Social Network Centrality and Hormones: The Interaction of Testosterone and Cortisol

Running head: Hormones and Social Network

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Abstract

In this study we tested whether testosterone and cortisol interacted in predicting social network centrality within a male rugby team. Using social network analysis (SNA), three measures of centrality were investigated: popularity (i.e., number of incoming ties a participant received), gregariousness (i.e., the number of ties leaving from the participant and reaching out to others), and betweenness (i.e., the number of times a person lies between two other individuals). In line with the idea that testosterone and cortisol jointly regulate the emergence of social status, we found that individuals with high basal testosterone and low basal cortisol were more popular and more likely to act as connectors among other individuals (i.e., betweenness). The same hormonal profile was not predictive of gregariousness. However, in line with the small literature on the topic, we found that cortisol was inversely correlated with gregariousness. Despite the cross-sectional and correlational nature of our research design, these findings represent the first empirical evidence that testosterone and cortisol interact to predict complex measures of social hierarchy position derived from social network analyses.

Keywords: Testosterone, Cortisol, Social Status, Social Network Analyses**,** Centrality

Introduction

Achieving high social-status is a complex process regulated by a variety of factors, including environmental contingencies (Baumeister et al., 1988), individual differences in psychological variables such as intelligence, empathy, personality traits (e.g., dominance and extraversion), and physiological profiles (Lord et al., 1986; Anderson et al., 2001; Mehta and Josephs, 2010). In particular, researchers have focused on the role of two steroids hormones: testosterone and cortisol. Testosterone is produced by the gonads in response to the activity of the hypothalamic pituitary gonadal (HPG) axis and is implicated in somatic growth, development, and sexual differentiation. Cortisol is the end product of the hypothalamic pituitary adrenal (HPA) axis and is important for re-establishing homeostasis after physical and psychosocial stressors. Besides regulating growth, reproduction, and homeostasis, testosterone and cortisol are also known for their permissive effects on socio-emotional behaviors (Eisenegger et al., 2011), some of which have also been linked to high social status and leadership, such as dominance, empathy, and risk taking (Rubin et al., 2005; Anderson and Galinsky, 2006).

Social-status and the dual-hormone hypothesis

In non-human primates, physical strength plays a major role in conflict resolution and dominant individuals are more likely to acquire high social rank (Fossey, 1972; King et al., 2008). In humans, despite the role played by prestige in shaping social hierarchies (Cheng et al., 2013), the propensity to use coercive, assertive, and aggressive behavior is also a viable mean to attain status (Hawley, 2002; Cheng et al., 2013). The link between testosterone and status-seeking behaviors is also well established (for a review, see Archer, 2006). Conversely, leaders tend to have lower levels of circulating cortisol (Sherman et al., 2012) and relegation to low rank positions within a group have been associated with high cortisol levels (Zilioli et al., 2015), which in turn are associated with anxiety (Brown et al., 1996) and submissive behavior (i.e. social withdrawal and inhibition; Kagan et al., 1988; Goldsmith and Lemery, 2000; Klimes–Dougan et al., 2001). Although these findings seem to suggest that testosterone and cortisol are independently and oppositely linked to status seeking behaviors, recent evidence indicates that they might interact in predicting dominance (Mehta and Josephs, 2010; Sherman et al., 2015). For example, Mehta and Josephs (2010) found that cortisol moderated the association between testosterone and assessed dominance in participants assigned to a leadership position in a role-playing task. Specifically, leaders were perceived as dominant only if they had a combination of high testosterone and low cortisol. Recently, Sherman et al. (2015) corroborated these findings by showing that leaders with a high-testosterone/low-cortisol profile had a higher number of subordinates over which they exert authority. Interestingly, testosterone and cortisol also interact in predicting other behaviors that have been found to be associated with leadership, such as empathy (Zilioli et al., 2014) and risk-taking (Mehta et al., 2015).

Traits such as trustworthiness and empathy work to maintain group cohesion (Van Vugt and Schaller, 2008), so it is no surprise that these traits predict the emergence of leadership (Kellett et al., 2006), especially those forms of leadership that are legitimized by followers - but not those based exclusively on dominance or strong asymmetries (Galinsky et al., 2006). Circulating levels of testosterone are inversely associated with caring behavior (Baucom et al., 1985), emotional empathy (Harris et al. 1996), and empathic accuracy (Ronay and Carney, 2013); however, as in the case of dominance, the link between empathy and testosterone might also be moderated by cortisol levels (Zilioli et al., 2014). An analogous conclusion can be drawn for another type of behavior associated with leadership, risk-taking. Because leadership is more likely to emerge in situations when groups are endangered, individuals more prone to take risks and initiatives are more likely to ascend to leadership positions (Van Vugt, 2006). Again, although testosterone positively predicts risk-taking (Apicella et al., 2014), a more nuanced understanding of this relationship invokes the moderating role of cortisol, with risk-taking being positively associated with testosterone, but only among individuals with low basal levels of cortisol (Mehta et al., 2015).

Taken together, these studies suggest that testosterone and cortisol jointly regulate a suite of behaviors and dispositions implicated in social status, a theory known as the dual hormone hypothesis (Mehta and Josephs, 2010; Mehta and Prasad, 2015).

Social networks and the behavioral endocrinology of social status

An individual's social status can be reflected not only by the number of his/her subordinates (Sherman et al., 2015) or by the way he/she directs problem solving in dyadic interactions (Mehta and Josephs, 2010), but also by his/her position within a social network. Achieving social status depends also on the relationships an individual is able to build and control (Mehra et al., 2006). In other words, because groups are networks of interpersonal ties, it is important to consider social status also in terms of the patterns of relationships connecting individuals. In social network analysis (SNA), social status tends to correspond to the idea of centrality within the social network (Bass and Stogdill, 1990; Brass, 1992; Hanneman and Riddle 2005). Most of the human social neuroendocrinology literature has investigated the link between circulating hormones and status within dyads (for a review, see Archer et al., 2006), neglecting the relationship between hormones and social status in the context of social networks. Determining whether testosterone and cortisol are associated with measures of network centrality is the main goal of the current study.

In SNA various measures of centrality can be derived. A first measure that is particularly relevant for social status is degree centrality. Degree centrality is measured in terms of how many direct connections (e.g., $A \rightarrow B$ or $B \rightarrow A$) the individual has with other members of their social network (Balkundi and Harrison, 2006). Because direct connections can either converge towards an individual (i.e., $B \rightarrow A$) or reach out to others from the same individual (i.e., $A \rightarrow B$), degree centrality can be distinguished in *out-degree* centrality (Figure 1A), also known as gregariousness and *in-degree* centrality (Figure 1B), also known as popularity (Kornienko et al., 2013). Another centrality measure is betweenness centrality, which represents how many times an individual acts as a bridge along the shortest path between any two other individuals (Freeman, 1977). In other words, A's betweenness measures the extent to which any pair of nodes within the network depend on A in order to reach, communicate, or exchange information between each other (i.e., $B \rightarrow A \rightarrow C$).

Degree and betweenness centrality can be highly correlated, especially in the case of a star-like network, wherein the person at the center of the star has the highest number of connections and acts as a connector among all other individuals (Figure 1C, person *E*). However, a star-like network is arguably an exception, and real life social networks may have a more distributed centralization, such as in Figure 1D (Krackhardt 1990). In Figure 1D the difference between degree centrality and betweenness is more evident: Person *H* (represented by the letter B inside of the node) has the highest betweenness (e.g., if person *I* or person *J* wants to reach person *A*, they must pass through *H*), while *E* (represented by the letter D inside of the node) has the highest degree centrality. High betweenness individuals have a strong influence over the flow of information in the social network and can connect otherwise disconnected networks. Empirical work has shown that betweenness predicts earlier promotions within an organization (Brass 1984; Burt 1992) and correlates positively with leadership emergence (Mullen et al., 1991) as well as perceptions of leadership (Brass, 1984; Mullen et al., 1991; Balkundi and Kilduff, 2006). For these reasons, among the various measures of centrality betweenness is likely to be the more indicative of social status within SNA (Krackhardt 1990).

The present study

Only a handful of studies have looked at the relationship between cortisol and testosterone in the context of social network structure (Kornienko et al., 2013; Kornienko et al., 2014; Ponzi et al., 2015). For example, studying a group of mostly women students, Kornienko and colleagues (2013; 2014) found that cortisol -but not testosterone- was associated with both in-degree and out-degree centrality, such that less gregarious and more popular people had higher baseline levels of cortisol. The current study builds on these findings and extends them by enriching the methodology of data collection, including betweenness as an additional measure of social status, and testing the new hypothesis that testosterone and cortisol might interact in predicting social network centrality.

Methods

Participants

Participants were a subset of male rugby athletes from the Burnaby Lake Rugby Club (Burnaby, B.C, Canada). Participants were presented first with a short description of the study, and consent to participate was solicited. Although forty-four participants provided consent (100% of the cohort), three of them dropped out of the study, leaving a final sample of 41 individuals. The mean age of participants was 27.93 years (SD = 4.91, range: 19-40 years) and the sample consisted of only males (85.4% Caucasian; 4.9% Asian, 7.3% Mixed Race, 2.4% Hispanic). All procedures were subject to review and prior approval by the Simon Fraser University Research Ethics Board.

Procedure

Data collection took place on Tuesdays, Wednesdays, and Saturdays. For two participants, some of the measures were collected through email due to limited availability of the participants. During data collection participants were first photographed, filled out a series of questionnaires, and provided body and strength measurements. Next, participants provided two saliva samples, one before team practice and one after team practice. After providing the second saliva sample, participants were asked to complete a computer task, unrelated to the present study. Lastly, participants received the Cognitive Social Structures task (see below, for details), which was completed at home and returned to the researcher on the next available occasion.

Cognitive Social Structures task

The social network of the rugby team was obtained using the Cognitive Social Structures (CSS, Krackhardt, 1987; Casciaro et al., 1999), a typical approach in SNA. Each participant was asked the following questions: “Among your teammates, who likes to hang out with *i* ?”; and, “Among your teammates, who does *i* like to hang out with?”, where *i* was every player on the team, including the respondent. This approach, also known as the roster method (Friedkin, 1981), allows collecting more detailed and reliable data than the nomination method, which is affected by mono-source bias as people simply report whom they like to hang out with. Based on the two questions asked, we were able to create a matrix of social relationships for each participant. This matrix represents each participant’s perceptions of who likes to hang out with whom. Thus, a total of 40 matrices with 1600 relationships each were created. In order to obtain a unique matrix representing the agreement of in-going and out-going relationships across the teammates, we aggregated the participants' perceptual matrices using the Locally Aggregated Structures procedure (LAS, Krackhardt, 1987). Following this procedure, a relationship is considered existent only if both nodes of a tie (i.e. both individuals in a relationship) agree that such relationship exists. For example, the relationship "*i* likes to hang out with *j*" exists only if both *i* and *j* agree that *i* likes to hang out with *j*. Note that in this case, *i* and *j* agree that there is an in-going relationship that from *i* to *j*. However, if *i* and *j* disagree on the opposite relationship "*j* likes to hang out with *i*", this relationship will be considered as absent in the network and in the resulting LAS network *i* and *j* will be connected only by a directed tie that goes from *i* to *j*, indicating an asymmetrical tie. Next, three measures of centrality were derived for each participant: in-degree centrality, out-degree centrality, and betweenness (Freeman et al., 1980). In-degree centrality, which is a measure of popularity, indicates the number of incoming ties a participant received; in our case, the number of teammates that reported liking to hang out with that participant. On the other hand, out-degree centrality, which is a measure of gregariousness, represents the number of ties leaving from one participant and reaching out to others. In our study, out-degree centrality corresponded to the number of teammates each participant reported to like hanging out with (Kornienko et al., 2013). Lastly, betweenness is defined as

$$C_B(K) = 2 \sum_i^n \sum_j^n \left[\frac{g_{\mathrm{ij}}(\mathrm{K})}{g_{\mathrm{ij}}}\right]$$

for all unordered triplets *i,j,k* ($i < j$, and $i \neq j \neq k$), where *n* is the number of nodes in the network, *gij* is the number of geodesics (shortest paths) between node *i* and *j* in the network and *gij (K)* is the number of geodesics between *i* and *j* that include *k* (Freeman 1979; Krackhardt 1990). It represents the number of times a person lies between the shortest pathway connecting two others within the network and indicates the level of influence this subject has over the flow of information within the network (Krackhardt 1990). Analyses were conducted using Ucinet 6.581 (Borgatti et al., 2002) and SPSS.

Hormone Assays

On either Tuesday or Thursday, between 6 pm and 9 pm, each participant provided two saliva samples via passive drool before and after team practice, except for one player who, due to personal impediment, provided his saliva samples on a non-training day. Samples were chilled immediately following collection and then frozen within few hours and held at -20 °C until they were transferred to the lab for assay. Samples were assayed in duplicate using competitive enzyme immunoassays for testosterone and cortisol (Salimetrics LLC, State College, PA). The average intra-assay coefficient of variation was 3.84% for testosterone and 8.89% for cortisol, while the inter-assay coefficients were 5.85% and 6.39% for testosterone and cortisol, respectively. One individual failed to provide saliva samples, reducing the sample size to forty participants. In the current study, because we were interested in baseline hormonal concentrations, only the saliva sample collected before practice was used for the analyses. Baseline measures were collected between 6 and 7 pm.

Statistical analysis

Hierarchical multiple linear regressions were conducted in order to test the impact of testosterone, cortisol, and their interaction on popularity, gregariousness, and betweenness. Cortisol and betweenness measures exhibited skewed distributions (cortisol skewness = 3.55; betweenness skewness = 2.43), and were therefore log-transformed[1] (cortisol skewness after transformation = .79; betweenness skewness after transformation = .17). All predictors were standardized (Z-scores).

Data collected for social network analysis are characterized by lack of independency and are autocorrelated (Hanneman and Riddle, 2005; James et al., 2009); therefore, we conducted non-parametric regression analyses using the regression package of Ucinet 6.581 (Borgatti et al., 2002), which follows two steps. In the first step an ordinary least square (OLS) multiple regression is performed, while in the second step the elements of the dependent vector are randomly permuted and the regression is recomputed, storing the new R^2 and coefficients. This step is repeated many times (30000 random permutations in the current study) in order to estimate the standard errors. Statistical significance of a coefficient

[1] Because betweenness contained few zeros, a constant of 1 was added before the log transformation.

depends on the proportion of random permutations that yielded a coefficient as extreme as the one computed in Step 1 (Ucinet 6.581). OLS were used to disentangle the interaction via simple slope analysis (Aiken and West, 1991).

Results

Preliminary analyses

Descriptive statistics for cortisol (raw scores), testosterone concentrations, popularity, gregariousness, and betweenness are presented in Table 1, while bivariate correlations among study variables are reported in Table 2. Cortisol concentrations (r = .41, p = .009) were influenced by wake-up time, so we included wake-up time as a covariate in our main analysis below (for a similar approach, see Mehta and Josephs, 2010).

Hormones, Betweenness, Popularity, and Gregariousness

Similarly to others (Mehta and Josephs, 2010; Tackett et al., 2014), we conducted hierarchical multiple regression analyses in which we entered our measures of centrality as the dependent variables and the following variables as predictors: wake up time, cortisol and testosterone in Step 1, and the testosterone by cortisol interaction in Step 2. In support to the dual-hormone hypothesis, in Step 2 (R^2 = .37, F (4,35) = 5.15, p < .01), there was a significant testosterone x cortisol interaction for betweenness (β = -.42, p = .03, 95% CI: -1.75, -.21)[2]. Simple slope analyses revealed that at low levels of cortisol –but not high levels of cortisol (b = -.42, *SE* = .47, p = .38)- testosterone was positively associated with betweenness (b = 1.54, *SE* = .48, p < .01) (Figure 2). In other words, a hormonal profile characterized by high testosterone and low cortisol was associated with higher scores of betweenness. These results are also presented in the sociometric graph, wherein friendship relationships (arrows) among team members (squares) are depicted and each square is sized proportionally to the individual level of betweenness (Figure 3).

A similar hierarchical multiple regression analysis was conducted for popularity (Table 4). In support of the dual hormone hypothesis, in Step 2 (R^2 = .25, F (4,35) = 2.83, p

[2] We created an additional covariate based on self-report use of medications and self-report bleeding gum/oral infections. After including this covariate the magnitude of the testosterone by cortisol interaction remained largely unchanged (β =-.41, p = .04).

= .04) there was a significant testosterone by cortisol interaction for popularity (β = -.41, *p* = .03, 95% CI: -3.59, -.2) (Table 4). Simple slope analyses revealed that at low levels of cortisol –but not high levels of cortisol (b = -1.25, *SE* = 1.02, *p* = .23)- testosterone was positively associated with popularity (b = 2.58, *SE* = 1.04, *p* = .02). In other words, a hormonal profile characterized by high testosterone and low cortisol was associated with higher scores of popularity (Figure 4).

The same interaction was not significant for gregariousness (β = -.08, *p* = .69, 95% CI: -1.70, 1.11) (Table 5). In keeping with previous work (Kornienko et al., 2013; Kornienko et al., 2014), in Model 1(R^2 = .19, F (3,36) = 2.81, *p* = .05) a marginally significant main effect of cortisol on gregariousness emerged (β = -.38, *p* = .06, 95% CI: -2.38, -.08), indicating that players with low gregariousness had high cortisol levels.

Discussion

The aim of this study was to test whether testosterone and cortisol jointly predicted how central an individual is within his social networks. Particularly, we focused on three measures of centrality: betweenness, popularity, and gregariousness. Our results suggest that individuals with high basal testosterone and low basal cortisol have higher levels of betweenness and popularity, but not gregariousness.

Individuals that score high on betweenness are individuals who act as intermediary between members of the network; for this reason, this measure of centrality refers to the subject 's level of influence over the flow of information occurring within the network and it can be intended as an index of social status (Brass, 1984; Mullen et al., 1991; Balkundi and Kilduff, 2006). In our sample, betweenness was highly correlated with popularity (Valente et al., 2008), indicating that athletes with high betweenness also had the highest number of incoming ties. Because our social network was based on players' preference to hang out with each other, our results suggest that individuals with high testosterone and low cortisol are the most popular within the team and more likely to act as connectors among other individuals, possibly by helping the group remain unified and coordinate its activities (Fransen et al., 2015).

This finding is particularly interesting in light of previous results showing that the same hormonal profile is associated with perception of status (Mehta and Josephs, 2010; Edwards and Casto, 2013) and status-related behaviors (Mehta and Prasad, 2015). For instance, Mehta and Josephs (2010) found that individuals assigned to a leadership position were judged as more dominant –a broad term that included enthusiasm, energy, confidence, verbal fluency, extroverted behavior and did not necessarily coincide with coercion- if their testosterone level was high and their cortisol level was low, while Mehta et al. (2015) found that testosterone was positively associated with risk-taking, but only among individuals with low basal levels of cortisol. Thus, it is plausible that high testosterone low cortisol individuals occupy central positions in their social networks because of their assertive, extraverted, and confident demeanor as well as their risk-oriented behavior, which is often a viable pathway to enhance one’s status in different forms of social competition (Ronay and von Hippel, 2010; Ellis et al., 2012). These and other studies (Mehta and Josephs, 2010; see also, Zilioli and Watson, 2012), suggest that this specific hormonal profile might act as the biological mechanisms through which individuals achieve a more centralized and higher status position within a social network. Lastly, it should be noted that being at the top of the hierarchy might be associated with exposure to unique stressors, such as the fear of losing status and the burden to provide for subordinate friends. Moreover, heightened HPA activity is associated with fear, higher sensitivity to punishment and threat (Van Honk et al., 2003), and anxiety (Brown et al., 1996). These functions might be responsible for the lack of association between testosterone and betweenness among high cortisol individuals, who, because of the sustained activity of the stress axis, might be inhibited in achieving and maintaining influential positions within their social network.

In our sample, the combined effect of cortisol and testosterone in predicting centrality was restricted to betweenness and popularity and did not extend to gregariousness. In other words, high testosterone/low cortisol individuals did not necessarily have more outgoing ties than other members. However, when we used the non-parametric mutlivariate approach a marginal main effect of cortisol emerged, such that individuals with higher levels of cortisol scored low on gregariousness. This finding corroborates previous research by Kornienko et al. (2013; 2014), who found that same-class nursing students were more likely to be at the periphery of their social network if they had high levels of cortisol. This finding can be read in light of the associations between high circulating cortisol and behavioral inhibition, social withdrawal, and submissive behavior (Kagan et al., 1988; Goldsmith and Lemery, 2000; Klimes–Dougan et al., 2001; Brown et al., 1996). However, because of the correlational nature of our study, the same phenomenon could be explained in terms of the social environment influencing an individual's hormonal profile. For example, it is possible that segregated positions within the social hierarchy might lead to a higher volume of cortisol secretion, in keeping with the abundant literature showing a positive covariation between subjective feelings of social isolation and salivary cortisol (Cacioppo et al., 2000; Pressman et al., 2005; Steptoe et al., 2004; Edwards et al., 2010). This alternative explanation –that one's position and status within the network influences his hormonal secretion– can be also extended to our dual-hormone findings. For example, it is possible that occupying a high position on the social ladder may act as a buffer against stress, especially when the social hierarchy of the group is stable (Zilioli and Watson, 2014), while achieving powerful positions might lead to higher secretion of testosterone. Thus, future studies involving multiple and longitudinal hormonal and social network measures will be necessary before stronger causal claims could be made. Future work will also benefit from testing the association between hormones and social network measures of centrality with larger sample sizes and with social groups other than sport teams. Finally, the present research investigated hormones and social network centrality in males. Future research with large sample sizes will be required to test whether the dual-hormone interactions we observed extend to female social networks (Edwards & Casto, 2014) and mixed-sex networks.

Despite these caveats, these results provide the first evidence that the dual hormone hypothesis (Mehta and Josephs, 2010; Mehta and Prasad, 2015) can be successfully applied to measures of centrality within a social network structure.

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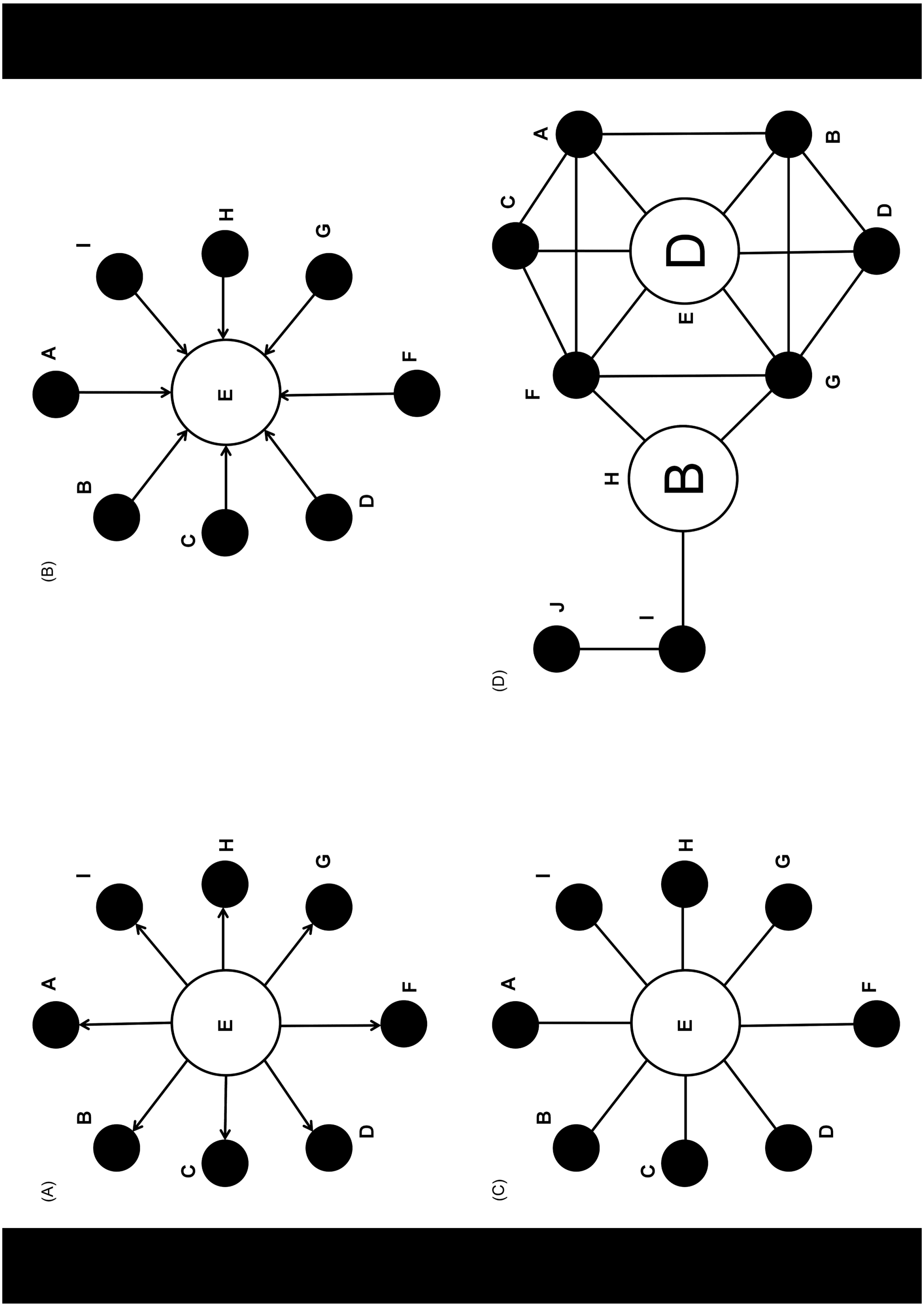

Figure 1. Examples of social networks underscoring the difference between degree and betweenness centrality. To simplify our example, in (C) and (D) we assume that the number

of in-degree and out-degree ties for each node are the same, making the ties within the network symmetrical thus not requiring directionality. The upper part of the panel shows the difference between out-degree (A) and in-degree (B) centrality in a star graph. In (C) *E* has the highest degree centrality (with 8 in-degrees and out-degrees) and betweenness centrality, while in (D) Person *H* (represented by the letter B inside of the node) has the highest betweenness centrality, while *E* (represented by the letter D inside of the node) has the highest degree centrality. Note: (*D)* was adapted with permission from Krackhardt, D., 1990.

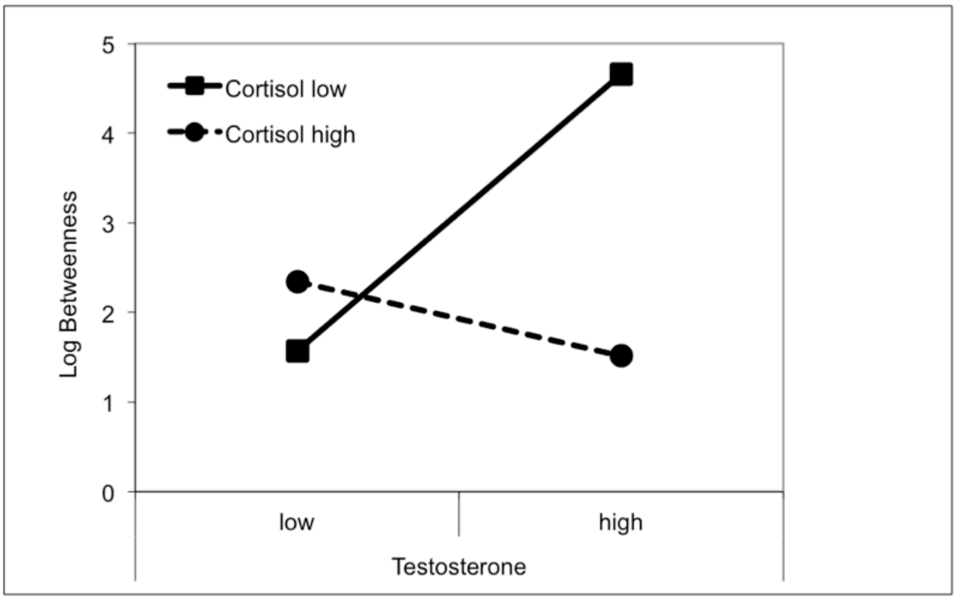

Figure 2. Log-Betweenness as a function of testosterone and cortisol (Study 2). Note: Plotted points represent conditional low and high values (±1 SDs) of testosterone and cortisol (log-transformed).

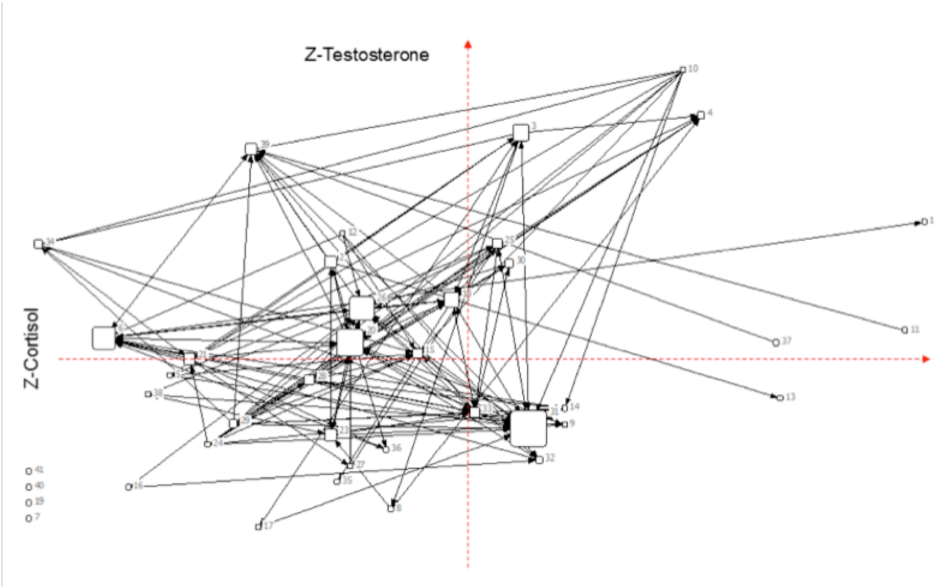

Figure 3. Sociometric graph representing the relationship “who likes to hang out with whom” resulting from the LAS procedure. The size of each square is proportional to the untransformed levels of betweenness. The x and y axis represent the Z-scores for the log-transformed cortisol and for testosterone respectively. The two axes cross at Z scores of testosterone and cortisol equal to 0. Within the upper left quadrant, where Z-scores for testosterone are high and Z-score for cortisol are low, there are more players with higher scores of betweenness.

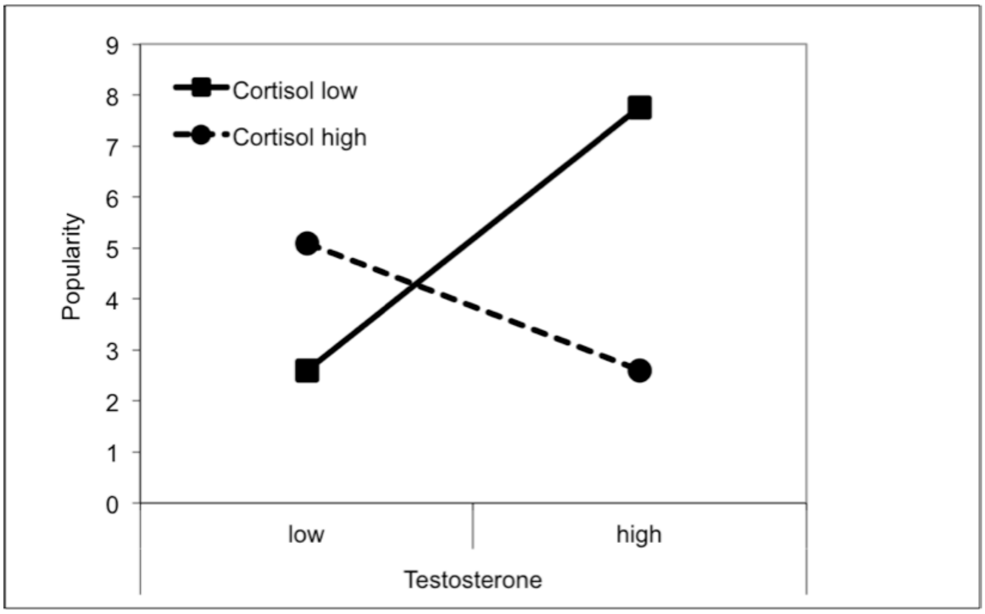

Figure 4. Popularity as a function of testosterone and cortisol (Study 2). Note: Plotted points represent conditional low and high values (±1 SDs) of testosterone and cortisol (log-transformed).

Table 1

Descriptive Statistics

Descriptive variables	**M**	**SEM**	**SD**
Testosterone (pg/mL)	73.63	3.39	21.42
Cortisol (μg/dL)	0.11	0.02	0.11
Popularity	3.90	0.62	3.94
Gregariousness	3.83	0.51	3.21
Betweenness	40.32	10.48	66.30

Note: Raw values for cortisol and betweenness are reported.

Table 2

Bivariate Correlations Between Study Variables

Descriptive variables	1	2	3	4	5
1. Testosterone	1	0.331*	0.032	0.029	0.102
2. Log Cortisol		1	-0.325*	-0.386*	-0.428**
3. Popularity			1	0.572**	0.857**
4. Gregariousness				1	0.683**
5. Log Betweenness					1

Note: * p < .05, ** p < .01

Table 3

		OLS				**Permutation test**
		b	SE	β	95% CI	Prob as extreme
Step 1						
	Wake-up time	0.03	0.32	0.01	[-.62, .68]	.94
	Log Cortisol	-1.04	0.34	-0.53	[-1.73, -.36]	.01
	Testosterone	0.55	0.31	0.28	[-.08, 1.17]	.12
Step 2						
	Wake-up time	-0.39	0.34	-0.20	[-1.07, .30]	.36
	Log Cortisol	-0.60	0.36	-0.30	[-1.32, .13]	.19
	Testosterone	0.56	0.29	0.28	[-.018, 1.15]	.13
	Cortisol X Testosterone	-0.98	0.38	-0.42	[-1.75, -.21]	.03

Note. Dependent variable: Log-Betweenness

Table 4

		OLS				**Permutation test**
		b	SE	β	95% CI	Prob as extreme
Step 1						
	Wake-up time	0.12	0.68	0.03	[-1.27, 1.51]	.87
	Log Cortisol	-1.54	0.72	-0.39	[-3.01, -.07]	.05
	Testosterone	0.64	0.66	0.16	[-.70, 1.98]	.37
Step 2						
	Wake-up time	-0.69	0.73	-0.18	[-2.18, .80]	.39
	Log Cortisol	-0.67	0.78	-0.17	[-2.25, .92]	.46
	Testosterone	0.67	0.62	0.17	[-.60, 1.93]	.36
	Cortisol X Testosterone	-1.91	0.82	-0.41	[-3.59, -.24]	.03

Note. Dependent variable: Popularity

Table 5

		OLS				Permutation test
		b	SE	β	95% CI	Prob as extreme
Step 1						
	Wake-up time	-0.42	0.54	-0.13	[-1.50, .67]	.50
	Log Cortisol	-1.23	0.57	-0.38	[-2.38, -.08]	.06
	Testosterone	0.49	0.52	0.15	[-.56, 1.54]	.39
Step 2						
	Wake-up time	-0.54	0.62	-0.17	[-1.79, .71]	.42
	Log Cortisol	-1.10	0.66	-0.34	[-2.43, .24]	.13
	Testosterone	0.50	0.53	0.16	[-.57, 1.56]	.41
	Cortisol X Testosterone	-0.30	0.69	-0.08	[-1.70, 1.11]	.69

Note. Dependent variable: Gregariousness