Hormones and Behavior 80 (2016) 92–102

Contents lists available at ScienceDirect

Hormones and Behavior

journal homepage: www.elsevier.com/locate/yhbeh

Cortisol and testosterone associations with social network dynamics

Olga Kornienko [a,b,*], David R. Schaefer [c], Serena Weren [d], Gary W. Hill [e], Douglas A. Granger [a,b,f,g,h,*]

[a] Institute for Interdisciplinary Salivary Bioscience Research, Arizona State University, United States
[b] Department of Psychology, Arizona State University, United States
[c] School of Human Evolution and Social Change, Arizona State University, United States
[d] School of Music, Loyola University New Orleans, United States
[e] Herberger Institute for Design and the Arts, Arizona State University, United States
[f] Johns Hopkins University School of Nursing, United States
[g] Johns Hopkins University Bloomberg School of Public Health, United States
[h] Johns Hopkins University School of Medicine, United States

ARTICLE INFO

Article history:
Received 29 June 2015
Revised 14 January 2016
Accepted 29 January 2016
Available online 4 February 2016

Keywords:
Hormones
Cortisol
Testosterone
Social networks
Stochastic-actor based modeling

ABSTRACT

This study integrates behavioral endocrinology and network science to explore links between hormones and social network dynamics. Specifically, we examine how cortisol (C) and testosterone (T) are associated with creation of new friendships and maintenance of existing friendships. A collegiate marching band was used as a model system of a mixed-sex social organization. Participants (n = 193; 53% female; M age = 19.4 years, 62.1% European-American) provided friendship nominations at time 1 and two months later at time 2. At time 1, participants donated saliva before and after rehearsal (later assayed for C and T). Stochastic actor-based models revealed that individuals with higher C levels were less likely to *maintain* their social relationships and more likely to *create* new friendships. In contrast, individuals with higher T levels were more likely to *maintain* friendships and less likely to *create* new relationships. Findings suggest that individual differences in C and T are associated with the initiation and maintenance of friendships and have several noteworthy theoretical implications.

Introduction

Social neuroscience posits that human brain, behavior, and underlying neuroendocrine mechanisms have co-evolved with the social structures of group living, ranging from dyads and families to social networks (e.g., Cacioppo et al., 2014; Eisenberger and Cole, 2012). Network science considers the intricate pattern of social relationships in which individuals are embedded to be a fundamental feature of group living (for reviews see, Borgatti et al., 2009), and shows that social network structure and dynamics are related to the expression of individual differences in physiology, behavior, and health (e.g., Berkman et al., 2000; Smith and Christakis, 2008; Valente, 2010). More than five decades of behavioral endocrinology research supports these perspectives by revealing that the expression of hormone-behavior associations is often socially regulated (e.g., Gunnar and Donzella, 2002) and documenting associations between hormones and status hierarchies (e.g., Mazur and Booth, 1998; Sapolsky, 1990, 2005). Generally speaking, behavioral endocrinology assumes that as individuals adapt to their social environments, hormone levels are associated with specific thoughts, emotions, and behaviors, which are related to the creation, maintenance, and changes in social relationships. Surprisingly, however, key facets of this set of assumptions have yet to be directly empirically tested in social networks. Network science provides the means to pinpoint the processes that are involved in how networks emerge and change (for reviews see Robins, 2013; Snijders et al., 2010; Snijders, 2011; Valente, 2010), and modern salivary bioscience enables the measurement of hormones from multiple individuals simultaneously in networks (Granger et al., 2012). Building on these advances, we examine how hormone levels are related to network dynamics in a mixed-sex social organization.

Network science and behavioral endocrinology

The structure and quality of social relationships among members of a group are integral for understanding the fundamental features of sociality and its role in reproductive success and survival (e.g., Silk, 2007). Network science provides conceptual and analytical tools to link the social group structure and dynamics to the behavior of its constituent members (Pinter-Wollman et al., 2014; Whitehead, 2008). Social network *structure* is an emergent property of a social organization that is represented by enduring patterns of social *relationships*, which are, in turn, comprised of series of social *interactions* (Hinde, 1976). Whereas multiple types of relationships exist in social networks across

* Corresponding authors at: Institute for Interdisciplinary Salivary Bioscience Research, 550 E. Orange Street, Arizona State University, Tempe, AZ, 85287-3604, United States.
E-mail addresses: Olga.Kornienko@asu.edu (O. Kornienko), Douglas.Granger@asu.edu (D.A. Granger).

http://dx.doi.org/10.1016/j.yhbeh.2016.01.013
0018-506X/

the animal kingdom, we focus on *friendships* as enduring affiliative relationships (e.g., Brent et al., 2013). Network structure can be thought of as a static snapshot of a pattern of friendships, whereas network dynamics describe how this structure changes over time. Thus, the nature of, and way in which, social relationships among group members are initiated, maintained, and lost is central to understanding the structure and function of human social ecology for individual behavior and adaptation (e.g., Pinter-Wollman et al., 2014).

Social neuroscience suggests that the nature and complexity of the human brain have evolved to process the high volumes of ambiguous social information necessary for group living (e.g., Chang et al., 2013; Silk, 2007). Recent evidence documents that the size and complexity of online and real-life social networks are closely related with the size of brain structures implicated in social cognition (Bickard et al., 2011; Kanai et al., 2011). Specifically, individuals with larger and more complex social networks had larger amygdala volumes (Bickard et al., 2011), a brain region that is heavily involved in the processing of emotional information with a dense population of receptors for stress hormones (Lindau et al., 2010). Accordingly, we are interested in extending this research into naturalistic settings of real-life networks within a large organization and developing a better understanding of the associations between changes in social structures (i.e., network dynamics) and hormones. In the absence of prior investigations of linkages between hormones and network dynamics, we next consider how individual differences in cortisol and testosterone have been related with social behavior, relationships, and structures.

Hormones, social behavior, and relationships

Decades of behavioral endocrinology research have shown that the links between the activity of the hypothalamic–pituitary-adrenal (HPA) and hypothalamic–pituitary–gonadal (HPG) axes and behavior underlie social interactions and relationships (Nelson, 2011). The majority of empirical evidence suggests that individual differences in HPA axis activity are associated with social anxiety, inhibition, withdrawal, and loneliness and that these associations are highly regulated by the social environment (e.g., Granger et al., 1994; Granger et al., 1996; Gunnar and Donzella, 2002; Hawkley and Cacioppo, 2010; Kagan et al., 1987; Shoal et al., 2003; Weiner, 1992). Some studies suggest that HPA activity facilitates social contact as a means to reduce stress and anxiety (e.g., Carter, 1998; Hostinar et al., 2014; Taylor, 2006).

Studies of testosterone–behavior associations suggest that HPG axis activity can be either negatively or positively associated with social affiliation. On one hand, the inverse associations between testosterone and social behavior may stem from its role in risk-taking, aggressive and antisocial behavior, dominance, winning/losing, fear reduction, and contests for social rank and status (Booth et al., 1999; Eisenegger et al., 2011; Mazur and Booth, 1998). On the other hand, research suggests that testosterone is associated with enhanced social affiliation presumably in the service of social status pursuits. Specifically, testosterone has been linked to higher levels of prosocial and fairness-oriented behaviors suggesting that involvement in status-related behaviors might also be driven by prosocial tendencies (Boksem et al., 2013; Eisenegger et al., 2010; Smeets-Janssen et al., 2015; van Honk et al., 2012). Thus, associations between testosterone and social behavior may manifest not only through agonistic strategies, as documented by past research on dominance hierarchies, but also through prosocial behavior and approach motivation systems (Eisenegger et al., 2011). This possibility is consistent with the notion that humans acquire status by using a variety of socially-sanctioned strategies to establish dominance (e.g., affiliation, leadership) when they compete in athletics, academics, and professional organizations (Liening and Josephs, 2010).

Another pattern of association between hormones and social affiliation has been observed suggesting that individuals become similar to one another in their hormone levels when they share the context of social relationships. Several research groups have identified this dyadic pattern of attunement or similarity in hormone levels which has been revealed for dyads in close social relationships including parent–child, newlywed and dating couples, and best friends (Bernhardt et al., 1998; Granger et al., 1998; Sethre-Hofstad et al., 2002; van Bakel and Riksen-Walraven, 2008; Papp et al., 2009; Saxbe and Repetti, 2010; Waters et al., 2014). Importantly for present purposes, even when these dyads share genetics, the majority of the variance in attunement or similarity in hormone levels has been explained by the shared social environment (Schreiber et al., 2006).

Hormones and structure of social networks

Research to date has advanced our understanding of hormone regulation of social relationships, but limited empirical attention has been focused on the role of social structure on hormone–behavior associations (for an exception see research with non-human primate dominance hierarchies; Sapolsky, 1990, 2005). Social network structure emerges from enduring patterns of social relationships, which are, in turn, comprised of social interactions characterized by patterns, content, and quality (Hinde, 1976). Recent work on nonhuman and human primates suggests that hormones are associated with social network structure (Brent et al., 2011; Kornienko et al., 2013, 2014). Specifically, high-ranking free-ranging female macaques were shown to have lower glucocorticoid levels when their association networks were smaller and more focused, as indexed by a lower number of outgoing connections (Brent et al., 2011). Among female nursing students, salivary cortisol levels were inversely associated with number of perceived friends, whereas testosterone was not related to friendship network structure (Kornienko et al., 2014). This network-informed research has elucidated the associations between hormones and social structure. However, it has only focused on a static snapshot of a network structure. This approach precludes examination of dynamic processes guiding the changes of social relationships comprising the networks. Understanding the role hormones play in social network dynamics has the potential to discover how the biological basis of behavior is associated with social structure emergence and has implications for proximal and ultimate mechanisms of sociality (Pinter-Wollman et al., 2014).

Hormones and social network dynamics

We are interested in how hormone concentrations are associated with changes in friendship networks over time. Social networks evolve through multiple, intertwined processes, which are collectively referred to as *network selection* processes (Rivera et al., 2010; Steglich et al., 2010; Snijders et al., 2010). Network selection processes include two broad categories: (a) network selection based on individual characteristics (e.g., sex, age; McPherson et al., 2001) and (b) network structural processes reflecting how connections between individuals depend on their connections with other members of a group (e.g., whether two people have a friend in common). Three social processes by which individual characteristics are related to friendship network change include (1) *network activity*, which assesses the focal individual's perspective on their friends in the group, (2) *network popularity*, which measures how the focal individual is perceived as a friend by other group members, and (3) homophily, which describes a tendency to befriend similar others (Steglich et al., 2010). Because multiple processes operate jointly in producing social network structure, inferring which process is responsible for patterns observed in a network is challenging. To understand the role of an attribute such as hormones during network selection, one must statistically control for co-occurring and, thus, confounding network processes.

One confounding network process we need to account for stems from a correlation between hormone levels and biological sex. For example, one of our goals is to assess if people choose friends with similar levels of T. This outcome could arise spuriously given the correlation