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Exposure to perceived male rivals raises men's testosterone on fertile relative to nonfertile days of their partner's ovulatory cycle

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ABSTRACT

The challenge hypothesis posits that male testosterone levels increase in the presence of fertile females to facilitate mating and increase further in the presence of male rivals to facilitate male–male competition. This hypothesis has been supported in a number of nonhuman animal species. We conducted an experiment to test the challenge hypothesis in men. Thirty-four men were randomly assigned to view high-competitive or low-competitive male rivals at high and low fertility within their partner's ovulatory cycle (confirmed by luteinizing hormone tests). Testosterone was measured upon arrival to the lab and before and after the manipulation. Based on the challenge hypothesis, we predicted that a) men's baseline testosterone would be higher at high relative to low fertility within their partner's cycle, and b) men's testosterone would be higher in response to high-competitive rivals, but not in response to low-competitive rivals, at high relative to low fertility within their partner's cycle. Contrary to the first prediction, men's baseline testosterone levels did not differ across high and low fertility. However, consistent with the second prediction, men exposed to high-competitive rivals showed significantly higher post-test testosterone levels at high relative to low fertility, controlling for pre-test testosterone levels. Men exposed to low-competitive rivals showed no such pattern (though the fertility by competition condition interaction fell short of statistical significance). This preliminary support for the challenge hypothesis in men builds on a growing empirical literature suggesting that men possess mating adaptations sensitive to fertility cues emitted by their female partners.

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Introduction

In many species, the fleeting period of peak fertility that precedes and includes the day of ovulation is the only time when a female can conceive. Given the crucial significance of the fertile window for male reproductive success, a straightforward hypothesis is that males will evolve to detect any available cues of impending ovulation in females. In turn, males might respond to these cues with hormone changes that facilitate mating with fertile females and also facilitate competing with male rivals to prevent them from usurping potential reproductive opportunities.

The challenge hypothesis posits that male testosterone increases in the presence of fertile females and increases further in the presence of fertile females *and* male rivals (Wingfield et al., 1990). A substantial literature has supported the challenge hypothesis across a range of non-human animals, including species of fish (Hirschenhauser et al., 2004; Pankhurst and Barnett, 1993), lizards (Moore, 1986), and primates (Cavigelli and Pereira, 2000; Rose et al., 1972). For example, in one landmark study, male chimpanzees' testosterone levels increased in the presence of parous females in the fertile phase of their cycles (parous females are those who have successfully reproduced in the past; Muller and Wrangham, 2003). Further, this increase in testosterone was associated with increased rates of male–male aggression.

Human ovulation cues

Emerging evidence indicates that men can detect cues of ovulation (reviewed by Haselton and Gildersleeve, 2011). For example, men give higher attractiveness ratings to body odor samples (e.g., Doty et al., 1975; Gildersleeve et al., 2012) and vocal clips (Pipitone and Gallup, 2008; Puts et al., 2013) collected on high- as compared with low-fertility days of the cycle. Moreover, in one study, male patrons at gentlemen's clubs gave lap dancers larger tips on high- as compared with low-fertility days of the dancers' cycles (Miller et al., 2007). In the context of romantic relationships, in two studies, women reported that their male partners were more jealous and possessive on high- relative to low-fertility days of their cycles (Gangestad et al., 2002;

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Haselton and Gangestad, 2006; see also Pillsworth and Haselton, 2006b). In sum, a growing body of evidence indicates that there are cues of ovulation that women's male partners might detect and respond to with shifts in both attraction (facilitating mating) and mate guarding (facilitating male–male competition).

Testosterone and human mating

Consistent with the challenge hypothesis, several key pieces of evidence hint that testosterone might underlie shifts in men's responses to women and male rivals across the ovulatory cycle. First, there is support for the notion that men's testosterone increases in the presence of cues to potential reproductive opportunities in order to facilitate courtship behavior. Several studies have shown that men's testosterone levels increase in the presence of physically attractive women (Roney et al., 2003, 2007; van der Meij et al., 2008) and in response to higher ratios of women relative to men (Miller et al., 2012). In addition, in two studies, men who smelled body odor samples collected from women on high-fertility days of the cycle subsequently showed higher levels of testosterone than did men exposed to body odor samples collected from women on low-fertility days of the cycle (Miller and Maner, 2010; but see Roney and Simmons, 2012). Second, consistent with the notion that men's testosterone increases in the presence of male rivals in order to increase competitive motivation, several studies have shown that men's testosterone levels increase prior to competitive interactions with other men (e.g., tennis matches and judo competitions; Booth et al., 1989; Mazur et al., 1997; Salvador et al., 2003; Suay et al., 1999). In sum, consistent with the challenge hypothesis, current findings point to testosterone as a plausible mediator of changes in men's motivations and behaviors in response to fertile women and male rivals.

The current study

We devised a test of the challenge hypothesis involving romantic couples. The present study tested two predictions that follow from the challenge hypothesis: a) men's baseline testosterone will be higher at high relative to low fertility within their partner's cycle, and b) men's testosterone will be higher in response to high-competitive rivals (but not in response to low-competitive rivals) at high relative to low fertility within their partner's cycle.

Methods

Participants

Participants were thirty-five heterosexual romantic couples, the majority of whom were university students. Women reported regular menstrual cycles and had not used any form of hormonal contraception (e.g., birth control pills, Norplant, vaginal ring, birth control patch, Depo-Provera, Mirena IUD) in the three months prior to their participation. Couples were ineligible if the woman reported an average cycle length shorter than 24 or longer than 35 days or rated her confidence in her cycle length as less than seven on a 9-point scale (1 = not at all confident; 9 = very confident) and, in a follow-up question, reported that she was usually "off" by more than four days in her prediction of her next menstrual onset. The mean age of female participants was 20.51 years (*S.D.* = 3.01, range = 18–32). The sample of female participants was ethnically diverse; 37.1% self-identified as Asian, 20.0% as Caucasian, 11.4% as African-American, 5.7% as Hispanic, and 25.8% as "other" or multiple ethnicities. The mean age of male participants was 21.46 years (*S.D.* = 3.06, range = 18–33). The sample of male participants was also ethnically diverse; 48.6% self-identified as Caucasian, 25.7% as Asian, 8.6% as Hispanic, 2.9% as African-American, and 14.2% as "other" or multiple ethnicities. Mean relationship length was 16.25 months (*S.D.* = 11.58; range = 2–53 months).

Scheduling and LH testing

Prior to enrolling in the study, women completed an initial phone interview that included questions about their average cycle length, regularity, and past two dates of menstrual onset. We used this information to schedule each couple to complete two lab sessions—one session on an estimated high-fertility day of the female partner's cycle and one session on an estimated low-fertility day of her cycle. We used the reverse counting method to identify high- and low-fertility target days for scheduling these sessions (e.g., see Gangestad et al., 2002; Haselton and Gangestad, 2006). We assumed that ovulation occurs, on average, approximately 15 days prior to next menstrual onset (Dixon et al., 1980; Wilcox et al., 1995; but see Cole et al., 2009 for evidence suggesting that ovulation occurs slightly later in the cycle). Specifically, we scheduled couples to complete their high-fertility lab session 16 to 18 days prior to the female partner's predicted date of next menstrual onset (one to three days prior to her predicted date of ovulation) and their low-fertility session three to 10 days prior to her predicted date of next menstrual onset. Actuarial data indicate that these target days generally fall within the high- and low-fertility phases of the menstrual cycle, respectively (Wilcox et al., 2001). The order of couples' high- and low-fertility sessions depended on the female partner's position in the ovulatory cycle at the time of her initial phone interview. If a woman's next predicted menstrual onset was between four and 17 days away, we scheduled her and her partner to complete their low-fertility session first ($n = 16$). Otherwise, we scheduled them to complete their high-fertility session first ($n = 19$).

To verify that high-fertility sessions took place just prior to or on the day of ovulation (when fertility is highest), women completed a series of five ovulation tests in their predicted high-fertility window. All but three women completed ovulation tests from two days before to two days after their high-fertility session. Due to scheduling constraints, the remaining three women completed ovulation tests from one day before to three days after their high-fertility session. We removed the ovulation test wrappers so that participants could not easily identify the purpose of the tests. The tests measured luteinizing hormone (LH) in urine, which typically rises 24–48 h prior to ovulation (Testart and Frydman, 1982). In one study, LH tests were 97% accurate in verifying ovulation as detected by ultrasound (Guermandi et al., 2001). An LH surge was observed, on average, 0.60 days before the high-fertility session, ranging from three days before to two days after (*S.D.* = 1.59). Therefore, on average, high-fertility sessions took place approximately one day before ovulation.

Although LH tests are widely regarded as one of the most rigorous methods for determining women's position in the ovulatory cycle, recent evidence indicates that there is variation in the amplitude, duration, and number of LH peaks women experience (Direito et al., 2012). This variation might introduce error into estimates of the timing of ovulation based on LH tests alone. To increase confidence that high- and low-fertility sessions took place within the appropriate phases of the menstrual cycle, we followed up with women via phone or email to obtain a *confirmed* date of their next menstrual onset following completion of the study. Participants who completed their low-fertility session first also reported the date of menstrual onset between their low- and high-fertility sessions. If women could not be reached to confirm their date of menstrual onset following completion of the study, we *estimated* this date using their self-reported date of last menstrual onset and average cycle length ($n = 6$). Based on these dates, high-fertility sessions occurred, on average, 16.9 days before menstrual onset, ranging from 20 to 13 days prior to menstrual onset (*S.D.* = 1.73). Low-fertility sessions occurred, on average, 5.0 days before menstrual onset, ranging from 12 days prior to menstrual onset to two days after menstrual onset (*S.D.* = 1.73).

To be eligible for inclusion in the analyses, participants had to show evidence of an LH surge within two days prior to and three days after their high-fertility session and fall into one of two categories:

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