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Recommendations for the study of women in hormones and competition research

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"There is no mark on the wall to measure the precise height of women".
[-Virginia Woolf, *A Room of One's Own*]

Predominant theories in the social endocrinology of competition and status, the *biosocial model of status* (Mazur, 1985; Mazur, this issue) and *challenge hypothesis* (Wingfield et al., 1990; Wingfield, this issue) have sought to explain the biological underpinnings of dominance-related behaviors by suggesting that these behaviors are driven by fluctuating levels of testosterone during periods of social competition. Although the challenge hypothesis was initially intended to describe increases in testosterone during reproductive or territorial challenges in male birds, it was later applied to human males to explain increases in testosterone in response to face-to-face competitions for social status (Archer, 2006). The biosocial model of status expands upon the notion that testosterone is linked to competitive behavior by proposing that testosterone increases in response to status gained through victory and decreases in response to status lost through defeat (Mazur and Booth, 1998). Although both theories primarily focus on male behavior, Allan Mazur, in his initial description of the biosocial model of status (1985) was open but cautious about the theory's relevance to females:

> "This model relies more on research in males than on females. It is proposed as a theory about both sexes, but with a caution that little is known about sex differences in the relation of hormones to dominance behavior (p. 377)"

Despite efforts to apply these models to human females (e.g., Carré et al., 2013; Cashdan, 1995; Casto and Edwards, 2016a; Mazur et al., 1997), women, relative to men, remain an under-studied population in research on hormones and competition (van Anders and Watson, 2006). In this commentary, we make five recommendations for the study of women in hormones and competition research.

1. Include women in study designs

There is approximately two to three times the number of studies on the hormonal response to competition in men compared to women (Carré and Olmstead, 2015; Geniole et al., this issue).[1] Studies in this special issue (*Hormones and Human Competition*) also disproportionately represent men in both theoretical discussion and sample population. Similar if not greater disparities exist for the more general use of male compared to female animals in non-human literature (Beery and Zucker, 2011; Hughes, 2007; Prendergast et al., 2014).

Women are excluded from study designs in the hormones and competition literature for several reasons. One reason is that the 'winner-loser effect' (i.e., winners have higher testosterone increases to competition than losers) tends to yield stronger effect sizes in men compared to women (e.g., see Wu et al., this issue). Indeed, a recent meta-analysis of studies on the testosterone response to competition determined that although the winner-loser effect was not moderated by sex, the effect was only statistically significant in men (men Cohen's $d = 0.23$; women $d = 0.14$, Geniole et al., this issue). Given the pressure to publish, it would seem more advantageous to plan studies that are more likely to generate significant effects (i.e., studying testosterone-behavior relationships in men). However, this meta-analytic comparison was made with substantially fewer studies of women than men. Without more equal representation, uncertainty about the true difference in the effect size between men and women remains. Additionally, it is possible that lower effect sizes among the limited sample of women participants are a result of male-centric experimental designs among studies that do

[1] The underrepresentation of women in social endocrinology is unique to studies of *endogenous* testosterone levels. There is a related literature on the behavioral effects of testosterone administration where, for some time, women were sampled almost exclusively due to the lack of an established protocol in men (Bos et al., 2012; Mehta et al., 2015; van Honk et al., 2004; the first validated protocol for T administration was a study of sexual arousal in women, Tuiten et al., 2000). Additionally, women are often over-represented in other areas of psychological research as a matter of convenience (due to the larger number of women majoring in psychology and therefore, available in departmental subject pools).

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include women (this point is elaborated in Recommendation 2). In any case, the potential gender or sex[2] difference in the testosterone response to competition presents two options for future studies: include women and test for gender effects or, limit conclusions to half the population – the former being more scientifically rigorous than the latter.

Women may also be excluded from study designs to avoid what are thought to be 'complicating' factors of menstrual cycle phase and hormonal contraceptive use. It is true that testing menstrual cycle phase effects requires a larger sample size and a more technical and costly methodology for validly determining cycle phase (see Recommendation 3 for further discussion). However, given the relatively small effect sizes of menstrual cycle phase on human behavior (for meta-analysis, see Wood et al., 2014) and relatively small changes in testosterone across the cycle, menstrual cycle phase could be ignored in studies of the testosterone response to competition (van Anders et al., 2014). Although hormonal contraceptive use typically results in lower baseline testosterone among users compared to non-users (Coenen et al., 1996; Liening et al., 2010) and appears to impact social behavior (Montoya and Bos, 2017), information about contraceptive use is easily ascertained from participants and can be included as a factor in statistical designs. Additionally, despite differences between users and non-users in baseline testosterone, testosterone *change* associated with competition does not appear to be affected by contraceptive use (e.g., Edwards and O'Neal, 2009). Thus, cycle phase and contraceptive use do not inherently create major complications for a study design and do not form the basis of a strong argument for excluding women. Further, the perception that sources of hormonal variation in women are problematic for study designs is especially unfair given that researchers do not exclude male participants on account of the variety of factors that reliably impact testosterone levels in men – body fat, relationship status, and parental status (Burnham et al., 2003; Gray et al., 2002; Pasquali, 2006; van Anders and Goldey, 2010; Vermeulen et al., 1999).

A third reason some researchers may exclude women is because of concern about the validity of standard immunoassay techniques for salivary testosterone measurement, particularly for saliva samples provided by women (Granger et al., 2004, 2007; Welker et al., 2016). Indeed, a recent study comparing testosterone levels obtained from enzyme immunoassays (EIA) kits to liquid chromatography tandem mass spectrometry (LC-MS/MS), a more sensitive and accurate method of salivary hormone measurement, showed inflated levels of testosterone from EIAs compared to LC-MS/MS at lower concentrations, levels that are typically observed in women. However, this study also revealed that the correspondence between testosterone levels obtained from EIAs and LC-MS/MS were low to moderate in women *and* men (Welker et al., 2016). With the potential for validity issues when using EIAs to determine salivary testosterone regardless of participant gender, there seems little reason to selectively exclude women. Additionally, although access to LC-MS/MS is limited, researchers could use this technique to reliably assay saliva samples in studies including women and men.

Given the absence of firm exclusion criteria, women should be included in study designs on the testosterone response to competition. To quote McCarthy et al. (2012) regarding the exclusion of female animals in neuroscience research,

> "In our view, what most deters investigators from including females in their studies are misconceptions; misconceptions that it is difficult to do it right, and misconceptions of the value of comparing males and females, with many neuroscientists thinking they are not likely to learn anything useful, much less make novel discoveries (p. 2241)."

2. Employ more inclusive theoretical models of competitive and status-motivated behavior

That the challenge hypothesis and biosocial model for status have been tested primarily with men comes as no surprise given that the 'male' sex hormone testosterone is at the center of these theories – women have substantially less circulating testosterone than men. Although testosterone surges at critical periods of development are responsible for phenotypic masculinization in genetic males, there is ample evidence that both men *and* women show transient elevations in testosterone in response to a variety of social behaviors (for review Eisenegger et al., 2011; Casto and Edwards, 2016b; e.g., Hahn et al., 2016). Despite this, research on testosterone and social behavior remain in many ways tied to a masculine perspective (van Anders, 2013). In an attempt to address this bias, Sari van Anders et al. (2011) introduced a gender inclusive model of hormone-behavior relationships – the Steroid/Peptide Theory of Social Bonds (S/P Theory). The S/P theory encourages a perspective in which predictions are made about how social behaviors, motivated by nurturance and competition, relate to basal and changing hormone levels regardless of gender (for more detailed explanation, see van Anders, 2013; van Anders et al., 2011). Nearly five years after its publication, this inclusionary reformulation has received little attention in the hormones and competition literature.

Like testosterone, competitive behavior is also subject to a masculine bias: competitive, instrumental, and agentic behaviors are considered more desirable and thus, are reinforced at greater rates in men compared to women (Prentice and Carranza, 2002; Rudman and Glick, 2001; Rudman and Phelan, 2008; Runge et al., 1981; Schmader and Block, 2015; Spence and Helmreich, 1980). Consequently, women are less likely than men to choose to enter a competition (Apicella et al., 2017; Niederle and Vesterlund, 2007) and less likely to perform well in competitive environments (Gneezy et al., 2003). Perhaps even framing tasks as "competitions" with an explicit win-loss focus creates a situation in which the desire to compete and perform well directly conflicts with the desire to behave in a way that is socially acceptable (women face backlash for agentic behavior, Amanatullah and Morris, 2010; Rudman and Glick, 2001). Indeed, the role of socialization on competitive behavior is clear: gender differences in competitiveness are reversed or attenuated within matrilineal societies where women are encouraged to compete throughout development (Andersen et al., 2013; Gneezy et al., 2009).

Despite the influence of gender socialization on the expression of competitive behavior, studies of the hormone-competition relationship rarely account for individual differences in how men and women conform to gender roles of masculinity and femininity, agency and communality (for one notable exception, see van Anders et al., 2015). Gender identity is a complex and multidimensional construct extending beyond self-categorization into a gender group (male, female, transgender male, transgender female, genderqueer, or intersex; Carver et al., 2003; Joel et al., 2013; Tate et al., 2014). Thus, simply inquiring about participant's gender category misses important information about that individual relative to competitive behavior. Moreover, certain components of gender identity such as gender-role attributes (agency vs. communality, Spence and Helmreich, 1980) and gender typicality (Egan and Perry, 2001; Tate et al., 2015) explain differences in the expression of

[2] Although *sex* and *gender* are different constructs, sex having more to do with biology and gender having more to do with socially or culturally-based conceptions of sex, the terms are overlapping and often used interchangeably in psychological research (Glasser and Smith, 2008). There is an insightful, yet complicated literature and ongoing debate on how to define and measure sex versus gender and the degree with which this distinction is meaningful (for a comprehensive review, Muehlenhard and Peterson, 2011). In this manuscript, we attempt to follow the APA publication manual recommendation to use *gender* "when referring to men and women as social groups" and *sex* when referring to instances when "the biological distinction is predominant" (p. 71, APA, 2010). However, we acknowledge that these distinctions are particularly difficult to make when discussing relationships between hormones and social behavior (e.g., see van Anders et al., 2015). Further, we acknowledge that most studies of the social neuroendocrinology of competition do not directly measure sex or gender beyond asking participants to indicate if they are "male" or "female" or to enroll in the study only if they are male or female – a practice that conflates sex and gender.

competitive behavior, even above and beyond categorical sex or gender (e.g., Abele, 2003). In particular, a continuous measure of gender typicality, the degree with which an individual feels that he or she conforms to the behaviors and cognitions of other individuals of the same gender (Egan and Perry, 2001; Tate et al., 2015) could be used a predictor or moderator of competitive behavior and the hormonal response to competition. We hypothesize that because competitive behavior is male-socialized, those most likely to demonstrate competitive behavior, perhaps with hormonal consequence, would be both male-typical men and female-nontypical women. To test this, we recommend that researchers include measures of gender-role conformity or gender typicality in studies of hormones and competition. There are numerous person and context factors that moderate relationships between competition and testosterone change (for review, Casto and Edwards, 2016b). Like other person factors that have received empirical attention (e.g., implicit power motivation, Stanton and Schultheiss, 2009; trait dominance, Mehta et al., 2015, Slatcher et al., 2011), gender typicality should also be explored as a person factor that predicts or moderates competitive behavior and the hormonal response to competition.

Social context is also highly relevant to the emergence of competitive behavior, particularly for women, who may risk social reprisal for the expression of overt competitiveness. As a result, women express more implicit forms of competitiveness and compete only under certain social contexts. For example, women choose to compete at equal rates to men when competing against their own personal standard (Apicella et al., 2017) or when told that at least one women (among a mixed-sex competitor pool) would be selected as a winner (Niederle et al., 2013). In negotiations, women tend to show more competitiveness than men if their opponent uses a tit-for-tat strategy (i.e., mimicking the participant's previous action, Walters et al., 1998). A particularly salient social context variable relevant to the expression of competitive behavior is the type of competitive task. Women are less experienced, interested, or confident in competitive computer games (for review, Hartmann and Klimmt, 2006), especially games that require skills in which men have an advantage over women. For example, games like Tetris, a task based almost exclusively on one's ability to mentally rotate geometric shapes quickly, have been commonly used in competition studies despite overwhelming meta-analytic evidence that men have superior mental rotation ability over women, particularly under time constraints (Maeda and Yoon, 2013). Additionally, achieving or maintaining social status in various contexts requires different types of competitive behavior, less or more prosocial, in men and women – women perhaps needing to be more affiliative to achieve status, particularly among groups of other women (Cashdan, 1998; Hays, 2013). As a result, women's competitive motivation could, more so than in men, be relatively uninspired by the isolating laboratory cubicle. Indeed, empirical research shows that a predominant reason that women are less interested in competitive digital games is their lack of meaningful social interaction (Hartmann and Klimmt, 2006). Thus, although the role of social context factors in moderating hormonal response to competition is already of great interest in social neuroendocrinology (e.g., Casto and Edwards, 2016b), researchers should consider important gender-relevant context factors in attempting to better understand the social neuroendocrinology of women. Theoretical discussion on gender differences in the hormonal and behavioral response to stress, 'fight-or-flight' versus 'tend-and-befriend,' is a good example of efforts towards addressing the divergence and convergence between men and women in hormone-behavior relationships (Byrd-Craven et al., 2015; Geary and Flinn, 2002; Taylor, 2006; Taylor et al., 2000).

3. Consider other hormones (e.g. estradiol and progesterone)

Testosterone (in addition to cortisol) has generally been the target hormone for studies of competitive and status-related behavior. However, it is possible that fluctuating levels of other hormones, such as estradiol and progesterone, also relate to these behaviors. Although there are methodological challenges with accurately measuring salivary estradiol and progesterone, there are validated protocols for assay of these hormones (e.g., mass-spectrometry, Gao et al., 2015; immunoassay, Shirtcliff et al., 2000). Additionally, there is a promising line of research indicating a positive relationship between estradiol levels and implicit power motivation (Schultheiss et al., 2004; Stanton and Edelstein, 2009; Stanton and Schultheiss, 2007) as well as assertiveness in women (Blake et al., 2017). At least one study has also provided evidence of an interaction between estradiol and cortisol levels in predicting youth "socially dominant" externalizing behavior in girls and boys (Tackett et al., 2015).

Levels of estradiol and progesterone vary significantly depending on menstrual cycle phase (Choe et al., 1983; Gandara et al., 2007; Lu et al., 1999) and with hormonal contraceptive use (Liening et al., 2010; Rivera et al., 1999). Thus, as a proxy for these hormones, menstrual cycle phase and hormonal contraceptive use have been tested in relation to competitive behaviors, mostly those having to do with intra-sexual competitiveness in mating contexts (e.g. Durante et al., 2008; Puts, 2005). Studies that have explored menstrual cycle effects on competitive behavior outside of mating contexts have showed that intra-sexual competitiveness among women is highest near ovulation, when estradiol levels are also relatively high (e.g., Eisenbruch and Roney, 2016; Pearson and Schipper, 2013) or when progesterone levels are relatively low (Buser, 2012). Additionally, women who use hormonal contraceptives (which typically results in relatively high circulating levels of synthetic progesterone and low levels of estradiol) make less advantageous competitive bidding decisions compared to non-users (Pearson and Schipper, 2013). These studies suggest that both endogenously fluctuating (i.e., menstrual cycle phase shifts and potentially age-related shifts) and exogenously altered (i.e., hormone contraceptive use and potentially hormone replacement therapy) levels of estradiol and progesterone are important for understanding competitive behavior.

For studies examining menstrual cycle phase effects, it is recommended that researchers use the most stringent protocols for determining menstrual cycle phase, such as luteinizing hormone tests in combination with the backwards-counting method (see Blake et al., 2016; Bullivant et al., 2004; van Anders et al., 2014) and consider cross-referencing phase timing with hormone measurement. Despite the rigor and expense of these methods, there is great opportunity to expand our understanding of the biological underpinnings of competition, particularly in women.

4. Test for the interaction of gender with other predictors in statistical models with the combined sample of men and women

Once women are included in study designs, important decisions must be made about treating the categorical variable of gender or sex (depending on whether the researcher is interested in *gender* or *sex* effects) as a factor in statistical analyses. To test for gender/sex effects in statistical analyses, it is recommended that researchers first test main effects and interactions with the combined sample of men and women rather than testing effects separately within each group (Bluhm, 2013; Hayes, 2005). If a significant interaction emerges between gender/sex and other predictors, then this indicates that an effect is either smaller or larger or in a different direction in men compared to women and vise-versa. Post-hoc analyses and graphical representation should also be used to determine the magnitude and direction of effects within men and women separately (Stanton, 2011). In this special issue, we note that Sherman et al., Mehta et al., and Prasad et al., provide examples of using the gender-interaction approach. As discussed in Recommendation 2, gender typicality or some other measure of gender-related attributes, could be used as a predictor or moderator in addition to categorical gender.

5. In exploring gender differences, also consider gender similarities

After accounting for gender-related social factors in study designs and properly testing these factors in statistical analyses, researchers may find that men and women demonstrate fewer overall differences in competitive behavior and related hormonal responses to competition than previously thought. Although men and women are biologically different in many ways (e.g., genetics, genitalia, prenatal exposure to and circulating levels of testosterone), the size of the effect of these differences on cognition and behavior is smaller than expected or often reported. Meta-analytic evidence in support of Hyde's (2005, 2014) *gender similarities hypothesis* demonstrates that effect sizes for 'gender differences' in a broad domain of psychological and behavioral variables are small (Cohen's $d = 0.20$) to trivial ($d < 0.10$). These effects could still be meaningful, but do not neatly or consistently sort gender into two distinct categories (Reis and Carothers, 2014) or qualify as representative of innate or biological "sex dimorphism," a term that should be reserved for instances where "two distinct forms" are clearly apparent (e.g. genitalia, McCarthy and Konkle, 2005). Thus, gender differences in human behavior often reflect individual differences on a continuum, only predictably sorting into male or female at the extremes. There is even more overlap than expected in some sex-linked anatomical characteristics. For example, second-digit-to-fourth-digit (2D:4D) ratio is widely used as a predictor of hormone-mediated traits resulting from prenatal exposure to testosterone and therefore, should distinctly separate men and women (Hönekopp and Watson, 2010). However, the sample distributions of the mean on 2D:4D ratio for men and women are almost entirely overlapping (e.g., Muller et al., 2011; Putz et al., 2004).

Given the considerable overlap in various aspects of neuroanatomy and behavior (for review, Rippon et al., 2014), the traditional 'yes-or-no' approach of null hypothesis significance testing of gender effects can lead to inaccurate assertions of men and women as being 'same or different' (Maney, 2016). Moreover, p-values for the effect of gender under 0.05 do not speak to the magnitude of the difference, and those above 0.05 do not indicate that men and women are necessarily the same. Thus, researchers testing gender as a factor should interpret effect sizes within men and women rather than take an absolute dichotomous or same-different approach. This could prevent the inaccurate classification of women as being non-competitive or having no hormonal consequence to competition as a result of a non-significant p-value. Furthermore, for researchers interested in gender effects, we recommend Joel and McCarthy's (2016) framework for interpreting sex differences in which additional dimensions should be examined, that is, whether the sex difference is persistent vs. transient, context dependent vs. independent, and whether the end point is sexually dimorphic or continuous. Finally, subjective interpretation of gender effects even with moderate to large effect sizes should consider cultural, developmental, and contextual influences (as previously discussed) along with the degree of overlap in behavior (Rippon et al., 2014). Gender differences are important and interesting, but researchers should be careful not to ignore concomitant similarities.

Conclusion

The goal of social neuroendocrinology is to discover the hormonal underpinnings of socially-relevant behaviors. However, studies of hormones and human competition, highlighted in this special issue, have focused primarily on men and approached study designs with a male-centric understanding of competition. We encourage researchers to expand theories on hormones and competitive and status-motivated behavior with concerted attention to gender socialization and related social context factors. Additionally, researchers should explore relationships between competitive behavior and other 'sex' hormones such as estradiol and progesterone that may be particularly relevant to competitive behavior in women. We also suggest that researchers test for gender as a factor in statistical analyses with combined samples of men and women but also report effect sizes within each gender in order to properly interpret the magnitude of gender effects. Most importantly, if nothing else, we ask that researchers include women as participants in study designs.

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