an increase in cortisol his dog experienced. Handlers' change in T, however, accounted for less of the variance in dogs' change in cortisol than did handlers' pre-competition T ($R^2 = 0.127$ vs. $R^2 = 0.509$, respectively). This difference in amount of variance accounted for was statistically significant ($t = 2.553$, $P = 0.013$).

After a win, handlers' change in T was not a significant predictor ($t = -1.713$, $P = 0.094$; $R^2 = 0.007$) of change in dog cortisol from pre- to post-competition. Thus, handlers' T, whether basal or change, was not a useful predictor of dogs' change in cortisol among winning teams.

Differences between winners and losers

Were the individuals who lost the competition different from those who won? We argued that, after a victory, handler T was not a predictor of handlers' post-competition behavior and their dogs' change in cortisol because handlers' dominance needs were not threatened or challenged. An alternative explanation is that handlers who won and lost this competition differ from each other on a trait or dimension associated with vulnerability to the stress of competition.

In the current analyses, we found that handlers' pre-competition T was a significant predictor of competition outcome such that handlers' with higher pre-competition T were more likely to win. This is the expected result because higher levels of T are associated with increased frequency of behaviors aimed at obtaining high status (Beaver and Amoss, 1982; Cavigelli and Pereira, 2000; Oliveira et al., 1996). However, this difference between groups does not predict the pattern of results revealed by the present study.

Another factor that could serve to distinguish the two groups is competitive history. Handlers accustomed to winning (because of a history of many wins) might be more reactive to loss than handlers whose competitive histories include more losses than wins; those most accustomed to loss may appear to show a blunted response to loss. To examine whether the winners and losers had different performance histories, we looked at the rate at which participants reported having won or performed well in past competitions. Data were analyzed using Poisson regression; the Poisson regression model revealed no significant difference ($P = 0.29$) in rate of wins between winning and losing handlers in the current competition, suggesting that performance history cannot explain the T differences observed for winners and losers.

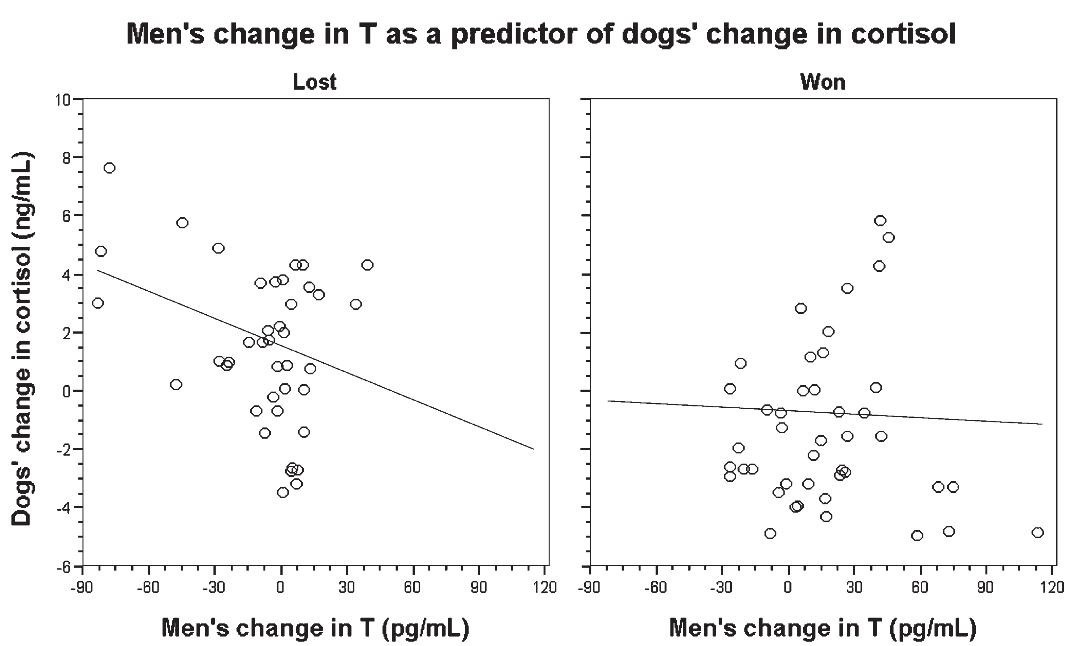

Fig. 3. Handler change in T from pre-competition to post-competition as a predictor of dogs' change in cortisol.

Age and experiential factors within losing teams

Dogs on the losing teams varied greatly in age, from 2 to 7 years, and thus whether they had differences in experience that explain the differences in their cortisol change scores must be considered. Specifically, dogs with less competitive experience might find the competition more stressful and thus have a larger change in cortisol. To examine this, we ran a Pearson correlation in which we examined the relationship between losing dogs' change in cortisol (controlling for pre-competition levels) and the number of competitions their handlers reported they had competed in as a team. We did not find a significant relationship between the two variables ($r = 0.263$; $P = 0.101$).

Handlers also varied greatly in age, ranging from 20 to 65 years old, so that handlers' age could also be a potential variable or confound. To addressing this question, we first looked at whether there was a relationship between handlers' age and win/loss status. We found that losing handlers had a mean age of 44 years (SD = 8.6 years), and winning handlers had a mean age of 45 years (SD = 11 years). Results from a *t* test indicated that there is not a significant difference in age between the two groups ($t = -0.409$; $= 0.684$). Second, we looked at whether age was related to pre-competition T levels. A Pearson's correlation revealed no significant relationship between the age and pre-competition T ($r = 0.009$; $P = 0.932$). Next, we looked at losing teams to examine whether the relationship between testosterone and post-competition behavior might be age-determined. We did not run a parallel analysis of winning teams because our study revealed a decoupling of T level and behavior in winners. Specifically, we examined whether including age in the analysis allows us to predict more of the variance in the behavior of men who lost. To assess this, we ran a simultaneous regression with both age and pre-competition T as predictors of time spent in affiliative behavior after a loss. The regression was significant ($F = 9.920$; $P < 0.001$). The statistics associated with the coefficients on the predictors indicated that pre-competition T (beta $= -0.465$, $t = -3.163$, $P = 0.003$) was a significant predictor, but age (beta $= -0.215$, $t = -1.459$, $P = 0.153$) was not. The addition of age as a predictor variable did not substantially increase the amount of variance for which we were able to account. The regression with only pre-competition T as a predictor accounts for 31.2% of the variance ($R^2 = 0.312$), and the regression with both predictors accounts for 34.9% of the variance ($R^2 = 0.349$). This difference of 3.7% is not significant ($F = 2.129$; $P = 0.153$).

In light of recent controversy surrounding the lack of a relationship between basal T and dominance (see, e.g., the commentaries following Mazur and Booth's 1998 review article; also, Archer, 2006), we were surprised by the relative predictive power of pre-competition T in predicting both men's behavior and dogs' change in cortisol. After a competitive loss, men's pre-competition T predicted more than 50% of the variance in stress-related hormone changes of individuals of another species. The higher a man's pre-competition T, the larger an increase in cortisol his dog was likely to experience if the human/canine team experienced a loss. However, given the sizeable number of findings showing weak or null effects of T on behavior, why did we observe such a large effect?

Recent research has suggested that T is a proxy for implicit power and dominance motives (Schultheiss et al., 2005; Wirth et al., 2006). Both high T and high implicit power have in turn been linked to the perception of a competitive loss as a dominance threat (see Josephs et al., 2003; Josephs et al., in press; Newman et al., 2005; Schultheiss et al., 2005; Wirth et al., 2006). Recent research has also indicated that men high in pre-competition T are especially stressed by a loss (e.g., DeVries et al., 2003; Wirth et al., 2006). In the current study, men with high pre-competition T may have become especially frustrated when they found out that their team lost the competition, which not only represents a loss of status but also a loss of an opportunity to compete again to regain status. Indeed, for men high in pre-competition T, the experience of a competitive loss translated into real-world behaviors—an increase in punitive behaviors (physical pushing, yelling), a decrease in affiliative behaviors (playing with the dog, petting the dog), and a marked increase in cortisol levels in their dogs.

Although still quite speculative, one possibility for the great variability in effect sizes that is seen across the literature might be the presence/absence of such moderating variables as status threat or status uncertainty (i.e., the competitive situation involving risk of losing or chance of gaining status). Josephs et al. (in press) showed that, when status is threatened, basal T correlates strongly with behavior (effect sizes of greater than one standard deviation were observed). However, when status was not threatened, no such relationship existed. How much of the variability in effect sizes these moderating variables can explain has yet to be determined.

Although not as strong a predictor as pre-competition basal T, men's T change also significantly predicted change in dogs' cortisol level from pre- to post-competition. The larger a decrease in T a handler experienced after a loss, the greater an increase in cortisol his dog experienced. Mazur and Booth (1998) theorized that increases and decreases in T levels reflected satisfaction and frustration in the drive for dominance. Falling T levels might reflect this frustration, which in turn might help to explain the relationship to dogs' changes in cortisol. Furthermore, this explanation ties in nicely with the idea that pre-competition T is a strong predictor of post-competition behavior and dogs' change in cortisol.

Despite the strength of this study's findings, the design of the study has notable limitations and weaknesses. First, the study's primary strength may also be its primary weakness—we observed a naturally occurring competition. Because we were unable to manipulate the competition, we were not able to randomly assign participants to conditions. We were (as discussed above) able to rule out the possibility that the losing group was more vulnerable to stress as a function of differences in histories of win and loss between the two groups. However, we were unable to rule out the possibility that the losing participants might be psychologically more vulnerable to stress for other reasons.

Second, because we were unable to randomly assign dogs to handlers, we are limited in the degree to which we can draw causal inferences about handlers' pre-competition T in predicting dogs' cortisol change. There may be other factors, related to or unrelated to pre-competition T levels, that influenced cortisol change. Such factors may include the dogs' health history and variations in lifestyle.

Third, our statistical analysis of the role of the moderators (e.g., yelling, petting the dog's head) led us to the implicit conclusion that all dogs react to each behavior in the same way. However, given that each dog is a unique individual with a different life history, it is to be expected that some dogs would be stressed by having their heads petted, others would be soothed, and still others would be unaffected. The current study does not have the statistical power to study these individual differences. A detailed and comprehensive examination of the dog–human interactions taking more individual variations in both species into account would certainly provide a richer understanding of these issues.

Fourth, consistent with most research on T and aggression, our study included only men. Future research should test whether our findings generalize to interactions involving women or whether women show a different pattern of behavior. The few studies that have examined women's behavior found that T levels do predict a variety of behaviors in women (e.g., social dominance, Cashdan, 1995; cognitive performance, Josephs et al., 2003; physiological arousal, van Honk et al., 2001). Other studies have shown that women's T levels also change from pre- to post-competition. However, research on stress and social behavior in women (e.g., Taylor et al., 2000) suggests that women respond to stress, such as that surrounding a competition, by showing an increase in affiliative behaviors, whereas men show a fight or flight response and are more likely to respond aggressively when stressed. This suggests that, if women were examined in the conditions of the current study, women who lost might show more affiliative behaviors. Clearly, more research is needed to examine the role of hormones and sex differences in social behavior under stress.

Weaknesses of the current study aside, the elevated level of cortisol in dogs after a loss suggests that man is not always dog's best friend. The consequences of repeated social interaction with a man who is experiencing a competitive loss and who has a high or rising T level may be hazardous to the health of the dog. Given the frequency of dog–human interactions, some people's dependence on dogs, and society's professed love of dogs, minimizing these negative effects should be a high priority. A dog who suffers frequently elevated cortisol levels may suffer the associated illnesses, including degradations in their ability to serve in high-stress roles (e.g., as guide dogs, police dogs).

The current findings suggest stress-reduction interventions designed to lessen the likelihood and severity of stress reactions in working and companion animals. Such interventions may take the form of teaching people to consciously regulate their behavior. The experience of hormonal change is probably not a conscious one, but people may be able to learn to detect it and associate changes in effect. The goal would be to avoid showing behaviors that would then increase stress in others. To do so, a person could be trained to show affiliative behaviors (e.g., playing with or petting the dog) when experiencing an especially frustrating event, such as a loss of status or dominance.

These findings may have implications beyond the interactions between humans and companion animals. It should be considered whether these types of patterns may occur in interactions between parents and children and whether similar interventions would be useful and effective in parent–child social interactions.

Acknowledgments

Preparation of this article was supported by an NSF research grant to Robert A. Josephs and an NSF fellowship to Amanda C. Jones. We are also indebted to Kerri Sharp for her help with data collection, to Yvon Delville and Pranjal Mehta for their help with hormone analyses and feedback, and to Greg Hixon for his statistical expertise.

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