Accepted Manuscript

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PII:	S0031-9384(18)30300-7
DOI:	https://doi.org/10.1016/j.physbeh.2019.03.025
Reference:	PHB 12506
To appear in:	*Physiology & Behavior*
Received date:	4 June 2018
Revised date:	21 March 2019
Accepted date:	26 March 2019

Please cite this article as: D. Tortosa, R. Costa, A.A. Crespo, et al., Hormonal and emotional responses to competition using a dyadic approach: Basal testosterone predicts emotional state after a defeat, Physiology & Behavior, https://doi.org/10.1016/j.physbeh.2019.03.025

Hormonal and emotional responses to competition using a dyadic approach: basal testosterone predicts emotional state after a defeat

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ABSTRACT

The present study analyzes the testosterone (T), cortisol (C) and emotional response in competitive interactions between dyads, as well as the relationship between basal T and the emotional response. Seventy-two men and women (36 dyads) participated in same-sex dyads in a face-to-face laboratory competition, and thirty-two men and women (16 dyads) carried out the same task in a non-competitive condition. Salivary samples (5ml of saliva, plastic vials) were provided at three time points (baseline, task, and post-task), and subsequently T (pg/ml) and C (nmol/L) concentrations were measured using ELISA method. Participants completed self-reported measures of emotional valence, emotional arousal and perceived dominance by means of the Self-Assessment Manikin (SAM), at three time points (pre-task, task, and post-task). Two-level crossed Multilevel Models (MLM) showed a participants' stability in C (Mean ± SEM: baseline: 3.84 ± .28, task: 2.92 ± .28 and post-task: 2.62 ± .3), emotional valence (pre-task: 4 ± .06, task: 3.66 ± .1 and post-task: 3.84 ± .09), arousal (pre-task: 3.29 ± .09, task: 3.83 ± .09 and post-task: 3.38 ± .1) and dominance (pre-task: 3.28 ± .08, task: 3.4 ± .1 and post-task: 3.44 ± .09) values, which in the case of emotional valence and dominance was modulated by time-point, outcome and sex. Furthermore, analyses revealed that opponents' C, arousal and dominance values at one time-point influenced participants' values at the following time-point modulated by outcome, sex and time-point. Moreover, MLM indicated that in loser men, individuals higher in basal T (126.31 ± 6.4) displayed higher negative emotional valence after the defeat (post-task: 3.6 ± .21), while in women basal T (99.78 ± 12.6) was not significantly related to post competition emotional valence. These findings reinforce the importance of studying the relationship between hormonal and psychological changes in dyadic competition, and confirm that men and women differ in their psychophysiological responses to competition.

Keywords:

Competition, Dyads, Testosterone, Cortisol, Sex-differences, Emotional state

1. Introduction

Competition is a social interaction in which there is a confrontation between individuals or groups to achieve a limited goal and/or status (Salvador, 2005). Thus, in general, when one part obtains the goal the other does not. From an evolutionary perspective, competitive interactions are a natural way to obtain resources in order to adapt to environmental situations that affect the organization of social species (Blanchard, McKittrick, & Blanchard, 2001; Koolhaas, De Boer, Buwalda, & Van Reenen, 2007). Competitive behavior is a recurrent situation in humans, and it plays an important social role in obtaining not only primary reinforcements (such as food), but also other secondary resources (such as a high socioeconomic status) (Salvador & Costa, 2009). Consequently, competition, and especially its outcome (victory vs. defeat) may have important consequences for achieving significant aims in daily life (Salvador, 2012).

Due to its importance, competitive behavior has been extensively studied in close relation to steroid hormones, mainly testosterone (T), but also cortisol (C) (Casto & Edwards, 2016). Currently, several experimental and review studies are still trying to find out whether there is a psychophysiological response pattern to competition in humans (e.g. Abad-Tortosa, Alacreu-Crespo, Costa, Salvador, & Serrano, 2017; Casto & Edwards, 2016; Costa & Salvador, 2012; Oliveira & Oliveira, 2014), based on the biosocial model of status (Mazur, 1985) and the challenge hypothesis (Wingfield, Hegner, Dufty, & Ball, 1990).

Both sport settings and laboratory tasks have supplied the background for studying the effect of competition on androgens in humans, originally focusing on men, although the number of studies with women has increased in recent years. Although studies in sport competition have displayed a robust winner-loser effect, results from laboratory studies have shown a smaller T effect (Carré & Olmstead, 2015; Geniole, Bird, Ruddick, & Carré, 2016), largely due to the diverse methodologies used, the sample size and the reduced number of studies comparing men and women responses (Casto & Prasad, 2017). Several studies found a competition effect in men, with T increases in response to competition in both winners and losers (Apicella, Dreber, & Mollerstrom, 2014; Steiner, Barchard, Meana, Hadi, & Gray, 2010; van der Meij, Buunk, Almela, & Salvador, 2010), while others did not find it (Gray, Vuong, Zava, & Mchale, 2018; Mazur, Susman, & Edelbrock, 1997; van Anders & Watson, 2007). One important issue on the study of competition effect is the existence of a control group, or the comparison between "competition day" vs "non-competition day". This methodology has been used mainly in sports (Salvador, Suay, Gonzalez-Bono, & Serrano, 2003; Suay et al., 1999) and it is missed out in the biggest part of the laboratory paradigms. Likewise, some studies found a winner effect, with T increases in winners, but not in losers, in women (Costa & Salvador, 2012), or in men but not in women (Carré, Campbell, Lozoya, Goetz, & Welker, 2013). Other studies found no significant T changes or even decreases during the experiment in mixed-sex samples (Carré, Putnam, & McCormick, 2009; Mazur, et al., 1997; Mehta, Snyder, Knight, & Lassetter, 2015; van Anders & Watson, 2007). All these studies have presented diversity of task paradigms: in some of them the outcome was manipulated (Mehta et al., 2015), in others the outcome was determined by skills and real performance (Costa & Salvador, 2012), while in other studies the outcome has been defined by chance (McCaul, Gladue, & Joppa, 1992) or a mix of chance and skills (Steiner et al., 2010). This diversity of paradigms could be one of the reasons for the heterogeneous results in laboratory context in contrast to the sport competition studies.

Respect to C response to competition and its outcome, several studies have shown decreasing C levels throughout the competition in men and women (Mazur et al., 1997; Costa & Salvador, 2012), whereas others have described C increases in men (Hasegawa, Toda, & Morimoto, 2008). Only a few laboratory studies have found a winner effect after competition in men and women (Mehta, Jones, & Josephs, 2008; Wirth, Welsh, & Schultheiss, 2006).

As noted above, there is a variety of significant and non-significant effects of competition on hormones, and it has been pointed out that a large amount of studies in the literature were underpowered to detect a small effect size, as the reported in laboratory competition (Geniole et al., 2016). As highlighted by Geniole et al. (2016), it is important, not only increase the sample sizes but also examine the psychological, contextual and hormonal factors that are underlying the variability in the winner-loser effect size.

In addition to the competition and outcome effects, literature has suggested that individuals' psychological variables might have an influence on hormonal response to competition (Salvador & Costa, 2009), and vice versa, individual differences in hormonal levels could modulate psychological response to competition and outcome. For example, T changes were related to task enjoyment (Mehta et al., 2015), pride or happiness (Mazur & Lamb, 1980) in winners, and with a general satisfaction with the outcome (Oliveira, Gouveia, & Oliveira, 2009), while pre-match T was related to anxiety (Arruda et al., 2014). Also C has been related to psychological factors as anxiety (Aguilar, Jiménez, & Alvero-cruz, 2013) or power motivation (Wirth et al., 2006). But, in addition, literature has suggested that basal hormonal levels, which has been considered a "trait index" (Welker, Gruber, & Mehta, 2015), could predict post competitive psychological and behavioral states. Thus, high T losers have been associated with accuracy (Henry, Sattizahn, Norman, Beilock, & Maestripieri, 2017) or avoidance of future competitions (Mehta et al., 2008), while in some cases basal C or T modulate the situational relationship between hormones and factors like self-assurance or dominant behavior (Mehta & Josephs, 2010; Zilioli & Watson, 2013). As we can see along the literature, hormones have been often related to different factors linked to emotional states. However, these results did not reveal whether there is a relationship between smaller components of the emotion or whether the results in one sex can be extended to the other.

According to Russell and Mehrabian (1977), three independent and bipolar dimensions, valence (pleasure-displeasure), arousal (calm-excited), and dominance (dominance-submissiveness), are necessary and sufficient to adequately define emotional states. Following this dimensional approach, several studies described a consistent positive relationship between the 'arousal' component and the activation of the autonomous nervous system (ANS), especially when measured by skin conductance levels (Khalfa, Isabelle, Jean-Pierre, & Manon, 2002; Krumhansl, 1997). However, related to the 'valence' component, studies found less consistent results, although it has been related to the neuroendocrine system. For example, the administration of exogenous T was related to reduced skin conductance responses, as well as reduced affective startle modulation, in anxiety-prone participants during the display of negative stimuli (Hermans et al., 2007). In addition, higher C levels were associated with a propensity to a negative valence perception for ambiguous stimuli (Brown, Raio, & Neta, 2017). The third dimension proposed by Russell and Mehrabian was 'dominance', which refers to the sensation of control, understood as the perception of being dominant or submissive, controlling or being controlled in a specific situation. Dominance, as an individual trait, was extensively studied in association with competitive behavior, and research in humans suggested that dominance is also an essential parameter related to the hormonal response (Allan Mazur & Booth, 1998; Mehta & Josephs, 2010). As the literature reveals, dominance in the competitive context has been studied as a personality trait; however, measuring dominance as a state, that is, the perceived dominance in the specific situation, could provide insights into the hormonal response to competition.

In order to shed light on the research on the competition and winner effect, and complement previous literature with the study of the emotional state, we aimed to analyze the hormonal and emotional responses associated with competition and its outcome in young men and women, using a dyadic approach, by studying: (a) the hormonal response, (b) the emotional response, and (c) the relationship between hormonal and emotional levels, in a laboratory competition. To do so, we analyzed the participants' hormonal and emotional response to a laboratory face-to-face competition based on real outcome, as well as whether there is an influence of their partners' psychophysiological response. Additionally, a control group (no competition) was also analyzed in order to compare the effects.

We expected to confirm the effect of competition on the hormonal and emotional responses. More specifically, we expect that competition and its outcome is modulating participants' psychophysiology by means of decreases in C and increases in T, perceived arousal, dominance, and positive emotional valence, while the contrary pattern is expected in losers. On the other hand, exploring the role of the opponent using Actor-Partner Interdependence Models (Gonzalez & Griffin, 2012; Kenny, Kashy, & Cook, 2006) implies, as a novelty in competition literature, that it will be explored if hormonal and emotional levels of members of the dyad influence each other, as it has been suggested in studies in other fields of research (Ketay & Beck, 2017; Ketay, Welker, Beck, Thorson, & Slatcher, 2018; Slatcher, Mehta, & Josephs, 2011). Finally, based on previous studies linking mood to T (e.g. Oliveira et al., 2009), it was expected to observe a positive relationship between basal T, and emotional valence.

2. Methods

2.1. Participants

In all, 120 university students (50 men and 70 women) from different faculties at the University of Valencia, Spain, participated in this study. The recruitment was verbally announced in different classrooms belonging to the psychology, biology, sociology, physics and sport science degrees. After that, all the stakeholders facilitated their email address to the recruiters. Subsequently, our group contacted with the volunteers in order to provide them the screening questionnaire. Based on their answers, volunteers were only selected if they had no physical or psychological illnesses, were non-smokers (less than 5 cigarettes per day), did not consume drugs regularly, and did not practice more than 10 h of physical activity per week. In the case of women, the use of contraceptive methods was controlled.

Participants who met these criteria were contacted by telephone and asked to maintain their normal food intake and sleep patterns, avoid drinking alcohol, and refrain from strenuous physical activity the day before the experimental session. They were also asked to avoid smoking, eating, and taking any stimulant drinks for 2 h before the experiment. Five participants were eliminated from the sample for not complying with the experimental requirements, and three other participants were removed due to irregularities during the saliva sampling. The final sample was composed of 112 young students (46 men and 66 women) who were 21.7 ± .3 years old and had a Body Mass Index

(BMI) of 22.9 ± .3. Participants were initially randomly divided into two groups depending on their participation in the competitive condition (Experimental group, EG) or the non-competitive condition (Control group, CG). After the competition, subjects in the EG group were divided into winners and losers depending on the real outcome obtained. At the end of the experimental phase and data processing, the sample was composed of 36 winners (13 men and 23 women), 36 losers (13 men and 23 women), and 32 controls (16 men and 16 women), and a total of 52 dyads.

2.2. Design and procedure

The EG and CG formed same-sex pairs in one 90-min session conducted between 15:30 and 20:00 pm, in order to control circadian rhythms. All the participants received verbal and written general information about the procedure and the hormonal and psychological recordings, and they signed an informed consent. The study was approved by the Ethics Research Committee of the University of Valencia in accordance with the ethical standards established in the 1964 Declaration of Helsinki and its amendments.

2.2.1. Baseline period.

Participants arrived at the laboratory and were seated alone in two separate rooms where they could not see each other. There the participants read and sign the informed consent and provided information about general habits. Afterwards (approximately 25-30 min after the arrival), they received instructions to take the first saliva sample (baseline).

2.2.2. Pre-task period.

After that, participants were moved to room 2, where an experimenter (of the same sex as the participants) seated them at a table face-to-face. After a 5-min habituation period, the task instructions were given. The experimenter explained to the EG that they were going to compete for a prize. S/he gave them the task explanations through oral and written instructions and showed them the economic reward (5€). In the CG, the experimenter explained the task but did not give instructions to compete or offer any reward. The experimenter then gave a brief example of the task, and the participants practiced for 2 min to familiarize themselves with the task. Subsequently, but before the task began, participants filled out the first measure (pre-task) about their emotional state.

2.2.3. Task period.

Next, the subjects participated in the competitive (EG) or noncompetitive task (CG). The task lasted 20 min, and was divided into 5 trials of 2.5 min each. In the middle of the task (after trial three), the participants filled out the second emotional state measure (task). In the EG, the experimenter withdrew and corrected the task following each trial; afterwards, s/he gave them feedback about their performance. After the last trial, the total scores were provided, and the economic reward was given to the winner. In the CG, the task was merely withdrawn following each trial, but in this case it was not corrected, and the experimenter did not give them any feedback about their performance or a reward.

2.2.4. Post-task period.

Immediately after the task, the participants answered the third measure about their emotional state (post-task) while the second saliva sample (task) was taken. Finally, they remained seated until 15 min after the task, when the third saliva sample was taken (post-task).

2.3. Measurements

2.3.1. Saliva collection and analyses.

To measure salivary T and C concentrations, testosterone and cortisol enzyme-immunoassay kit from Salimetrics (Salimetrics LLC, State College, PA, USA) were used. Assay sensitivity were < 1.0 pg/ml and < 0.007 ug/dL, respectively. In brief, saliva samples were pipetted into a microtitre plate coated with rabbit antibodies in duplicate, and competitively bound to the plate with hormone linked to horseradish peroxidase. After the plate was washed, the bound hormone was measured using the reaction of the peroxidase with tetramethylbenzidine (TMB). Finally, the optical density was read on a standard plate reader at 450 nm. The mean inter- and intra-assay variation coefficients were all below 10%. For each subject, all the samples were analyzed in the same trial. T levels were expressed in pg/ml whereas C levels were expressed in nmol/L. The procedure has been previously reported (De Bernardo et al., 2018; Manuck et al., 2010).

2.3.2. Emotional assessment.

In order to analyze changes of the emotional state over competition, the Self-Assessment Manikin (SAM) was employed (Bradley & Lang, 1994) in three different time-points: first, before the task, but after the task instructions (pre-task); second, in the middle of the task (task); third, after the task ended (post-task). The SAM instrument is a non-verbal pictorial assessment technique that directly measures the associated emotional valence, arousal, and dominance in order to examine situational emotional changes in response to an object or event (Bradley & Lang, 1994; Lang, Bradley, & Cuthbert, 1997; Mascret et al., 2016). Participants answered a question for each dimension on a pictorial instrument (Figure 1). Afterwards, for a more convenient data processing, we transformed their answers into a likert scale from 1 to 5, where 1 represents the maximum negative emotional valence, minimum emotional arousal, and perceiving oneself as completely dominated or submissive; and 5 represents the maximum positive emotional valence, maximum emotional arousal, and perceiving oneself in a completely dominant position.

Insert Figure 1

2.3.3. Task.

The task employed was ‘the letters squares’, a paper-and-pencil test that measures perception and attention (Cordero, Seisdedos, González, & De la Cruz, 1990), previously adapted and employed in laboratory competition (Costa & Salvador, 2012). Each subject received a page with 140 matrixes of 16 letters (4 × 4) each. The participants were asked to find one repeated letter in a line or column as fast as possible, and then repeat this process on the next matrix. The EG participants received adapted instructions in order to provoke and maintain competitiveness. First, participants were informed that they were participating in a competition and that the winner of this competition would receive an economic reward. In addition, after each trial, the experimenter gave them feedback about who was winning and who was losing. In the last trial, they were able to find out their total score. CG instructions only referred to the task and not to the competition, with no feedback on their performance or reward.

2.4. Data reduction and statistical analyses

First, the outliers were removed using the Mahalanobis distances method at the $p < .001$ criterion for repeated-measures variables (1 loser man on the emotional variables, and 1 control and 1 winner man on pre-task T and C). Kolmogorov-Smirnoff was used to check normality. C and T measurements showed a skewed distribution. Based on previous studies (Mehta & Josephs, 2006, 2010; Wirth et al., 2006), we log-transformed hormonal measurements (T and C) to approximate them to a normal distribution. Consequently, posterior analyses with hormones were carried out using log-transformed units, while for emotional measurements were used raw values.

Two-way ANOVAs were carried out with Condition (winners/losers/CG) and Sex (men/women) as independent factors, and BMI and socio-demographic variables as dependent variables. Next, homogeneity in the physiological baselines was examined using the same procedure. Finally, the homogeneity in T between women using or not hormonal contraceptives was checked by two way ANOVAs carried out with Condition and "Contraceptive" as independent factors, and the T levels as dependent variables.

Because the hormonal and emotional data are dyadic and measured over the time, we estimated two-level crossed models to account for non-independence in dyad members' data by estimating actor and partner effects. The multilevel models (MLM) were tested using the linear mixed-effects models procedure in SPSS (Ketay & Beck, 2017). In the EG, the dyad members where distinguishable (Kenny et al., 2006) based on the competition outcome factor (winners and losers), so we treated dyads as distinguishable in terms of the fixed and random effects (see Thorson, West, & Mendes, 2017, for details). On the contrary in CG, we treated dyads as indistinguishable (member cannot be distinguished because each dyad included members of the same sex and doing the same task without and outcome or feedback about performance). We used the term “actor” to denote predictor variables for one person that affects the same person’s outcome variable, and the term “partner” to denote predictor variables from a partner (Ketay et al., 2018).

First, we used analogous models to predict whether individuals’ own hormonal (T and C) and emotional (valence/arousal/dominance) values were stable over the time or influenced by partners’ values. Variables were grand-mean centered at the first point-time (baseline for hormones, and pre-task for emotional measures). Subsequently we calculated for each variable its corresponding value at the prior time point by using a lag length of one interval. Those models were adapted in terms of fixed and random effects for distinguishable dyads in the EG, and for indistinguishable in the CG.

Finally, only for EG, we used MLM to check whether individuals’ basal T, their partners’ basal T (BT) predict post competition emotional state, as reported in previous studies (Booth et al., 1989; Oliveira et al., 2009), depending on sex (men/women) outcome (winner/loser) and time-point (pre-task/task/post-task). Basal T was grand-mean centered and emotional valence was grand-mean centered at the first point-time (pre-task).

All statistical analyses were performed with the SPSS 22.0 for Windows. The alpha level was fixed at 0.05.

3. Results

We included the raw descriptive values for hormonal (see Table 1, supplementary material) and emotional measurements (see Table 2, supplementary material) in order to allow a more elucidative overview. Statistical analyses with T and C reported bellow employed log-transformed data.

Insert Table 1

3.1. Hormonal response

Testosterone stability and influence as a function of Time and Sex

Competition group:

To examine whether the T stability and influence change over the time, we conducted a two level crossed model regressing actor T levels on time (centered at Time-point 1 = baseline), actor and partner lagged (LAG) T (lag length of one interval), the distinguishing factors winner (dummy coded as 0 = losers and 1 = winners) and loser (dummy coded as 0 = winner and 1 = loser), sex (effect-coded as 1 = women and -1 = men) and the appropriate two-, three-way interaction terms.

There was no two- or three-way significant interaction (see Table 3, Model 2 and 3, supplementary material). Only the Model 1 (see Table 1) was showing significant main effects of Time ($F(1, 51.91) = 4.7$, $p = .035$), Sex ($F(1, 71.57) = 8.49$, $p = .005$), Actor_winner_T_{LAG} and Actor_loser_T_{LAG} ($F(1, 139.6) = 65.98$, $p = <.001$ and $F(1, 20.41) = 40.28$, $p = <.001$, respectively). Indicating a general T decrees over time, higher T levels in men than in women, and a T stability both for winners and losers, so that higher values (values above the grand mean) of actor's T at one time point, are associated with higher values of actor's T at the following time point. We observed no significant effects involving partner, suggesting that partner's T did not influence actor T levels.

Control group:

Across CG (with indistinguishable dyads), we conducted a two-level crossed model regressing actor T levels on time (centered at Time-point 1 = baseline), actor and partner lagged T (lag length of one interval), Sex (effect-coded as 1 = women and -1 = men) and the appropriate two-, three-way interaction terms. In this case results showed no significant main or interaction effect (Table 4, supplementary material), reflecting that Time or Sex did not affect the actor T levels, and there was neither a stability nor influence effect between dyad members.

Insert Table 2

Cortisol stability and influence as a function of Time and Sex

Competition group:

Regarding C, MLM analysis showed a significant effect of the three-way term Time*Sex*Actor_winner_C_{LAG} ($F(1, 39.49) = 12.79$, $p = .001$) (see Table 2, Model 3). Follow-up analysis revealed a significant effect of the two-way interaction term Time*Actor_winner_C_{LAG} in women ($F(1, 45.7) = 86.69$, $p < .001$) but not in men ($F(1, 23.29) = 2.03$, $p = .167$). Nevertheless, the stability among winner women was strong both from baseline to task ($b = .837$, $SE = .02$, $t(22) = 40.19$, $p < .001$) and from task to post-task ($b = .804$, $SE = .01$, $t(22) = 65.9$, $p < .001$), such that higher actor's C values predicted higher C levels at the following time point. We also supplemented these analyses by examining main effects throughout the EG (see Table 2). In all models, actor's C values were positively associated to the actor's C at the next time point, in both winner and loser. Overall, these patters suggest that there is a general C stability (see Figure 2).

Insert Figure 2

We observed no significant interaction effects but main effects involving partner C_{LAG} (see Table 2, Model 1 and 2) suggesting that partner's C could positively influence subsequent actor's C levels but this relationship would not be modulated by Time, Sex or Outcome.

Control group:

In CG, the results indicated a main effect of Actor_CLAG, and a two-way interaction effect of Sex* Partner_C_{LAG} (see Table 5, supplementary material). Follow-up analysis showed that, in men, partner's C had a negative influence on actor's C (b = -.361, SE = .11, t(11.8) = -3.19, p = .008) while, in women, the influence was positive (b = .449, SE = .11, t(14.3) = 3.79, p = .002).

Insert Table 3

3.2. Emotional response

Emotional valence stability and influence as a function of Time and Sex

Competition group:

As in the case of hormones, we conducted the same two-level crossed models, with the appropriate two- and three-way interaction terms, all over the emotional components (emotional valence (EV), emotional arousal (EA) and dominance (D)).

Concerning emotional valence, MLM analyses showed significant effects of the three-way interaction terms Time*Sex*Actor_winner_EV_{LAG} (F(1, 293) = 9.15, p = .003) and Time*Sex*Actor_loser_EV_{LAG} (F(1, 43.95) = 5.2, p = .027) (see Table 3, Model 3). Follow-up analyses revealed that the two-way interaction terms Time*Actor_winner_EV_{LAG} and Time* Actor_loser_EV_{LAG}, were significant in men (F(1, 18.8) = 6.24, p = .022 and F(1, 25.9) = 4.54, p = .043, respectively) but not in women (F(1, 36.1) = .26, p = .613 and (F(1, 39.1) = .029, p = .865). In winner men, the stability was decreasing over the time (see Figure 3). So that actor emotional valence at pre-task was positively influencing its task values (b = .92, SE = .269, t(12) = 3.41, p = .005), but the stability was weakened from task to post-task (b = .377, SE = .189, t(12) = 1.99, p = .070). On the contrary, the stability strengthened for loser men over the time (see Figure 3), thus actor's pre-task emotional valence was not predicting task values (b = -.37, SE = .859, t(12) = -.431, p = .674) but there was a significant influence between task and post-task valence (b = .758, SE = .087, t(12) = 8.7, p = <.001). These results suggest that winner and loser men experienced changes in their emotional valence values during competition. While in winners the own tendency is altered in post-task, in losers the emotional valence changes between pre-task and task and then remains stable until the end of the competition. On the other hand, winner and loser women expressed no differences in degree of emotional valence stability over the competition (see Figure 3).

Insert Figure 3

We observed no significant main effects or interactions involving partner emotional valence, suggesting that there was not an influence between members of the dyad.

Control group:

In CG, there was a three-way significant interaction of Time*Sex*Partner_EV_{LAG} ($F(1, 11.35) = 6.81$, $p = .024$) (see Table 6, Model 3, supplementary material). However follow-up analyses showed that the two-way interaction Time*Partner_ EV_{LAG} was not significant either in women ($b = -.294$, $SE = .369$, $t(20.25) = -.797$, $p = .435$) or in men ($b = -.421$, $SE = .344$, $t(22) = -1.22$, $p = .234$).

Insert Table 4

Emotional arousal stability and influence as a function of Time and Sex

Competition group:

For emotional arousal, MLM reported main effects of Actor_winner_EA_{LAG}, Actor_loser_EA_{LAG} (see Table 4, Model 1, 2 and 3) and Partner_loser_EA_{LAG} (see Table 4, Model 2 and 3), suggesting an emotional arousal stability among participants, and a positive influence of the losers' arousal, so that higher values of losers' arousal at one time point predicted higher values of winners' arousal at the following time point. Furthermore, in Model 3 (see Table 4) the analyses showed significant effects of the three-way interaction terms Time*Sex*Actor_winner_EA_{LAG} ($F(1,44.9)= 8.36$, $p = .006$) and Time*Sex*Partner_Loser_EA_{LAG} ($F(1,37.5)= 5.92$, $p = .02$). Regarding actors' stability, follow-up analyses did not revealed a significant two-way effect of Time*Actor_winner_EA_{LAG} neither in men ($F(1,24.1)= .2$, $p = .657$)nor in women ($F(1,45.5)= .009$, $p = .923$). However, partner_loser's arousal influence was moderated by Sex and Time. The two-way interaction Time*Partner_loser_EA_{LAG} was significant in men ($F(1,24.2)= 6.63$, $p = .017$) but not in women ($F(1,45.4)= 1.47$, $p = .231$). In men losers' pre-task values positively influenced winners arousal during the task ($b = .883$, $SE = .356$, $t(12) = 2.47$, $p = .029$) but losers' task arousal became not linked to winner post-task values ($b = .044$, $SE = .175$, $t(12) = .252$, $p = .81$).

Insert Figure 4

Overall, these patterns suggest that competition participants experienced stable patterns of emotional arousal regardless sex and outcome and, on the other hand, in men but not in women, losers' arousal had an influence on winners' values, which weakened when the competition ended (see Figure 4).

Control group:

In CG, we observed no significant main effects or two- three-way interaction suggesting that emotional arousal was not modulated by prior actor or partner values, time or sex (see Table 7, supplementary material).

Insert Table 5

Dominance stability and influence as a function of Time and Sex

Competition group:

Regarding dominance, we first tested whether the main effects of time, sex actors' prior dominance and partners' prior dominance predicted participant's dominance (see Table 5, Model 1). There was an increase in dominance over the time ($F(1,15.9)= 18.1$, $p = .001$) and significant positive effects of both winner and loser actors($F(1,47.8)= 12.8$, $p = .001$ and $F(1,195)= 13.7$, $p = <.001$, respectively), which indicated a dominance stability along the competition. There was also a positive effect of $partner\_winner\_D_{LAG}$ ($F(1,9.34)= 7.18$, $p = .024$),suggesting that higher values of winners dominance in one time point predicted higher dominance in losers at the following time point.

Subsequently we tested the two-way interaction terms (Table 5, Model 2). We found a significant effect of $Time*Actor\_loser\_D_{LAG}$ ($F(1,23.7)= 7$, $p = .014$). Follow-up analyses showed that, in losers, the stability was stronger between pre-task and task (b = .956, SE = .132, t(35) = 7.2, p = <.001), but weakened at the end of the competition (b = .227, SE = .137, t(35) = 1.66, p = .11), suggesting that the defeat could modify the dominance inner patterns (Figure 5).

There were no three-way interaction effect predicting dominance (see Table 8, Model 3, supplementary material).

Insert Figure 5

Control group:

In CG, we observed no significant main effects or two- three-way interactions, suggesting that perceived dominance was not modulated by prior actor or partner values, time or sex (see Table 9, supplementary material).

Insert Table 6

3.3. Basal testosterone as predictor of competition emotional valence.

We conducted multivariate multilevel models to examine whether basal testosterone (BT) and sex interacted to predict emotional valence changes over the different competition time-points (pre-task, task and post-task). We conducted a two-level crossed model regressing emotional valence concentrations on time (centered at Time-point 1 = pre-task), actor BT (grand-mean-centered), partner BT (grand-mean-centered), the distinguishing factors winner (dummy coded as 0 = losers and 1 = winners) and loser (dummy coded as 0 = winner and 1 = loser), sex (effect-coded as 1 = women and -1 = men), and the appropriate two- and three-way interaction terms.

The Time*Sex*Actor_loser_BT interaction term was significant (F(1,88.2)= 3.78, p = .05) (see Table 6, Model 3). Follow-up analyses revealed that the two-way interaction between time and actor_loser_BT was significant in men (F(1,41.9)= 11.1, p = .002) but not in women (F(1,52.9)= 1.42, p = .238). In losers, higher basal T men experienced higher emotional valence at pre-task (b = 1.29, SE = .441, t(12) = 2.94, p = .012), however the relationship became negative during the task (b = -3.3, SE = 1.28, t(12) = -3, p = .011) and even stronger at post-task (b = -3.67, SE = 1.1, t(12) = -3.5, p = .005), such that higher basal T values predicted lower post-task emotional valence. These results suggest that men higher in T experience a more negative emotional valence after the defeat than those with lower basal T, while this would not happen in winners (men or women) and loser women (see Figure 6).

Insert Figure 6

4. Discussion

The aim of the present study was, firstly, to investigate, using a dyadic approach, the hormonal (T and C) and emotional (valence, arousal and dominance) responses to competition, depending on the outcome and sex and, secondly, the role of basal T predicting emotional responses after competition. Our results revealed stable hormonal and emotional responses (T, C and arousal) during competition. In the case of T and emotional valence, competition group differed in their responses during competition respect to control group, where no changes nor predictions were found. Furthermore, there were an outcome and sex effect on emotional valence, where pre-task emotional valence predicted task valence in winners, whereas, in losers, valence during the task predicte d post-task valence. Moreover, regarding sex differences, only in women pre-task C levels predicted post-task C levels, independently of the outcome of the competition. Finally, basal T levels predicted the negative emotional valence after defeat, in men but not in women.

We did not find T or C differences between winners and losers. In addition, regardless of the outcome, we found an overall T decrease throughout the competition. These findings agree with previous laboratory competition studies that found a T decrease, no significant change during the competition, or even no competition or outcome effect (Carré et al., 2009; Gray et al., 2018; Mazur et al., 1997; Mazur, Welker, & Peng, 2015; Mehta & Josephs, 2006; Mehta et al., 2015; van Anders & Watson, 2007). However, these results contrast with other studies that, consistent with the biosocial theory of status, found a relationship between T and winning in men and women (Apicella et al., 2014; Costa & Salvador, 2012; Mazur, Booth & Dabbs, 1992). Regarding C as well, we did not find differences related to condition or outcome in any of the samples. Both men and women showed a decreasing C level during the experiment, regardless of the condition (winners, losers, or CG), as described in other studies (Mazur et al., 1997; McCaul, Glaude & Joppa, 1992; Mehta & Josephs, 2006). However, in the case of women pre-competition C levels predicted post-task C levels in both, winners and losers, showing a consistent relationship between C levels across the competition that it has not been found in men. Literature has showed higher C levels in men than in women along different competition phases (Filaire, Alix, Ferrand, & Verger, 2009; Kivlighan, Granger, & Booth, 2005), what seems to contradict the absence of C response to competition. In addition, recent meta-analysis indicated a higher C reactivity to competition (van Paridon, Timmis, Nevison, & Bristow, 2017), and higher C levels after a social stress (Liu et al., 2017). In summary, in our study, there was no competition or winner effect on T or C; nevertheless, in women, pre-competition C levels were related to post-competition C levels, independently of the result. As noted above, the body of laboratory studies has been shown problems to describe a clear competition or outcome effect on hormones and in general, it has been underpowered detecting winner-loser differences (Geniole et al., 2016). Our results, added to the literature, may indicate that current laboratory competition designs are not successful in elicit T and C changes, unlike in sports competition. The differences in motivation, consequences for real life or status, among others, could underlie this situation (Casto & Edwards, 2016). Future studies should elucidate this question and try to increase the ecological validity by, for example, including "audience" or increasing the prizes. In the concrete, our results suggest that our different conditions are not enough stimuli to elicit T or C responses. It is possible that T and C need higher intensity stimuli to express changes. This point out the need to include other psychological and physiological variables in the study of competitive behavior.

In contrast to the hormonal response, results for the emotional measurements showed different relationships on valence between winners and losers, but only in the case of men. Thus, there were an outcome and sex effect on emotional valence, where pre-task emotional valence predicted task valence in winners, whereas, in losers, valence during the task predicted post-task valence. As expected (Costa & Salvador, 2012; Oliveira et al., 2009), winner men increased their positive emotional valence during the competition, being predicted by pre-task levels. However, in the case of loser men emotional valence during competition predicted post-task valence. These results could be reflecting that a higher emotional state predicts higher emotional state during competition that could increase the probability of winning. In losers, this result could indicate that the emotions experienced during the competition (probably negative when they are experiencing a sense of losing), predicted post-task valence. In the case of women, a stable emotional valence throughout the competition without the influence of the outcome in comparison to men has been found. It should be kept in mind that emotional pre-task measures were taken after a short task training period; thus, it is possible that women had a positive coping expectation, feeling able to control their performance and the outcome. Regarding sex, the different emotional evolution of winner and loser men could be explained based on the mood adjustment approach (Knobloch, 2003), which suggests that individuals try to regulate their moods in order to meet the requirements of anticipated situations. Thus, depending on situational adjustment goals, individuals might prefer to maintain their mood in a state that leads them to focus on the task or display socially desirable emotions (Knobloch-westerwick & Alter, 2006). In this regard, it is possible that in social stress situations (as in this face-to-face competition), females are likely to use less aggressive behavior and focus on positive feelings, based on social rules. However, males are more likely to seek a state that is functional for retaliation, and, therefore, they might prefer to focus on more negative emotions (Brody, 1993; Brody & Hall. 1993). For example, positive emotions have been found to increase visuospatial attentional breath (Gable & Harmon-jones, 2008; Grol, Koster, & Bruyneel, 2014; Fredrickson & Branigan, 2005), improving performance, as in our task. Complementarily, loser's dominance, in both sexes, decreased after the competition that is consistent with the fact of losing a competition. However, dominance in winners did not change, in spite of winning the competition, having stable scores during all the competition. These results suggest that losing influences the sense of dominance, at least in this type of competition, where the task was easy to perform. It is possible that in difficult tasks winning could increase the sense of dominance. Regarding emotional arousal, the results were non-significant, showing that, in the competition group nor control group, arousal levels did not influence arousal during the experimental protocol. These results could be complemented with previous studies that found higher physiological arousal in competition compared to a non-competitive task (Abad-Tortosa, Alacreu-Crespo, Costa, Salvador, & Serrano, 2017), suggesting that psychophysiological activation is necessary to appropriately cope with competitive situations. However, this was not tested in this study.

Dyads analyses showed that in competition group, patterns of actors' T and C levels showed a general stability, so that high actor T levels were influenced by previous actor T levels and the same relationship was found by C levels. Respect to partners' influences, a different panorama was found. Actor T levels were not influenced by partners' T; whereas, partners' C levels affected subsequent actor C levels. Previous studies have found that actor social anxiety was related to C response to a social interaction, but partner's social anxiety was not related to C response (Ketay et al., 2018). But a former investigation pointed out that partner's attachment styles were linked to C response during friendship initiation by means of a self-disclosure task, in sex-mixed sample (Ketay & Beck 2017). Therefore, our results showed that although actor's C is not affected by task, sex or outcome, it is affected by C of the competition opponent. Complementarily, in CG actor's C was predicted by the interaction between sex and partner's C. The results point to that the presence of the partner in a social interaction is different depending on sex. In men, the more C of the actor, the lower C of the partner, maybe the situation (face-to-face completing the task) can be able to modify the perception similarly to mixed-sex interactions. These results are in the same line that Van der Meij et al. (2010) described a change in C in men in a social interaction with a woman. On the contrary, in CG women, the more actor's C, the more partner's C. It is possible that, in women, high C levels in one dyad member promotes high C on the other, maybe related to non-verbal clues. These interactions are complemented by emotional arousal and dominance. The competition group, as in the case of hormones, experienced stable patterns of emotional valence, emotional arousal and dominance. Besides, outcome emerges as a core variable in the explanation of emotional response to competition. In this sense, in men, loser's arousal influenced on subsequently winner's values, but winner's dominance predicted subsequent higher loser's dominance.

Regarding the hormones' influence on the emotional state, our study reveals that, in men but not in women, T levels moderated the emotional valence after the competition. In loser men, we obtained a negative relationship between post-task baseline T and the post-task emotional valence. Thus, higher T in men, would lead to experience higher negative mood after a defeat. These results raise the question of the role of T in competition and the winner effect. Our data in men did not show any differences in T depending on the outcome, nevertheless, T can influence the way participants experience the competition outcome. T and mood have been previously related (e.g. Allen Mazur & Lamb, 1980) but as far as we know, this is the first study to examine the differential effect of T on mood/emotional valence depending on the outcome. Our results are in accordance with Mehta et al. (2008) and Zilioli & Watson (2013) researches, which pointed out a relationship between basal T and post-competition changes in C and behavior associated with outcome, indicating in T men higher C levels and avoidance behaviors after a defeat, while high basal T was related to positive emotions after a victory (Mehta et al., 2015). In the same line, Carré, Putnam and McCormick (2009) found that a rise in T concentrations was positively associated with aggressive behavior in loser men, but not in winner men. These results, together with ours, could be different indicators for the same phenomena, a more stressful or negative defeat experience in high T men. An explanation could be that high T in men is a consequence of previous experiences of success or higher trait dominance and status (e.g. Carré et al., 2009; Mazur & Booth, 1998), thus the defeat for these individuals would mean a change in the hierarchy. Literature also has pointed out that high T increases reward-seeking, this could lead to excessive positive emotion, and could increase the likelihood of behavioral dysregulation (Welker et al., 2015). Thus, high basal T could elicit a bigger psychological dissonance after a defeat, provoking high intensity negative emotions. In this regard, it is possible that, in our investigation, high T men were more surprised or annoyed by the loss and, consequently, more focused on their negative feelings. This could be in line with Zilioli, Mehta and

Watson (2014), whom found higher T rises in losers who were surprised by the loss, compared to individuals who lost and were not surprised, indicating a relationship between T and outcome appraisal. Future studies should elucidate this question.

This study is subject to limitations. First, enzyme-immunoassay kit from Salimetrics employed to measure salivary T and C, have been shown higher T measurement error than liquid chromatography tandem mass spectrometry method. Especially in the case of women, it has been suggested that enzyme immunoassays overestimate T concentrations (Welker et al., 2016). This could mask some hormonal effects, mainly regarding women T responses. Second, our design with a non-manipulate outcome based on real performance may be a strength and weakness. We consider it adds ecological validity to our study and makes it more closely to sport competition or other natural situations. Also, allows us to study psychobiological patterns which could conduct to the victory or defeat. However, we cannot make a causal attribution to competition or outcome for the effects we have found, and other factors like effort or motivation could underlie these effects. Including both, manipulated and natural outcome conditions in the same study could clarify this issue. Finally, even when our study has a good sample size compared with many studies of hormones response to competition, speci ally taking to account the dyadic nature of the experiment, our sample is still underpowered to test some interactions, this could limit the statistical power to detect potential effects.

It is also necessary to mention other issues to consider in future research. First, future studies should increase the number of hormonal and emotional samples in order to provide a better overview; in this regard, basal levels of emotions would be advisable. Second, it is worth noting that men and women respond differently to competition, and this should be considered in future investigations by comparing the sexes, as recommended by Casto and Prasad (2017). Third, as pointed out recently (Geniole et al., 2016), future research in laboratory could beneficiate of a larger sample size in order to detect weaker hormonal changes. Finally, we want to emphasize the need to improve and homogenize the methodological designs (including the use of CG and the task paradigm) in order to advance the study of the psychophysiological response to competition in humans and the search for consistent results. In addition, research would benefit using different statistical analyses, as multilevel models that permit study the interaction between variables and participants of the dyad and this could clarify the inconsistencies found in the literature.

In conclusion, to our knowledge, this is the first study to examine hormonal and emotional changes in a competitive situation with non-manipulated outcome based on skills and including a control group and a detailed comparison of men and women. Moreover, what is more important, we incorporated a dyadic approach that have allowed us to study the effect of the opponent in the responses of winners and losers. Thus, our results revealed stable hormonal and emotional responses (T, C and arousal) during competition, but in the case of T and emotional valence, a competition effect. Moreover, there were outcome and sex effects on emotional valence, where pre-task emotional valence predicted task valence in winners, whereas, in losers, valence during the task predicted post-task valence. Furthermore, C and arousal levels were influenced by the opponent, showing an actor-partner interaction effect in the response to competition. Finally, we have found that T basal levels have a different influence on emotional response to competition and outcome depending on the sex such that higher T provoked higher negative emotional valence after the defeat in men but not in women.

In sum, our results showed a different evolution among the three emotional components measured, a link between hormones and emotion modulated by outcome and sex, as well as an influence of the partner on the psychophysiological responses. From our perspective, these results indicate the importance of deconstructing emotion and analyze sex differences, and emphasize the idea of studying the opponent to reach a better understanding of its role on the competitive psychophysiological response.

Acknowledgements

This research study was supported by the Spanish Education and Science Ministry (grants no. PSI2013-46889 and PSI2016-78763). The authors wish to thank Ms. Cindy DePoy for the revision of the English text.

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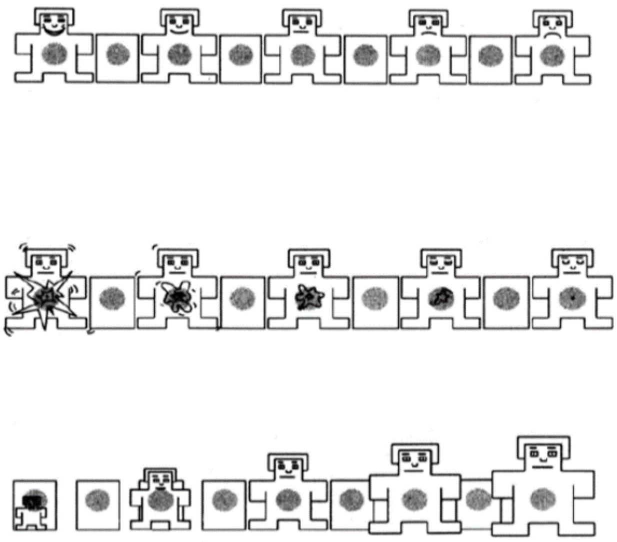
Figure 1. Emotional state self-assessment instrument employed before, during and after task.



I feel COMPLETELY happy, pleased, satisfied, optimistic — I feel COMPLETELY unhappy, annoyed, unsatisfied, melancholic, pessimistic

I feel COMPLETELY stimulated, excited, awake, activated, agitated — I feel COMPLETELY relaxed, clam, drowsy, inactivated,

I feel COMPLETELY dominated, influenced, submissive — I feel COMPLETELY dominant, influential, important

Based on Self-Assessment Manikin (Bradley & Lang, 1994)

Figure 2. Cortisol stability as a function of time, sex and participant outcome

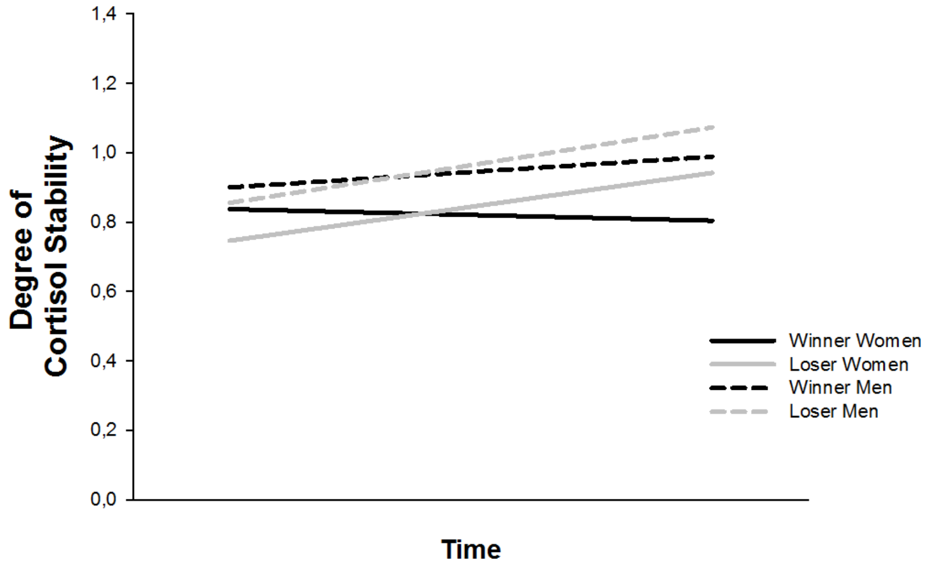


Figure 3. Emotional valence stability as a function of time, sex and participant outcome

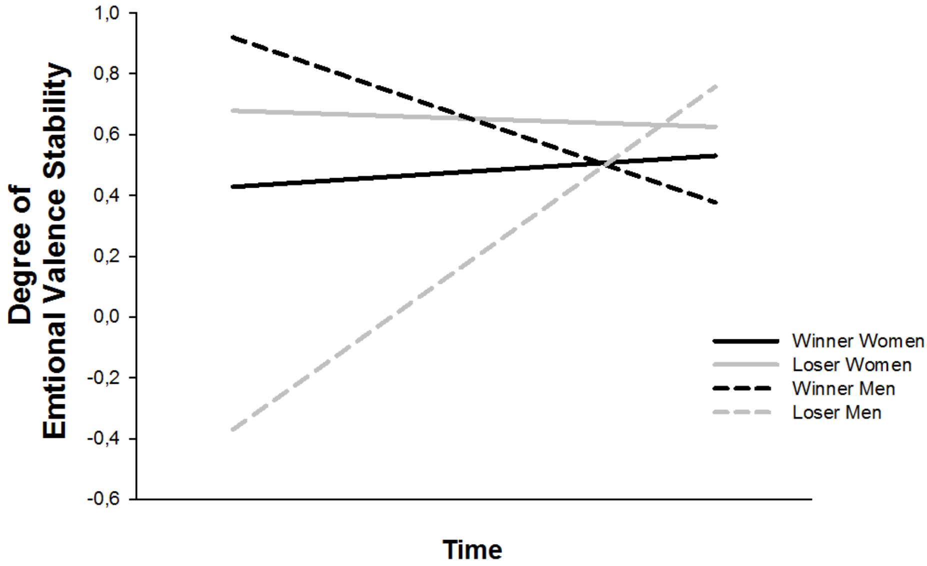


Figure 4. Emotional arousal influence as a function of time, sex and participant outcome

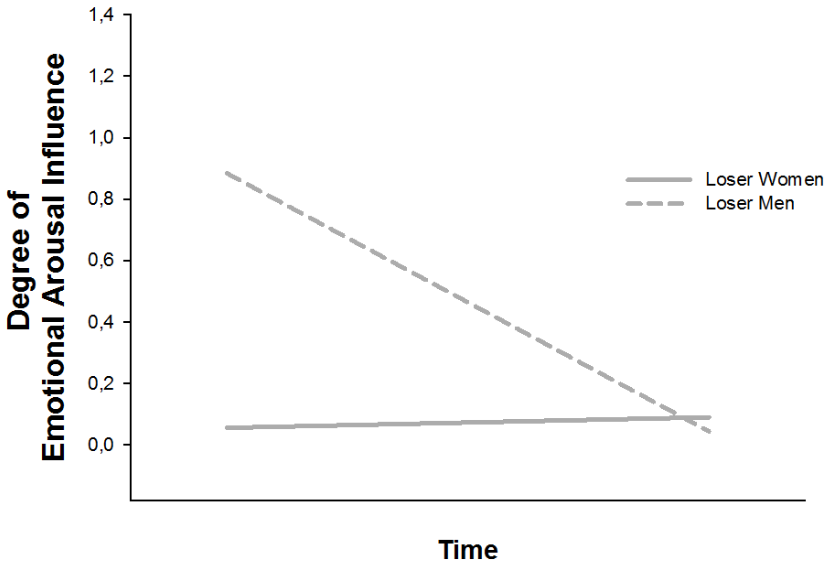


Figure 5. Dominance stability as a function of time, sex and participant outcome

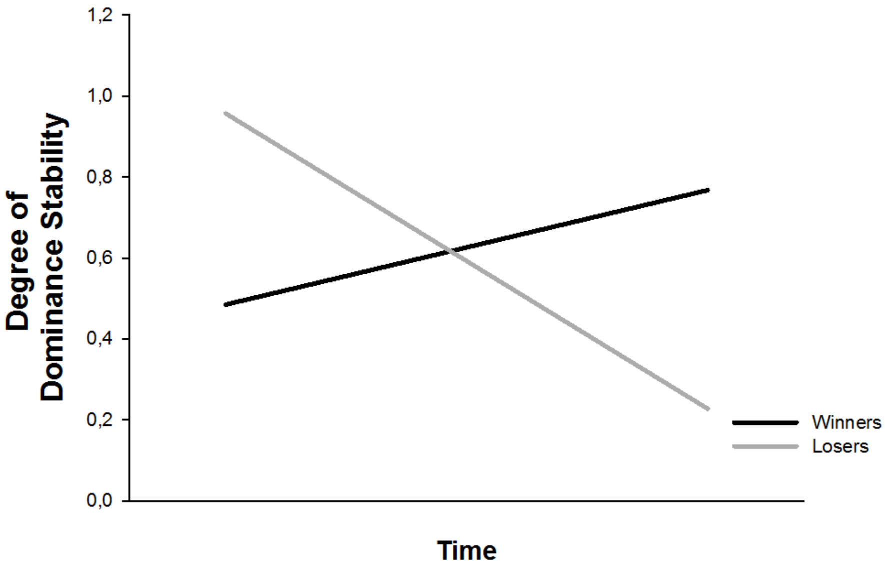


Figure 6. Post-task emotional valence as a function of sex, outcome and actor basal testosterone

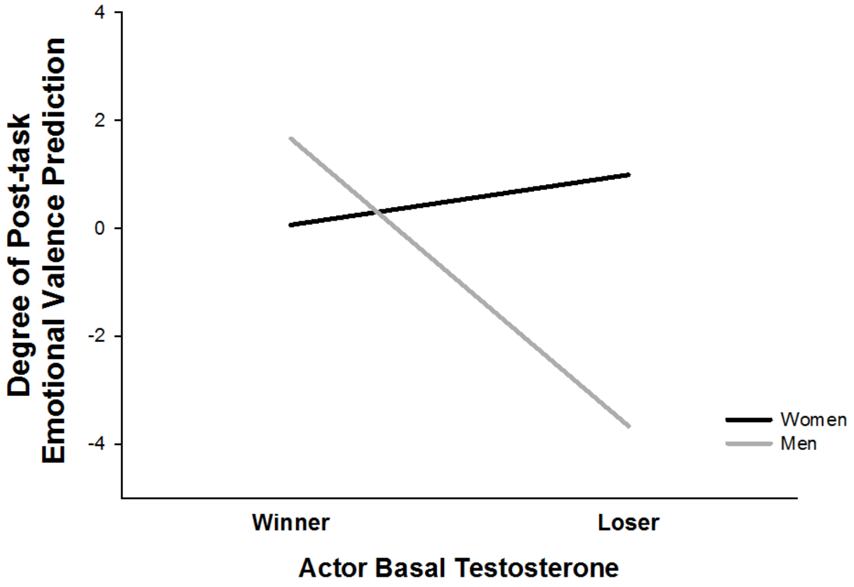


Table 1. *Competition Group:* Testosterone as a function of time, sex, actor prior testosterone, and partner prior testosterone

	b	**SE**	***t***	***df***	***p***
Model 1					
Time	-.013	.006	-2.17	51.91	.035
Sex	-.052	.017	-2.91	71.57	.005
T_{LAG}_AW	.771	.095	8.12	139.6	<.001
T_{LAG}_AL	.627	.099	6.35	20.41	<.001
T_{LAG}_PW	.116	.1	1.15	129.4	.251
T_{LAG}_PL	.217	.093	2.32	1.54	.183

Note: T_{LAG}_AW = prior testosterone in actor winner; T_{LAG}_AL = prior testosterone in actor loser; T_{LAG}_PW = prior testosterone in partner winner; T_{LAG}_PL = prior testosterone in partner loser

Table 2. *Experimental group:* Cortisol as a function of time, sex, actor prior cortisol, and partner prior cortisol

	b	SE	*t*	*df*	*p*
Model 1					
Time	.02	.014	1.38	406.7	.166
Sex	-.055	.022	-2.56	12.71	.024
C_{LAG}_AW	.672	.046	14.34	125.98	<.001
C_{LAG}_AL	.71	.048	14.59	95.65	<.001
C_{LAG}_PW	.369	.049	7.5	143.88	<.001
C_{LAG}_PL	.393	.045	8.71	103.9	<.001
Model 2					
Time	-.378	.038	-9.85	25.1	<.001
Sex	-.21	.081	-2.56	27.5	.016
C_{LAG}_AW	.744	.116	6.37	84.2	<.001
C_{LAG}_AL	.683	.106	6.43	51.9	<.001
C_{LAG}_PW	.253	.114	2.2	83.4	.030
C_{LAG}_PL	.381	.11	3.47	58.9	.001
Time X Sex	.014	.015	.951	84.3	.344
Time x C_{LAG}_AW	-.148	.044	-3.31	65.8	.001
Time x C_{LAG}_AL	-.141	.046	-3.1	65.3	.003
Time x C_{LAG}_PW	-.068	.048	-1.41	90.9	.162
Time x C_{LAG}_PL	-.079	.042	-1.84	48.9	.071
Sex x C_{LAG}_AW	-.073	.052	-1.41	25.1	.168
Sex x C_{LAG}_AL	-.1	.053	-1.95	56.3	.056
Sex x C_{LAG}_PW	.023	.055	.435	131.1	.664
Sex x C_{LAG}_PL	.028	.046	.619	20.6	.543
Model 3					
Time	-.382	.039	-9.68	25.43	<.001
Sex	-.023	.267	-.088	45.19	.93

C_{LAG}_AW	.841	.12	7	50.7	<.001
C_{LAG}_AL	.697	.111	6.26	45.34	<.001
C_{LAG}_PW	.117	.121	.976	49.39	.334
C_{LAG}_PL	.382	.112	3.38	48.89	.001
Time X Sex	-.068	.11	-.624	51.23	.536
Time x C_{LAG}_AW	-.184	.047	-3.91	39.12	<.001
Time x C_{LAG}_AL	-.15	.047	-3.15	55.84	.003
Time x C_{LAG}_PW	-.018	.049	-.375	55.96	.71
Time x C_{LAG}_PL	-.079	.045	-1.76	40.64	.085
Continued	***b***	**SE**	***t***	***df***	***p***
Sex x C_{LAG}_AW	.283	.124	2.28	52.29	.026
Sex x C_{LAG}_AL	.111	.163	.679	54.35	.5
Sex x C_{LAG}_PW	-.157	.168	-.933	54.38	.355
Sex x C_{LAG}_PL	-.126	.116	-1.1	51.22	.285
Time x Sex x C_{LAG}_AW	-.173	.048	-3.57	39.49	.001
Time x Sex x C_{LAG}_AL	-.1	.066	-1.53	58.25	.13
Time x Sex x C_{LAG}_PW	.096	.067	1.42	56.58	.161
Time x Sex x C_{LAG}_PL	.073	.046	1.58	42.1	.121

Note: C_{LAG}_AW = prior cortisol in actor winner; C_{LAG}_AL = prior cortisol in actor loser; C_{LAG}_PW = prior cortisol in partner winner; C_{LAG}_PL = prior cortisol in partner loser

Table 3. *Experimental Group*: Emotional valence as a function of time, sex, actor prior emotional valence, and partner prior emotional valence

	b	SE	*t*	*df*	*p*
Model 1					
Time	.016	.032	.51	6.47	.63
Sex	-.147	.071	-2.1	4.23	.1
EV_{LAG}_AW	.558	.144	3.85	3.61	.022
EV_{LAG}_AL	-.022	.115	-.193	3.93	.857
EV_{LAG}_PW	-.138	.093	-1.48	12.7	.163
EV_{LAG}_PL	-.059	.182	-.326	.1	.916
Model 2					
Time	.06	.036	1.66	80.4	.099
Sex	.076	.245	.31	7.1	.765
EV_{LAG}_AW	2.4	.446	5.38	12.9	<.001
EV_{LAG}_AL	.069	.672	.1	15.1	.919
EV_{LAG}_PW	.413	.537	.769	11.2	.458
EV_{LAG}_PL	-.317	.576	-.55	18.9	.589
Time X Sex	-.075	.097	-.768	6.1	.471
Time x EV_{LAG}_AW	-.725	.164	-4.4	8.95	.002
Time x EV_{LAG}_AL	-.016	.231	-.072	14.9	.944
Time x EV_{LAG}_PW	-.221	.188	-1.17	10.6	.265
Time x EV_{LAG}_PL	.053	.2	.264	13.9	.796
Sex x EV_{LAG}_AW	-.3	.169	-1.78	14.6	.095
Sex x EV_{LAG}_AL	.013	.134	.099	22.9	.922
Sex x EV_{LAG}_PW	-.093	.11	-.889	13.1	.39
Sex x EV_{LAG}_PL	-.028	.217	-.13	80.3	897
Model 3					
Time	.078	.027	2.84	197	.005
Sex	.001	.232	.008	72.5	.994

EV_{LAG}_AW	2.2	.355	6.2	231	.000
EV_{LAG}_AL	-1.61	1.31	-1.22	44.1	.227
EV_{LAG}_PW	-.438	.545	-.81	508	.421
EV_{LAG}_PL	-.246	.885	-.279	47.1	.782
Time X Sex	-.051	.092	-.56	60.6	.577
Time x EV_{LAG}_AW	-.664	.136	-4.88	264	.000
Time x EV_{LAG}_AL	.8	.455	1.76	45.3	.085
Time x EV_{LAG}_PW	.1	.192	.548	546	.584
Time x EV_{LAG}_PL	.049	.341	.146	43.1	.885
Continued	***b***	**SE**	***t***	***df***	***p***
Sex x EV_{LAG}_AW	-1.29	.349	-3.7	331	.000
Sex x EV_{LAG}_AL	2.94	1.31	2.25	42.7	.03
Sex x EV_{LAG}_PW	.784	.537	1.45	600	.145
Sex x EV_{LAG}_PL	-.041	.883	-.047	49.1	.963
Time x Sex x EV_{LAG}_AW	.399	.132	3	293	.003
Time x Sex x EV_{LAG}_AL	-1	.45	-2.28	43.95	.027
Time x Sex x EV_{LAG}_PW	-.3	.185	-1.62	555	.106
Time x Sex x EV_{LAG}_PL	.001	.341	.000	46.8	1

Note: EV_{LAG}_AW = prior emotional valence in actor winner; EV_{LAG}_AL = prior emotional valence in actor loser; EV_{LAG}_PW = prior emotional valence in partner winner; EV_{LAG}_PL = prior emotional valence in partner loser

Table 4. *Experimental Group:* Emotional arousal as a function of time, sex, actor prior arousal, and partner prior arousal

	b	SE	*t*	*df*	*p*
Model 1					
Time	.1	.055	1.84	21.2	.079
Sex	-.016	.1	-.16	22.3	.874
EA_{LAG}_AW	.495	.154	3.21	17.9	.005
EA_{LAG}_AL	.5	.132	3.78	2.55	.043
EA_{LAG}_PW	-.091	.14	-.646	62.1	.521
EA_{LAG}_PL	-.041	.134	-.297	25.8	.769
Model 2					
Time	.2	.057	3.48	62.7	<.001
Sex	.241	.286	.844	56.8	.40
EA_{LAG}_AW	.92	.422	2.17	62.9	.033
EA_{LAG}_AL	1.63	.423	3.86	42.6	<.001
EA_{LAG}_PW	.155	.349	.445	41.6	.658
EA_{LAG}_PL	1.29	.491	2.64	52.4	.011
Time X Sex	-1.71	.131	-1.31	62.1	.194
Time x EA_{LAG}_AW	-.351	.151	-2.34	55.9	.023
Time x EA_{LAG}_AL	-.474	.161	-2.95	39.4	.005
Time x EA_{LAG}_PW	-.065	.128	-.51	35.9	.614
Time x EA_{LAG}_PL	-.543	.179	-3	49.1	.004
Sex x EA_{LAG}_AW	.338	.135	2.51	88.5	.014
Sex x EA_{LAG}_AL	.225	.121	1.85	13.5	.085
Sex x EA_{LAG}_PW	-.137	.124	-1.11	124	.271
Sex x EA_{LAG}_PL	-.021	.14	-.147	30.6	.884
Model 3					
Time	.232	.048	4.77	69.6	<.001
Sex	1.36	.378	3.61	39.4	.001

EA_{LAG}_AW	1.57	.548	2.87	43.2	.006
EA_{LAG}_AL	1.49	.458	3.25	34.2	.003
EA_{LAG}_PW	-.09	.434	-.21	35.3	.837
EA_{LAG}_PL	1.83	.572	3.2	33.6	.003
Time X Sex	-.687	.172	-3.98	43.3	<.001
Time x EA_{LAG}_AW	-.532	.2	-2.63	38.9	.012
Time x EA_{LAG}_AL	-.422	.175	-2.41	32.7	.022
Time x EA_{LAG}_PW	-.003	.165	-.018	35.4	.986
Time x EA_{LAG}_PL	-.746	.212	-3.51	37.8	.001
Continued	***b***	**SE**	***t***	***df***	***p***
Sex x EA_{LAG}_AW	-1.27	.579	-2.19	44.3	.033
Sex x EA_{LAG}_AL	-.417	.475	-.879	37.4	.385
Sex x EA_{LAG}_PW	-.476	.448	-1.1	37.1	.295
Sex x EA_{LAG}_PL	-1.35	.597	-2.27	32.5	.03
Time x Sex x EA_{LAG}_AW	.636	.22	2.89	44.9	.006
Time x Sex x EA_{LAG}_AL	.262	.184	1.42	37	.162
Time x Sex x EA_{LAG}_PW	.165	.173	.954	39.3	.346
Time x Sex x EA_{LAG}_PL	.552	.227	2.43	37.5	.020

Note: EA_{LAG}_AW = prior emotional arousal in actor winner; EA_{LAG}_AL = prior emotional arousal in actor loser; EA_{LAG}_PW = prior emotional arousal in partner winner; EA_{LAG}_PL = prior emotional arousal in partner loser

Table 5. *Experimental Group:* Dominance as a function of time, sex, actor prior dominance, and partner prior dominance

	b	SE	*t*	*df*	*p*
Model 1					
Time	.134	.031	4.24	15.9	.001
Sex	-.08	.073	-1.1	16.3	.288
D_{LAG}_AW	.413	.115	3.58	47.8	.001
D_{LAG}_AL	.595	.16	3.71	195	<.001
D_{LAG}_PW	.323	.12	2.68	9.34	.024
D_{LAG}_PL	-.128	.152	-.841	121.7	.4
Model 2					
Time	.123	.036	3.37	9.71	.007
Sex	.031	.31	.099	28.6	.922
D_{LAG}_AW	.935	.515	1.81	34.1	.078
D_{LAG}_AL	2.19	.641	3.42	24.1	.002
D_{LAG}_PW	.371	.475	.779	23.4	.444
D_{LAG}_PL	-.314	.711	-.442	35.5	.661
Time X Sex	-.051	.125	-.41	28.1	.687
Time x D_{LAG}_AW	-.2	.191	-1.1	30.8	.295
Time x D_{LAG}_AL	-.651	.246	-2.64	23.7	.014
Time x D_{LAG}_PW	-.018	.181	-.11	17.7	.918
Time x D_{LAG}_PL	.077	.264	.292	35.3	.722
Sex x D_{LAG}_AW	.076	.121	.631	20.1	.535
Sex x D_{LAG}_AL	.185	.161	1.15	6.71	.289
Sex x D_{LAG}_PW	-.047	.132	-.362	5	.732
Sex x D_{LAG}_PL	-.124	.155	-.797	52	.429

Note: D_{LAG}_AW = prior dominance in actor winner; D_{LAG}_AL = prior dominance in actor loser; D_{LAG}_PW = prior dominance in partner winner; D_{LAG}_PL = prior dominance in partner loser

Table 6. *Experimental Group:* Emotional valence as a function of time, sex, actor basal testosterone, and partner basal testosterone

	b	SE	*t*	*df*	*p*
Model 1					
Time	-.042	.044	-.963	57.1	.339
Sex	-.029	.134	-.218	622	.827
BT_AW	-.41	.764	-.537	1112	.591
BT_AL	.877	.864	1	1344	.31
BT_PW	.432	.848	.51	996	.61
BT_PL	-.564	.781	-.723	1530	47
Model 2					
Time	-.008	.051	-.148	31.1	.883
Sex	.055	.2	.273	82.1	.786
BT_AW	.179	1.12	.159	125	.874
BT_AL	-.958	1.63	-.586	197	.559
BT_PW	-1.1	1.59	-.671	151	.5
BT_PL	.661	1.17	.564	165	.574
Time X Sex	-.091	.064	-1.4	24	.174
Time x BT_AW	-.183	.317	-.579	20.9	.569
Time x BT_AL	.474	.417	1.13	40.4	.262
Time x BT_PW	.51	.365	1.39	21.3	.178
Time x BT_PL	-.666	.363	-1.83	39.7	.074
Sex x BT_AW	-.439	.953	-.461	1142	.645
Sex x BT_AL	.892	1.45	.613	332	.54
Sex x BT_PW	.51	1.46	.348	292	.728
Sex x BT_PL	.462	.94	.492	1286	.623
Model 3					
Time	.073	.093	.786	97.3	.434
Sex	.089	.193	.464	97.9	.644

BT_AW	.533	1.13	.472	121	.638
BT_AL	1	1.75	.581	136	.562
BT_PW	-2.21	1.64	-1.34	110	.183
BT_PL	.4	1.21	.332	144	.74
Time X Sex	-.174	.11	-1.65	57.1	.1
Time x BT_AW	-.244	.392	-.622	35.4	.538
Time x BT_AL	-1	.862	-1.17	88.1	.245
Time x BT_PW	.586	.811	.723	64.5	.472
Time x BT_PL	-.41	.443	-.915	53.5	.364
Continued	***b***	**SE**	***t***	***df***	***p***
Sex x BT_AW	-.756	1.15	-.657	125	.513
Sex x BT_AL	-1.47	1.75	-.841	137	.4
Sex x BT_PW	1.97	1.64	1.2	109	.232
Sex x BT_PL	3.58	1.22	.292	149	.771
Time x Sex x BT_AW	.048	.396	.123	35.5	.9
Time x Sex x BT_AL	1.67	.862	1.94	88.2	.05
Time x Sex x BT_PW	-.239	.811	-.295	64.6	.769
Time x Sex x BT_PL	-.061	.446	-.137	53.8	.892

Note: BT_AW = basal testosterone in actor winner; BT_AL = basal testosterone in actor loser; BT_PW = basal testosterone partner winner; BT_PL = basal testosterone in partner loser

Highlights:

- Cortisol, emotional valence and dominance participants' levels were modulated by outcome and sex
- Opponents' cortisol, emotional arousal and dominance influenced participants' values.
- No outcome or opponent effect was detected on testosterone.
- Basal testosterone predicts post-competition emotional valence in loser men but not in women.