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Sex differences in cortisol's regulation of affiliative behavior

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ABSTRACT

A contribution to a special issue on Hormones and Human Competition.
A stress perspective is used to illuminate how competitive defeat and victory shape biology and behavior. We report a field study examining how change in cortisol following perceived defeat (vs. victory) in a competition—in this case, a dog agility competition—relates to affiliative behavior. Following competition, we measured cortisol change and the extent to which dog handlers directed affiliative behaviors toward their dogs. We found striking sex differences in affiliation. First, men were more affiliative toward their dogs after victory, whereas women were more affiliative after defeat. Second, the greater a female competitor's increase in cortisol, the more time she spent affiliating with her dog, whereas for men, the pattern was the exact opposite: the greater a male competitor's increase in cortisol, the less time he spent affiliating with his dog. This pattern suggests that, in the wake of competition, men and women's affiliative behavior may serve different functions—shared celebration for men; shared consolation for women. These sex differences show not only that men and women react very differently to victory and defeat, but also that equivalent changes in cortisol across the sexes are associated with strikingly different behavioral consequences for men and women.

1. Introduction

Across many species, competition is influential for establishing social hierarchies (Chase, 1980). Furthermore, because it is the cumulative result of repeated competitive interactions that ultimately determines dominance rank, the eventual social hierarchy depends not only on whether one wins or loses but also on how one *responds to* winning and losing (Chase, 1980; Chase et al., 2002). For example, so-called winner and loser effects (e.g., winning increasing the probability of winning future contests; Chase et al., 1994) help explain why dominance hierarchies tend to be more linear—that is, marked by clear transitive relationships (e.g., *A* outranks *B,* who outranks *C*, and, critically, *A* outranks both *B* and *C*)—than would be expected based purely on the individuals' intrinsic differences (e.g., disparities in physical size; Chase et al., 2002). Thus, victory and defeat and their effects on biology and behavior are essential to understanding the dynamics of competition and the formation of social hierarchy.

In the current study, we apply a stress perspective to illuminate how competitive defeat and victory shape biology and behavior. Building on the theoretical proposition that women are more likely than men to engage in affiliative behavior during stressful conditions (Taylor, 2006; Taylor et al., 2000), we explored whether there are sex differences in affiliative physical behavior following defeat and, if so, whether they might be explained by differential biological responses to defeat.

1.1. Competitive defeat and affiliative behavior

During and following group competition, team members sometimes engage in affiliative physical contact. Because touch can enhance cooperation (Kurzban, 2001) and prosocial behavior (Crusco and Wetzel, 1984; Morhenn et al., 2008), this form of affiliation may facilitate trust among team members, thereby enhancing group functioning. Such affiliative physical contact may be initiated in both victory and defeat. For example, after momentary success or ultimate victory, teammates sometimes engage in celebratory contact (e.g., high fives). A recent field study of professional basketball players found that duration of these celebratory affiliative contacts predicted team performance: teams that engaged in these behaviors more often early in the season had greater success later in the season (Kraus et al., 2010). Affiliative contact may also occur in defeat. Given the soothing, stress-buffering, effects of affiliative physical contact (Coan et al., 2006; Fishman et al., 1995), defeat-induced affiliation, which would function as consolation rather than celebration, may be integral in shaping one's response to defeat.

There are theoretical reasons to expect sex differences in affiliative behavior in the context of competition, particularly in the face of defeat. Social defeat is a powerful social stressor (Albonetti and Farabollini, 1994; Björkqvist, 2001). The tend-and-befriend theory (Taylor, 2006; Taylor et al., 2000) argues that whereas fight-or-flight may be the

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modal stress response for males, females are more likely to seek out close others, thereby strengthening social bonds during times when they may be a particularly valuable social resource. There is some empirical evidence consistent with the tend-and-befriend theory. For example, a study of workers found that women were more likely than men to view workplace friendships as important sources of support during stress (Morrison, 2009). Similarly, a meta-analysis of sex differences in coping with stressors found that the biggest sex difference was that women were more likely than men to seek emotional support from others (Tamres et al., 2002). Although consistent with tend-and-befriend, it is possible that men also affiliate during stress just in less overtly expressive ways for fear of violating gender norms regarding emotional expressivity (Hess et al., 2000). Indeed, some studies have found that men show affiliative responses to stress (Berger et al., 2016), at least in the short term (Margittai et al., 2015). However, these findings contrast starkly with the marriage-conflict literature, which has found that husbands are considerably more likely than their wives to withdraw and seek interpersonal distance following stressful periods (Christensen and Heavey, 1990; Gottman and Levenson, 1988) and the recent finding that under stressful conditions, men provided lower-quality support to a relationship partner than did women (Bodenmann et al., 2015). Altogether, the evidence for sex differences in affiliation during acute stress is mixed, with Taylor and Folkman (2011) concluding that the sex difference is modest and that both men and women can display affiliative responses to stress.

Against this backdrop of mixed empirical evidence, the current study provides a test of the tend-and-befriend theory in the context of real-world competition. Following the tend-and-befriend theory, we tested the hypothesis that whereas female competitors are more likely to engage in affiliative physical behavior during defeat, male competitors may be less likely to do so.

1.2. Social defeat and cortisol

If there are, indeed, sex differences in the tendency to engage in affiliative behavior during the social stress of defeat, will this differential behavioral pattern be matched by different cortisol responses? As a potent social stressor, defeat should, theoretically, trigger the release of glucocorticoids, such as corticosterone in rodents and cortisol in humans. For example, a meta-analysis of cortisol responses in humans found that stressors involving social evaluative threat most reliably increased cortisol (Dickerson and Kemeny, 2004). Certainly, social defeat has a social evaluative component. Nevertheless, research on cortisol responses to social defeat has produced mixed results. Some studies have found no significant effect of defeat on cortisol (Bateup et al., 2002; Booth et al., 1989; Gladue et al., 1989). Other studies have found post-defeat increases in cortisol across numerous species (Keeney et al., 2006; Kramer et al., 1999; Overli et al., 1999), including humans (Casto and Edwards, 2016; Jiménez et al., 2012; Mehta et al., 2008). In humans, these increases appear to be most pronounced for individuals who have dominance-related traits or biology, such as an implicit motive to attain power (Wirth et al., 2006) or high basal testosterone (Mehta et al., 2008). If the effects of losing persist, with chronic defeat leading to chronic elevations in cortisol, they could contribute to the inverse relationship between social status and cortisol in both human and non-human species (Sapolsky, 1989; Sherman et al., 2012).

For those prone to engaging in affiliative behavior in defeat, might cortisol mediate this response? Glucocorticoids play a central role in the body's emergency, fight-or-flight response to acute stress (Miller and O'Callaghan, 2002). Do they also play a role in defeat-induced affiliation? The motivation for affiliation under acute stress is argued to have a neuroendocrine basis, with contemporary work focusing on two neuropeptides—oxytocin and vasopressin—that are linked to maternal aggression, attachment, affiliation, and social bonding (Feldman et al., 2007; Keverne and Curley, 2004). These endocrine-modulated behaviors strengthen the bond between females and vulnerable offspring, facilitating survival and increasing reproductive fitness (Carter et al., 2008; Campbell, 2008).

The literature on whether cortisol contributes to stress-induced affiliation is mixed, with some studies showing a positive association between cortisol and affiliation (Corter and Fleming, 1995; DeVries et al., 1996; Fleming et al., 1987, 1997; Kivlighan et al., 2005; McCarthy et al., 1992; Marazziti and Canale, 2004; Rees et al., 2004) and others showing a negative association between cortisol and affiliation (Feldman et al., 2010; Gordon et al., 2010; Mills-Koonce et al., 2009; Saltzman et al., 2011). Furthermore, because most studies of cortisol and affiliation include only same-sex samples (for an exception, see Kivlighan et al., 2005), conclusions about sex differences are limited by cross-study heterogeneity (Higgins and Thompson, 2002). The current study is designed to contribute to this literature by examining the relationship between cortisol and the affiliative behavior of both males and females in response to acute stress.

2. Overview of study

In this study, we aimed to test for sex differences in the role of defeat (vs. victory) and cortisol change in the emergence of affiliative behavior. We were uniquely positioned to examine cortisol and defeat-induced affiliation in a field setting, using a nearly ubiquitous form of affiliation in modern humans: interspecies affiliation between human and domestic dog. Specifically, we tested our hypotheses by studying a real-world competition, namely, a statewide (Texas) dog agility event. Dog agility is a competitive sport that tests a person's (the "handler") skills in training and handling of dogs over a timed obstacle course. A handler guides his/her dog through the course without aid of a leash or physical contact. As a rule, contestants take these competitions very seriously. Many events are televised nationally, with cash prizes often exceeding $25,000 USD.

Beyond providing the opportunity to study a large number of competitors in a high-stakes, real-world competition, this experimental context has additional benefits. First, dogs are a frequent target of human affiliative contact and such contact has stress-buffering effects. There is a large and growing literature on the psychological and physiological effects of human-animal interaction (Beetz et al., 2012), with reports of human-dog interactions producing neurobiological changes similar to those observed in interpersonal human interactions (Nagasawa et al., 2009; Odendaal and Mientjes, 2003). For example, in the face of acute stress, the presence of a companion dog can reduce self-reported anxiety and physiological measures of stress (Beetz et al., 2012). Consequently, a domestic dog might be an appropriate target of defeat-induced affiliation, especially for an individual prone to affiliative, tend-and-befriend impulses. Second, there seem to be fewer sex-typed norms regarding affiliative contact in this inter-species context. There are norms against men displaying affiliative physical contact in public (particularly in an intraspecies, intrasex context), which may inhibit men from initiating such behavior (Derlega et al., 1989). There seem to be fewer, or weaker, norms governing such behavior when it is directed towards domestic animals, such as dogs. As a result, by testing handler/dog teams, we were able to test for sex differences in a context where norms against male-initiated affiliation are assumed to be relatively weak or non-existent.

Previous research (Jones and Josephs, 2006) reported that upon completion of the agility course, some handlers affiliated with their dogs by playing with and/or petting them. Following the tend-and-befriend stress theory, we hypothesized that the duration of post-competition affiliative behavior would depend on the handler's sex, whether they had won or lost the competition, and cortisol reactivity. Specifically, we predicted that defeat would be associated with more affiliative behavior for female handlers but less affiliative behavior for male handlers.

We further predicted that female handlers' cortisol response would predict the amount of time spent engaging in affiliative behavior toward their dogs—the greater the increase in cortisol, the more time spent affiliating. Conversely, based on fight-or-flight and the marriage-conflict literature (Christensen and Heavey, 1990; Gottman and Levenson, 1988), we predicted that male handlers' cortisol response would negatively predict time spent engaging in affiliative behavior toward their dogs—the greater the increase in cortisol, the less time spent affiliating.

3. Method

3.1. Participants

A total of 184 handlers (93 men, $M_{age} = 44.39$; $SD_{age} = 9.75$, range = 20–65; 91 women, $M_{age} = 44.20$; $SD_{age} = 12.13$, range = 18–71) volunteered to take part in this study. This sample of dog handlers is the same as the sample reported previously (Jones and Josephs, 2006; Mehta et al., 2008, Study 1). Of the volunteers, 36 handlers were excluded because they were disqualified from the competition due to their performance (e.g., failing to complete the course) and therefore did not receive a score. Screening out these participants resulted in a final N of 148 handlers (83 men, 65 women).[2]

3.2. Measures

3.2.1. Perceived defeat

In the dog agility competition, performance of the handler/dog teams was scored out of maximum of 100 points. A score of 85 or better is a qualifying score, which is necessary to advance to the next level of competition. Following Jones and Josephs (2006) and Mehta et al. (2008, Study 1), we considered a qualifying score (≥85) to be a win and a non-qualifying score (<85) to be a loss. Because participants did not know the official results when their affiliative behavior was measured, participants' predictions of whether they had qualified or not predicted affiliative behavior (as reported below in the Results section, participants' perceptions were quite accurate, with only 2% of participants predicting incorrectly). After the competition but before official results were posted, participants indicated whether they thought they had qualified or not. For the regression analyses, this variable was effect coded (−0.5 = won, 0.5 = lost).

3.2.2. Duration of affiliative behavior

All handler/dog teams were videotaped immediately after completing the agility course prior to receiving the official results of their performance. Using the video recordings, we coded handlers' behaviors during the first 180 s immediately following the competition. Focusing on this period assured that we had equal samples of every handler's behavior. In previous research (Jones and Josephs, 2006), three judges independently coded duration of affiliative behavior (inter-rater reliability = 90.2% agreement; in cases of disagreement, times were averaged). In the analyses of Jones and Josephs (2006), two behaviors were categorized as affiliative: playing with the dog and petting the dog (on its ears, chin, and/or head). Based on and consistent with this earlier analysis, we treated the total amount of time (in seconds) a handler engaged in these affiliative behaviors as the primary outcome measure (e.g., a handler who spent 20 s playing with the dog and another 30 s petting its head would have spent a total of 50 s engaged in affiliative behavior).

3.2.3. Salivary cortisol

In advance of the study, participants were instructed that within three hours of the competition they should not (1) eat dairy products (e.g., milk, cream, or cheese) or anything containing live bacterial cultures (e.g., yogurt), (2) consume caffeine or alcohol, (3) smoke cigarettes, (4) exercise, or (5) brush their teeth. Pre-competition saliva samples were taken from the handlers at 90 min ($M = 93.89$; $SD = 3.95$) before the teams competed.[3] Post-competition saliva samples were collected from the handlers at 20 min ($M = 20.38$; $SD = 3.00$) after official results had been posted, allowing sufficient time for changes in serum cortisol at the end of the competition to impact cortisol in saliva (Riad-Fahmy et al., 1982; Schultheiss et al., 2012). All saliva samples were taken between 12 p.m. and 3 p.m., minimizing diurnal variability.

For both pre- and post-competition saliva sampling, participants chewed sugar-free gum to stimulate salivation and then drooled 2.5 mL of saliva into a sterile polypropylene microtubule. All saliva samples were sealed and frozen shortly after collection to avoid bacterial hormone degradation and to precipitate mucins. Prior to hormonal assay, all samples were defrosted, brought to room temperature and centrifuged at 3000 rpm for 15 min in order to separate the saliva from the residuals (e.g., mucins).

We measured salivary cortisol concentrations through competitive enzyme-linked immunosorbent assay (ELISA) kits manufactured by Salimetrics (State College, Pennsylvania). In every assay, seven known control concentrations were included, in addition to two samples of unknown concentrations from in-house salivary samples.

Every salivary sample was assayed twice (except for 7 samples, which were assayed three times). For the salivary samples in this study, inter-assay coefficient of variation (CV), averaged across high and low controls was 4.55%. The intra-assay CV across paired control samples of known concentration was never >4.57%. Intra-assay CV across paired control samples of unknown concentration never exceeded 5.06%. These variability indices were both within acceptable limits (Mehta and Josephs, 2010). If intra-assay CV across paired test samples varied >7.5%, the samples were assayed again. Re-assaying occurred for only seven samples.

Change in cortisol can be calculated in several ways. Change can be computed as absolute change in cortisol (in μg/dL) or as a percentage change from pre-competition concentrations. Also, one can save the unstandardized residuals of a regression analysis with pre-competition cortisol concentration as the predictor and post-competition cortisol concentration as the dependent variable. The saved unstandardized residuals can be used as cortisol change scores. This method, which has been used in previous research on hormone changes in competition (Mehta and Josephs, 2006), is statistically equivalent to conducting an analysis of covariance (ANCOVA) controlling for pre-competition cortisol levels (Gladue et al., 1989). The question of which approach is preferable has been long debated and remains unresolved (Allison, 1990; Burt and Obradović, 2013; Maris, 1998). The freedom of researchers to choose one measure over the others has the potential to introduce problematic flexibility in data analyses. In light of recent calls to reduce researcher degrees of freedom and provide greater transparency and thoroughness in reporting (Simmons et al., 2011), we have decided to report the analyses from all three ways of measuring cortisol change (residualized change, absolute change, and percentage change). Individuals whose change in cortisol was more than three standard deviations from the mean were considered outliers and excluded from analysis. Regardless of change score measure, this standard resulted in the exclusion of four female handlers.

4. Results

4.1. Preliminary analyses

Male and female handlers did not differ in their affiliative behavior, cortisol change, or pre-competition cortisol levels (p's > 0.57). Women spent an average of 26.61 s ($SD = 14.31$) engaged in affiliative behaviors; men spent an average of 25.34 s ($SD = 12.81$) affiliating. Male handlers were more likely than female handlers to perceive they had won, $\chi^2 =$

[2] Following Jones and Josephs (2006), but unlike Mehta et al. (2008, Study 1), we did not exclude menopausal women from analyses. However, excluding these women leaves the key results by-and-large unchanged (e.g., the two critical two-way interactions remain statistically significant for all three measures of cortisol change).

[3] These samples were also used to assay testosterone. A full analysis of the testosterone data is reported in Mehta et al. (2008). Although not the focus of the current study, we report control analyses using these baseline testosterone values.

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10.38, $p = 0.001$, phi = 0.27. Fifty-three percent of men thought that they had won; 26% percent of women thought they had won (i.e., 44 male winners, 39 male losers, 16 female winners, and 45 female losers). These perceptions were very accurate. Only 3 handlers (2%) were incorrect in their perception of whether they had won or lost.

4.2. Primary analyses

To test our primary hypotheses regarding affiliative behavior, we tested whether affiliative behavior varied as a function of sex, perceived defeat (vs. victory), and cortisol change. We predicted that the two key associations, perceived defeat and affiliative behavior, and cortisol change and affiliative behavior, would depend on the sex of the competitor. We tested these two predictions simultaneously in a single model. In a hierarchical linear regression model, the main effects of cortisol change, perceived defeat (-0.5 = perceived win, 0.5 = perceived loss), and sex (-0.5 = male, 0.5 = female) were entered in Step 1, and the two key 2-way interactions involving sex (Perceived Defeat × Sex and Cortisol Change × Sex) were entered in Step 2.[4]

Cortisol change was *z* scored prior to computing the interaction term in order to reduce nonessential multicollinearity between the main effect and its interaction term (Cohen et al., 2003) and to make the coefficient for cortisol change more interpretable (a one *SD* increase in cortisol is more realistic and interpretable than an increase of 1 μg/dL, a cortisol value far greater than any in the sample and roughly 7 *SD*s above pre-competition levels). Similarly, by effect coding the categorical variables as -0.5 and 0.5, the coefficients for perceived defeat and sex estimate the difference between winners and losers and between male and female competitors, respectively. We repeated the model for each of the three measures of cortisol change: residualized change (post-competition cortisol regressed on pre-competition cortisol), absolute change, and percentage change (from pre-competition levels). Examination of the collinearity diagnostics revealed that multicollinearity was not an issue in any of the three regression models. The Variance Inflation Factor did not exceed 1.4 for any variable (below 10 is considered acceptable; Belsley et al., 1980), indicating that there was minimal multicollinearity-induced inflation in the magnitude of the standard errors. (The lowest possible value is 1, which indicates no inflation). The results of the hierarchical regression analyses are summarized in Table 1.

As Table 1 shows, the results were similar for the different measures of cortisol change. For each measure, the Step 1 model (testing main effects) was not significant (F's < 0.3, p's > 0.85). Entering the interaction terms in Step 2 produced a significant increase in variance explained: $\Delta R^2 = 0.196$, $F(2, 138) = 16.91$, $p < 0.001$, for residualized change; $\Delta R^2 = 0.207$, $F(2, 138) = 18.15$, $p < 0.001$, for absolute change in cortisol; and $\Delta R^2 = 0.195$, $F(2, 138) = 16.80$, $p < 0.001$, for percentage change in cortisol. Across the three measures of cortisol change, both critical 2-way interactions were positive and statistically significant. The Perceived Defeat × Sex interaction (t's > 4.10, p's < 0.001) was the larger of the two effects (semi-partial r's (r_{sp}) between 0.31 and 0.32). The Cortisol Change × Sex interaction was also statistically significant (t's between 2.2 and 2.71; p's between 0.008 and 0.029) but of smaller magnitude (r_{sp} between 0.17 and 0.20). Notably, the two interactions were statistically independent, reflecting distinct effects, neither of which could be explained by the other.[5] Testing the 3-way interaction (Cortisol Change × Perceived Result × Sex) revealed no effect (t's between 0.58 and 1.27, p's between 0.20 and 0.59).[6]

4.3. Simple slopes analysis

We decomposed the two significant interactions using simple slopes analysis (Aiken and West, 1991), the results of which are summarized in Table 1. First, we decomposed the Perceived Defeat × Sex interaction, testing the relationship between perceived defeat and affiliative behavior separately for male and female competitors. Female competitors were significantly more likely to display affiliative behavior after perceived defeat than after perceived victory (B′s between 11.69 and 12.89, p's < 0.01, r_{sp} between 0.23 and 0.26). These coefficients indicate that female losers spent roughly 12 more seconds affiliating with their dogs than female winners did. Conversely, male competitors were significantly more likely to display affiliative behavior after perceived victory than after perceived defeat (B′s between -6.99 and -8.13, p's < 0.03, B = 3.39, $p = 0.04$, r_{sp} between -0.18 and -0.21). These coefficients indicate that male winners spent about 7-8 more seconds affiliating with their dogs than male losers did.

Second, we decomposed the Cortisol Change × Sex interaction. The three measures of cortisol change produced similar patterns in terms of the direction of the slopes but varied in whether the slope reached statistical significance. For female competitors, the simple slope was always positive, indicating that greater increases in cortisol were associated with more time spent affiliating. For residualized change and absolute change, the simple slope was statistically significant (B = 3.39, $p = 0.04$, $r_{sp} = 0.16$, and B = 3.53, $p = 0.04$, $r_{sp} = 0.16$, respectively); for percentage change, the slope was positive but not significant (B = 1.92, $p = 0.19$, $r_{sp} = 0.10$). For male competitors, the slope was always negative, indicating that greater increases in cortisol were associated with less time spent affiliating. For absolute change and percentage change, the simple slope was marginally significant (B = -2.54, $p = 0.08$, $r_{sp} = -0.13$, and B = -3.03, $p = 0.08$, $r_{sp} = -0.14$, respectively); for residualized change, the simple slope was negative but not significant (B = -1.64, $p = 0.27$, $r_{sp} = -0.08$).

The two significant interactions involving sex and the non-significant 3-way interaction confirm that the relationships of perceived defeat and cortisol with affiliative behavior (within each sex) were independent and additive rather than multiplicative. Women affiliated more when they thought they had lost, and also when cortisol increased. Men affiliated more when they thought they had won, and, if anything, affiliated slightly more when cortisol decreased, although this latter association did not reach statistical significance.

4.4. Mediation analyses

Given that our study was motivated, at least in part, by the question of whether stress-induced affiliation is mediated by cortisol, we next tested a formal mediation model. Although all competitors may have experienced some degree of stress regardless of outcome, previous analyses on this dataset (Mehta et al., 2008, Study 1) reported that losers showed an increase in cortisol relative to winners, a result that

[4] We also tested a model that included the other 2-way interaction (Cortisol Change × Perceived Defeat). This model revealed no significant Cortisol Change × Perceived Defeat interaction (t's < 1, p's > 0.70). The key results—the two significant 2-way interactions—were virtually unchanged if this interaction was included in the model.

[5] Physical exertion can affect cortisol (Farrell et al., 1983). Following Mehta et al. (2008, Study 1), we used the time it took competitors to complete the course as a proxy—it would presumably require greater exertion to run the course faster. Adding time and its interactions with perceived defeat, cortisol change, and sex revealed no significant effects involving time. Most importantly, the key two-way interactions (Cortisol Change × Sex and Perceived Result × Sex) remained statistically significant (for each cortisol change measure).

[6] Even though the 3-way interaction was not significant, we tested follow-up models testing the Cortisol Change × Sex interaction separately by outcome. For perceived victory, the Cortisol Change × Sex Interaction was non-significant (p's between 0.42 and 0.59). For perceived defeat, the Cortisol Change × Sex interaction was statistically significant for two measures (residualized change: B = 5.63, SE = 2.69, $p = 0.04$, $r_{sp} = 0.21$; absolute change: B = 8.64, SE = 3.42, $p = 0.04$, $r_{sp} = 0.26$) and marginally significant for the other (percentage change: B = 5.75, SE = 2.97, $p = 0.06$, $r_{sp} = 0.20$). Thus, although the magnitude of the two-way interaction did not differ significantly by perceived defeat (vs. victory), the Cortisol Change × Sex was most apparent for those who had the ostensibly more stressful experience of losing the competition.

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Table 1
Summary of results from hierarchical linear regression models predicting duration of affiliative behavior from perceived defeat, cortisol change, and sex.

	Measure of cortisol change											
	Residualized change				Absolute change				Percentage change			
Variable	B	SE	p	r_{sp}	B	SE	p	r_{sp}	B	SE	p	r_{sp}
Main effects (Step 1)												
Perceived Defeat	−1.27	1.29	0.62	−0.04	−0.28	2.58	0.91	−0.01	−0.68	2.57	0.79	−0.02
Cortisol Change	0.72	1.23	0.56	0.05	−0.51	1.23	0.68	−0.04	−0.01	1.23	0.99	0.00
Sex	1.52	2.38	0.52	0.06	1.40	2.38	0.56	0.05	1.45	2.37	0.54	0.05
	$R^2 = 0.005$				$R^2 = 0.004$				$R^2 = 0.003$			
Interactions (Step 2)												
Perceived Defeat × Sex	19.82	4.81	<0.001	0.31	19.47	4.75	<0.001	0.31	20.04	4.81	<0.001	0.32
Cortisol Change × Sex	5.03	2.23	0.03	0.17	6.07	1.12	0.008	0.20	4.95	2.24	0.03	0.17
	$\Delta R^2 = 0.196^{***}$				$\Delta R^2 = 0.207^{***}$				$\Delta R^2 = 0.195^{***}$			
Simple Slopes												
Female												
Perceived Defeat	11.69	3.82	0.003	0.23	12.48	3.67	0.001	0.26	12.89	3.78	0.001	0.26
Cortisol Change	3.39	1.65	0.04	0.16	3.53	1.71	0.04	0.16	1.92	1.47	0.19	0.10
Male												
Perceived Defeat	−8.13	2.92	0.006	−0.21	−6.99	3.01	0.02	−0.18	−7.16	2.97	0.02	−0.18
Cortisol Change	−1.64	1.49	0.27	−0.08	−2.54	1.46	0.08	−0.13	−3.03	1.70	0.08	−0.14

Note. Three separate models were tested (one for each measure of cortisol change). Effect coding was applied to both perceived defeat (−0.5 = perceived win, 0.5 = perceived defeat) and sex (−0.5 = male, 0.5 = female). Cortisol change variables were standardized (*z* scored) prior to computing interaction terms. B = unstandardized regression coefficient. SE = standard error (of B). r_{sp} = semi-partial correlation, an effect size estimate for individual predictors in multiple regression (Aloe and Becker, 2012).
*** $p < 0.001$.

held for both men and women.[7] If losing was particularly stressful (in terms of cortisol change), then the relationship between perceived defeat and affiliative behavior may be mediated by cortisol.

To test this possibility, we used structural equation modeling (SEM) and latent change score analysis (McArdle, 2009; McArdle and Nesselroade, 1994), which can estimate change as a latent variable based on as few as two measurement occasions (e.g., pretest and posttest). This approach is generally preferable to both residualized change scores and difference scores (Gollwitzer et al., 2014) in that it allows for great flexibility in the SEM framework and allows one to model change while leaving Time 1 (baseline) in the model (e.g., Bernard et al., 2015a, 2015b; Brandt et al., 2015; Miller et al., 2014). With sex as a grouping variable, we modeled latent change as described by McArdle (2009), then added perceived defeat and affiliation to the model to create a mediation model with the latent change score as mediator. Perceived defeat was allowed to covary with pre-competition cortisol (for female competition, there was no relation between the two, $r = 0.05$, $p = 0.69$; for male competitors there was a small, negative relationship, $r = -0.26$, $p = 0.02$). This model, depicted in Fig. 2, tested the direct path from perceived defeat to duration of affiliative behavior and the indirect path through cortisol change. This model had excellent fit as indicated by a non-significant chi-square, $\chi^2(2) = 0.50$, $p = 0.78$, a Root Mean Square Error of Approximation of 0.00 (MacCallum et al., 1996), and a Normed Fit Index of 0.995 (Schumacker and Lomax, 1996). For female competitors, the indirect effect (from perceived defeat to cortisol change to duration of affiliative behavior), which was computed with bias-corrected bootstrapped 95% CI's based on 1000 samples, was positive and statistically significant (standardized indirect effect = 0.064, 95% CI: [0.008, 0.173], $p = 0.02$), indicating mediation.[8] The direct effect was also statistically significant (standardized direct effect = 0.39, $p < 0.001$) suggesting partial mediation: for female competitors, the relationship between perceived defeat and more time spent affiliating was partially mediated by relative increases in cortisol. For male competitors, the indirect effect (from perceived defeat to cortisol change to duration of affiliative behavior) was negative and marginally significant (standardized indirect effect = −0.094, 95% CI: [−0.196, 0.016], $p = 0.07$). The direct effect was negative and statistically significant (standardized direct effect = −0.27, $p = 0.02$). Thus, there was some evidence that decreases in affiliative behavior after male's perceived defeat were partially explained by relative increases in cortisol. Altogether, relative increases in cortisol after defeat—observed for both males and females (as first reported by Mehta et al., 2008)—partially explained the defeat-related increases in female affiliation and decreases in male affiliation.

4.5. Moderated mediation

So far, we have presented separate evidence for both moderation and mediation. Next we tested moderated mediation, an approach that can represent and test moderation and mediation in a single model. In the mediation model, the *a* path (from perceived defeat to cortisol change) is the only path that should be invariant across sex. Based on our hypotheses and previous regression analyses, the *b* path (from cortisol change to affiliation) and *c'* path (direct effect from perceived defeat to affiliation) should vary significantly by sex. We tested this possibility in multiple steps. We first tested whether the overall model fit the data better when allowed to vary by sex. For the unconstrained model, the chi-square value was non-significant, $\chi^2(2) = 0.50$, $p = 0.78$. For the fully constrained model (with the three structural paths constrained to be invariant across sex), the chi-square value was statistically significant, $\chi^2(5) = 32.86$, $p < 0.001$, and significantly larger than the chi-square value for the unconstrained model ($\Delta\chi^2(3) = 32.36$, $p < 0.001$). Thus, the overall model varied significantly by sex. Next, we tested each of the three structural paths, one by one, to see if they varied significantly by sex (Sauer and Dick, 1993). Constraining the *a* path to be invariant across sex did not significantly alter χ^2 relative to the unconstrained model, $\Delta\chi^2(1) = 1.14$, $p = 0.29$, indicating that the positive relationship between perceived defeat and cortisol change did not vary significantly by sex (consistent with Mehta et al., 2008, Study 1). In contrast, constraining the *b* path to be invariant across sex

[7] The difference in cortisol change between the average loser and the average winner was 0.11 μg/dL. For comparison, in the original report introducing the Trier Social Stress Test (TSST; Kirschbaum et al., 1993), salivary cortisol increased between 5.3 and 8.2 nmol/L (0.192 - 0.297 μg/dL). At between 37% and 57% of the effect of the TSST, perceived defeat was at least mildly to moderately stressful (in terms of cortisol change) relative to the TSST (perhaps the most robust and universally reliable psychological stressor).

[8] Eight women reported being on birth control medication (no other medications were reported). The indirect effect for female competitors remained significant if a dummy variable indicating whether or not the female competitor was on birth control (0 = No, 1 = Yes) was added to the model as a predictor of both cortisol change and affiliation and allowed to covary with perceived defeat and pre-competition cortisol (standardized indirect effect = 0.07, 95% CI: [0.005, 0.203], $p = 0.024$).

significantly altered χ^2 relative to the unconstrained model, $\Delta\chi^2(1) = 7.19$, $p = 0.007$, indicating that this path, from cortisol change to affiliation, varied significantly for male and female competitors. Similarly, constraining the *c*' path to be invariant across sex significantly altered χ^2 relative to the unconstrained model, $\Delta\chi^2(1) = 15.88$, $p < 0.001$, indicating that the path from perceived defeat to affiliative behavior varied significantly for male and female competitors.

In sum, we found clear evidence of moderated mediation: two of the paths in the mediation model varied significantly by sex. Relative increases in cortisol in response to defeat partially explained changes in affiliation for both male and female competitors: for male competitors these relative cortisol increases partially explained their diminished affiliation following defeat; for female competitors, these relative cortisol increases partially explained their greater affiliation following defeat.

4.6. Control analyses

We conducted one final set of analyses to determine the robustness of the current findings and whether they can be explained by the results reported previously by Mehta et al. (2008, Study 1) and Jones and Josephs (2006). Those previous analyses (on the same dataset) report two findings involving baseline testosterone that might bear on the current findings: (1) an outcome-dependent relationship, among male handlers, between pre-competition testosterone and cortisol change (a positive relationship for male losers; a negative relationship for male winners; Mehta et al., 2008, Study 1), and (2) a negative relationship, among male handlers, between pre-competition testosterone and duration of affiliation after defeat (Jones and Josephs, 2006). Given these findings, pre-competition testosterone is a potential confound in our primary analyses, particularly in the prediction of male affiliation.

To account for this confound, we added pre-competition testosterone to the mediation model, with a path from pre-competition testosterone to affiliation and a path to cortisol change, testing a direct effect of pre-competition testosterone on affiliation and an indirect effect through cortisol change. Because the previously reported relationships involving pre-competition testosterone depended not just on sex but also on outcome, we added the Pre-competition Testosterone × Perceived Defeat interaction term with structural paths to both affiliation and cortisol change. These two predictors were allowed to covary with each other and with pre-competition cortisol and perceived defeat. For male competitors, there was a positive and significant Pre-competition Testosterone × Perceived Defeat interaction in predicting cortisol change ($B = 0.12$, $SE = 0.025$, $p < 0.001$). This significant interaction represents the aforementioned Mehta et al. (2008, Study 1) finding of a relationship between pre-competition testosterone and cortisol change that depended on outcome (more positive for losers than for winners). For males, there was also a significant negative direct effect of pre-competition testosterone on affiliation ($B = -5.12$, $SE = 1.20$, $p < 0.001$), which did not vary significantly by outcome (Baseline Testosterone × Perceived Defeat: $B = -2.35$, $SE = 2.66$, $p = 0.38$). This effect of pre-competition testosterone on affiliation captures the aforementioned Jones and Josephs (2006) finding that, for male handlers, greater baseline testosterone was related to less time spent affiliating after defeat (the authors only reported the relationship for losers and did not report the interaction with outcome). For female competitors, the only path (involving baseline testosterone) that approached significance was the path from baseline testosterone to cortisol change ($B = -0.03$, $SE = 0.017$, $p = 0.08$); no other main or interactive effects involving baseline testosterone were significant (p's > 0.36).

As these results show, we have built a model that represents the key pre-competition testosterone findings from previous reports (Jones and Josephs, 2006; Mehta et al., 2008, Study 1). As such, we can assess our key findings while accounting for the potential confounding influence (for either male or female handlers) of pre-competition testosterone—including any main or interactive effects, whether direct or indirect (through cortisol change). In this model, the primary multiple group (moderated) mediation results remained by-and-large unchanged. The indirect effects (for male and female competitors) were again in opposite directions: For male competitors, the indirect effect was negative and statistically significant (standardized indirect effect = −0.122, 95% CI: [−0.245, −0.019], $p = 0.02$); for female competitors, it was positive and marginally significant (standardized indirect effect = 0.053, 95% CI: [−0.009, 0.154], $p = 0.09$). Also, the two paths that varied significantly by sex in the primary mediation model (the *b* and *c*' paths) still varied significantly by sex in this more complex model (perceived defeat to affiliation: $\Delta\chi^2(1) = 14.47$, $p < 0.001$; cortisol change to affiliation: $\Delta\chi^2(1) = 6.68$, $p = 0.01$). Thus, the two significant sex differences (which emerged in the hierarchical regression and the multiple group mediation analyses) remained significant when accounting for the potential confounding influence of pre-competition testosterone.

5. Discussion

We report a field study that examined cortisol responses and affiliative behavior during a real-world competition. As an earlier report based on the same dataset revealed (Mehta et al., 2008, Study 1), competitors who thought they had lost the competition (a group that was disproportionately women) had greater increases in cortisol than those who thought they had won. Although women were more likely than men to lose the competition, the effect of perceived defeat held for both male and female competitors. We extend these earlier analyses by examining affiliative behavior, specifically the duration of time the competitor spent petting or playing with his or her dog. Despite a similar cortisol response to perceived defeat, the behavioral response to perceived defeat differed by sex. Although male and female competitors were equally affiliative overall, they differed in *when* they affiliated. Male competitors were most affiliative in victory (when such affiliation presumably reflected celebration); female competitors were most affiliative in defeat (when such affiliation presumably reflected consolation). Because defeat is a social stressor (Albonetti and Farabollini, 1994; Björkqvist, 2001), this result is consistent with a recent finding that acute stress reduced retaliatory behavior among women but increased it among men (Prasad et al., 2016). Additionally, we found sex differences in the association between cortisol and affiliative behavior (see Kivlighan et al., 2005 for evidence regarding self-reported *motivation* to affiliate). The cortisol response to competition was associated with more time spent affiliating among female competitors. Male competitors showed some evidence, albeit somewhat weaker, of the opposite pattern, with greater increases in cortisol associated with less time spent affiliating.

Finally, a moderated mediation model clarified how these findings fit together. Although strong causal inferences are not justified given that the outcome of the competition was not experimentally manipulated, the findings are informative. The two sex-moderated pathways were clearly apparent as the path models differed significantly for male and female competitors. For female competitors, relative cortisol increases after defeat partially explained their greater affiliation after defeat; for male competitors, relative cortisol increases after defeat partially explained the fact that they spent less time affiliating after defeat. This sex-linked divergence is consistent with the tend-and-befriend portrayal of female behavior under stress and with the marriage-conflict literature, which reports stress-induced withdrawal behaviors in husbands, but interpersonal coping behaviors in wives (Christensen and Heavey, 1990; Gottman and Levenson, 1988). Furthermore, the results suggest that these divergent behavioral responses to stress in men and women may be mediated by the cortisol response to stress.

Although we have focused on the response to defeat, the amount of time spent affiliating was described by a Sex × Perceived Defeat crossover interaction (as Fig. 1 illustrates). After defeat, female competitors affiliated more than male competitors did; after victory, men affiliated

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more than female competitors did. This latter sex difference in post-victory (perhaps celebratory) affiliation seems to extend beyond the scope of the tend-and-befriend theory. Perhaps cortisol inhibits affiliation for men just as it facilitates affiliation for women. If so, then any event that reduces cortisol, such as winning, may disinhibit affiliative impulses. This interpretation is broadly consistent with evidence linking cortisol to behavioral inhibition (Fox et al., 2005; Kagan et al., 1987; Tops and Boksem, 2011; Roelofs et al., 2005). Winning-induced reductions in cortisol could release a broad array of appetitive or behavioral approach behaviors, including celebratory affiliation. This explanation, however, is incomplete. It can account for the celebratory affiliation among male competitors, yet it does not readily explain why this response—the disinhibition of behavioral approach—does not also occur for victorious female competitors.

6. Limitations and future directions

Several notable limitations of the current study warrant attention. We have interpreted male competitors' decreased affiliation after defeat and when cortisol was high as behavioral withdrawal. However, we did not measure behavioral withdrawal directly. Thus, we do not know whether low levels of affiliation reflect behavioral withdrawal or merely indifference. Additionally, we only measured one particular form of affiliation—affiliation towards the handler's dog. Competitors may have had other outlets for affiliative impulses, including friends and other handlers. As a result, other important affiliative behaviors may not have been captured by our relatively narrow focus on affiliation toward the dogs. Finally, the key variable, the perceived outcome of the competition, was not experimentally manipulated. The notable benefits of the field setting, including high ecological validity, came with the tradeoff of not being able to experimentally manipulate the outcome. Therefore, follow-up work that experimentally manipulates the competition outcome, providing a stronger test of causality, is an important direction for future research.

The future use of experimental designs would also address another limitation of the current study. In the dog agility competition we studied, women lost significantly more than men did. Although we were able to statistically account for this correlation in our analyses, this meant that female winners were underrepresented in the sample. Thus, strong conclusions regarding this particular subgroup must await follow-up research. An experimental design, besides providing a stronger test of causal direction, allows for a balanced sample in which men and women are equally represented among winners and losers.

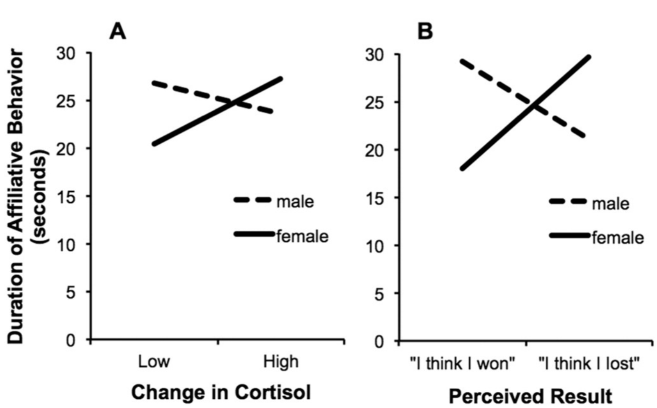

Fig. 1. Duration of affiliative behavior as a function of (A) sex and cortisol change and (B) sex and perceived result. Lines are the simple slopes from the hierarchical regression model reported in Table 1 (using residualized change as measure of change in cortisol). Low = Mean − 1 *SD*; High = Mean + 1 *SD*.

One issue we did not examine is the role of female reproductive physiology. Although we did account for the potential impact of contraceptive medication, we did not analyze other factors known to impact the neuroendocrine response to stress, such as the menstrual cycle phase (Kajantie and Phillips, 2006). It is possible that stress-related affiliation varies or is most pronounced at certain times in the menstrual cycle. In the absence of evidence that tests the role of menstrual cycle, it would be premature to assume that the patterns we observed hold under all conditions. It is possible that these relationships get stronger or weaker depending on particular details of female reproductive physiology.

Additionally, we only examined one aspect of the stress response. There are other important components that should be examined in future research. Psychological variables, such as self-reported stress or anxiety, could be incorporated. Similarly, there are other relevant physiological variables, such as the hormone progesterone, which may be released from the adrenal gland as part of the stress response (Wirth et al., 2007) and has been linked to affiliation (Schultheiss et al., 2004; Wirth and Schultheiss, 2006).

In a similar vein, an open question for future research is whether oxytocin, a hormone frequently implicated in stress-related affiliation (Feldman et al., 2007; Keverne and Curley, 2004), plays a role in either the cortisol-linked affiliation observed among female competitors after defeat or the cortisol-linked reductions in affiliation observed among male competitors after defeat. Given evidence that glucocorticoids and oxytocin (and oxytocin receptors) interact at the neural and cellular level (Liberzon et al., 1994; Liberzon and Young, 1997; Patchev et al., 1993), research that examines both hormones together in the context of stress-related affiliation could provide important data on whether (and how) these hormones interact to influence affiliation.

As noted earlier, how competitors respond to defeat and victory matters greatly for determining their success in future competitive interactions and their ultimate position in the social hierarchies that repeated competitions create (Chase, 1980; Chase et al., 1994, 2002). Future research could build on the current findings by exploring how sex-differentiated affiliative behaviors after defeat impact future success or motivation, such as the motivation to compete again (Mehta and Josephs, 2006). Does defeat-induced affiliative behavior, with its capacity to downregulate stress (Coan et al., 2006; Fishman et al., 1995), provide a competitive advantage? Does engaging in such behavior impact success in future competitions or impact the likelihood that one will seek out such contests?

7. Conclusion

The description of affiliation as a response to acute stress (Taylor et al., 2000) has highlighted sex differences in the human stress response. We applied this stress perspective to the study of how competitors respond to the social stress of defeat, finding that perceived defeat is associated with divergent, sex-linked, behavioral responses—affiliation/tend-and-befriend vs. withdrawal/fight-or-flight. Nevertheless, these strikingly different behavioral patterns may start with the same physiological event: increases in cortisol. We look forward to future research that further clarifies the physiological (and psychological) processes by which these stress-induced behaviors emerge.

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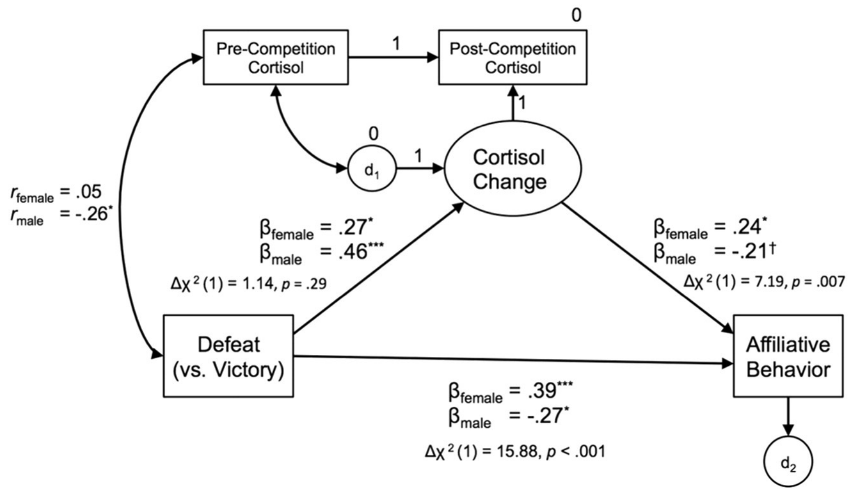

Fig. 2. Structural equation model depicting moderated (multiple group) mediation with a latent cortisol change score (McArdle, 2009) as mediator. Figure uses standard AMOS (Arbuckle, 2014) notation: circles represent unobserved variables; squares represent observed variables. d_1 and d_2 are disturbances. For each path, the change in chi-square statistic compares models in which that parameter was unconstrained vs. invariant across sex. A significant change in chi-square indicates that structural invariance was not observed (i.e., the regression coefficient varied significantly by sex). β = standardized regression coefficient. *r* = correlation coefficient. $^{\dagger}p < 0.10$. $^{*}p < 0.05$. $^{**}p < 0.01$. $^{***}p < 0.001$.

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