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Rapid endocrine responses of young men to social interactions with young women

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Abstract

It is well-established that males of many nonhuman vertebrate species exhibit hormonal reactions to stimuli from potential mates. The present studies were designed to test replication of preliminary findings suggesting that human males may exhibit such reactions as well. In Experiment 1, young men ($n=115$) provided saliva samples before and after either conversing with a woman confederate or sitting alone for 15 min. Changes from baseline in salivary testosterone concentrations were significantly greater among the men exposed to women, but only among subjects tested in the afternoon. In Experiment 2, male subjects ($n=99$) interacted with either a male or a female confederate with saliva samples collected before and after these interactions and all experimental sessions conducted in the afternoon. Men who interacted with women exhibited significant elevations of testosterone relative to both their own baseline concentrations and to change scores among the men who interacted with other men. In addition, women confederates' ratings of men's extraversion and degree of self-disclosure were positively correlated with changes in testosterone. In both experiments, furthermore, changes in cortisol concentrations from baseline were significantly greater among men who spoke with women relative to men in the control conditions. The results provide evidence that social interactions with potential mates can in fact trigger specific patterns of endocrine responses in human males.

Keywords: Testosterone; Cortisol; Human mating; Courtship

Introduction

Males of many vertebrate species exhibit testosterone increases within about 20 min of onset of exposure to females placed behind transparent barriers (Amstislavskaya and Popova, 2004; Batty, 1978; Bonilla-Jaime et al., 2006; Popova and Amstislavskaya, 2002; Purvis and Haynes, 1974) or to female chemosensory stimuli such as urine or vaginal secretions (e.g., James et al., 2006; Macrides et al., 1974; Pfeiffer and Johnston, 1994; Richardson et al., 2004; for evidence of such effects specifically in primates, see Cedra-Molina et al., 2006; Ziegler et al., 2005). Relatively little research has addressed whether human males also exhibit reactive testosterone increases in response to stimuli from potential mates. A few studies have reported increases in salivary or serum testosterone within 20 min of onset of exposure to sexually explicit films (Hellhammer et al., 1985; Redoute et al., 2000; Stoleru et al., 1993), though other researchers have reported null effects of exposure to such stimuli (Carani et al., 1990; Kruger et al., 1998; Lincoln, 1974). Only one previous study has examined men's hormonal responses to non-tactile interactions with women: Roney et al. (2003) found that men's salivary testosterone increased significantly over baseline concentrations 20 min after the onset of a five-minute conversation with a woman confederate. The magnitude of testosterone change was also positively correlated with the women confederates' ratings of how much the men were trying to impress them. The conclusiveness of that study was limited, however, by both its small sample size and the fact that the increase in testosterone found in men who spoke with women was not significantly greater than a nonsignificant increase found among men who spoke with male confederates in a comparison group. The present research was therefore designed to provide additional evidence regarding men's hormonal responses to potential mates.

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Although there have been few direct investigations of men's hormonal reactions to social interactions with women, other lines of research support the plausibility of such effects in humans. A number of studies have found that men's testosterone may increase after victorious competitive interactions (for reviews, see Archer, 2006; Booth et al., 2006; Mazur and Booth, 1998) or after challenges to dominance or status (e.g., Cohen et al., 1996). Booth et al. (2006; see also Mazur, 2005) have argued that these results are part of a bi-directional relationship between dominance and testosterone such that testosterone both facilitates behaviors that promote dominance competition and responds to the outcomes of status contests. This line of research not only supports the possibility of reactive testosterone changes in men, but also suggests that testosterone responses to potential mates might be expected as a means of facilitating status competition when the presence of new mating opportunities increases the potential payoffs from such behavior.

The present research also examined whether interactions with potential mates may have short-term effects on men's cortisol concentrations. The nonhuman literature has been mixed on this point, with null effects in response to chemosensory stimuli (Cedra-Molina et al., 2006; Ziegler et al., 2005) and cortisol increases after direct exposure to females (Bonilla-Jaime et al., 2006; Bronson and Desjardins, 1982; Mendoza and Mason, 1989). In the human literature, cortisol reactivity has generally been treated as a marker of negatively valenced reactions to eliciting events and a recent meta-analysis suggested that cortisol increases may be somewhat specific to conditions that include threats to one's social esteem (Dickerson and Kemeny, 2004). These authors further conjectured that cortisol reactivity may function to mobilize energy resources to help respond to threats, but in principle there is no reason to think that an energy mobilization mechanism of this sort would not also be functional in responding to positive events such as potential mating opportunities. The current studies therefore tested whether cortisol reactivity may extend beyond laboratory stress tasks and also play a role in more ecologically realistic social interactions. The availability of cortisol measures also allowed for examination of whether testosterone and cortisol responses might be related to one another, which could provide clues regarding the specific endocrine pathways implicated in hormonal responses to potential mates.

The present research employed two experiments in which men were randomly assigned to either conditions in which they interacted with women or to control conditions. Two primary hypotheses were posited a priori. First, we predicted that men exposed to women would exhibit more positive changes in testosterone from baseline than would men in the control conditions. Second, we predicted replication of the finding from the Roney et al. (2003) study showing that men's changes in testosterone correlated positively with women confederates' ratings of how much the men were trying to impress them. A number of more exploratory analyses were also planned. In one study, the women confederates' behavior was manipulated in order to test whether possible testosterone responses are sensitive to proceptive behaviors from potential mates. Tests of cortisol responses to potential mates (and the relationship of such responses to changes in testosterone) were also considered exploratory given mixed findings in the nonhuman literature and the lack of direct evidence for such effects in humans.

Methods

Subjects

Subjects in Experiment 1 were 115 heterosexual undergraduate men (mean age = 18.90 ± .13 years) who participated in exchange for partial fulfillment of a course requirement. One hundred two undergraduate men took part in Experiment 2, but data from two subjects who reported a gay sexual orientation and from one subject who was clearly inebriated at the time of testing were excluded from the data analyses. The remaining 99 men had a mean age = 18.98 ± .12 years. Subjects in Experiment 2 also participated in exchange for partial fulfillment of a course requirement.

Procedures

Experiment 1

As part of the informed consent process, subjects read a cover story that described the experiment as an investigation of whether salivary cortisol concentrations might predict self-recognition abilities. Subjects were told that a digital photo of their face would be morphed with the photo of an infant face in order to test whether they could pick this self-morphed face out of an array that included distracter faces. Consistent with this cover story, an initial saliva sample was collected and subjects' photos were taken with a digital camera. At that point, the experimenter told the subject that the morphing program takes about 15 min to run and that they should wait in an adjoining room until the program is finished. Variations in the waiting room experience constituted the experimental manipulation and subjects were randomly assigned to one of three conditions. Men in an alone condition ($n = 38$) simply sat by themselves for 15 min until the program had ostensibly finished. In the other two conditions, one of seven women confederates (ages 19–21) was already present in the room when the subject arrived and posed as another subject waiting for their morphing program to be completed. Chairs were arranged such that subjects always sat directly across from the confederates with a small conference table positioned between them. In the neutral condition ($n = 38$), confederates attempted to engage in a natural, friendly conversation without attempting to be flirtatious. In the flirtatious condition ($n = 39$), the women confederates attempted to be flirtatious and signal interest in the subjects. Confederates were free to employ whatever means of conveying interest that seemed natural to them and specific scripts were not employed due to concern that doing so could make the interactions excessively artificial. Conversations lasted precisely 15 min, at which point the experimenter separated the subject and confederate to ostensibly allow them to independently complete the rest of the study protocol.

Subjects produced a second saliva sample at 20 min after the onset of the waiting room manipulation. Consistent with the cover story, they then completed a bogus face choice task (there was in fact no morphing program). Finally, as part of a phased debriefing process, subjects in the two confederate conditions completed surveys in which they rated their impressions of the confederates and the nature of their conversations with them (see below). Subjects in all conditions also completed various demographic and sexual history surveys. A final saliva sample was collected upon completion of the surveys at an average of 35.60 ± .44 min after the onset of the waiting room manipulation. Saliva was collected by passive drool into polypropylene vials with storage at −80 °C until assay. Experimental sessions were run at 1100, 1230, and 1400 h with young women serving as experimenters across all conditions.

Experiment 2

Subjects read a brief cover story that described the study as an investigation of the relationship between cortisol levels and speed of verbal processing. Sex of experimenter comprised the experimental manipulation, with half of the subjects randomly assigned to interact with one of four female experimenters (ages 20–21) and half assigned to interact with one of three male experimenters (ages 20–24). The female experimenters attempted to be flirtatious and signal interest

throughout the sessions; male experimenters simply attempted friendly conversation. After a baseline saliva sample, subjects completed a series of computer-based reaction time tasks designed to measure their implicit self-conceptions (e.g., the implicit association test; see Greenwald et al., 1998). Interspersed between these tasks were three four minute waiting periods during which the next computer program was ostensibly loading. Experimenters made conversation with the subjects during these waiting periods. During the first two waiting periods, experimenters also took measurements of subjects' wrists, elbows, and shoulders, ostensibly to correlate measurements with hormone levels, but in reality for the purpose of increasing the amount of behavioral interaction. At the conclusion of four computer tasks, a post-manipulation saliva sample was collected while the subjects completed background surveys. This sample was collected at an average of 44.83±.63 min after the first sample. Saliva was collected by passive drool into polypropylene vials with storage at −80 °C until assay. Because evidence for testosterone increases in Experiment 1 was found only in the 2 PM timeslot (see Results), start times in Experiment 2 were restricted to afternoon sessions at 1330, 1445, and 1600 h.

Rating instruments

Participants in Experiment 1 completed a survey assessing their reactions to the confederate and their conversation together. All items employed 7-point likert scales. Three items assessed subjects' impressions of confederates' physical attractiveness: beautiful, sexy, and cute (α=.87). Subjects also indicated how desirable they found their conversation partners as possible long-term and short-term romantic partners. A four-item scale assessed perceived positivity of the conversation, with subjects indicating how pleasant, stressful, exciting, and interesting they found the interaction (α=.69 after reverse scoring stressful). Single items assessed how much the subjects thought the confederates made eye contact and how much they believed the confederates liked them. Among a battery of background questions, of relevance to the current article were reports of whether subjects were in a relationship and their estimated lifetime number of sex partners. Only the background surveys were completed by subjects in Experiment 2, though a clerical error in the skip pattern in one survey entailed that data on number of sex partners were available only from men who reported currently being in a relationship.

Women confederates in both experiments completed a survey that assessed their impressions of the subjects' behaviors during the brief social interactions. A factor analysis of this same survey in the Roney et al. (2003) study revealed three distinct factors, and factor analyses in the present experiments produced similar factor structures. For comparability across studies, then, the factor scales from the Roney et al. (2003) study were employed as composite variables in the present report. The three factors and their highest loading items were as follows: a display factor ('tried to impress you,' 'showed off to you,' 'eager to talk about himself') characterized by items in which the subjects were projecting information about themselves and interpreted as a measure of courtship-like behavior, a polite interest factor ('listened carefully,' 'interested in hearing about you,' 'asked questions about you') characterized by items suggesting attempts to gather information about the women, and an arousal factor ('was speaking fast,' 'was excited,' 'was not bored'). Confederates' ratings were standardized within women (i.e. for each woman, ratings of each man were converted to *z*-scores) to account for differences in response scale usage before correlating ratings with hormone variables. Only the display scale scores were significantly correlated with changes in testosterone in the Roney et al. (2003) study and the present studies therefore hypothesized a replication of this finding.

The male and female experimenters in Experiment 2 also completed a survey assessing more global ratings of subjects' behaviors during the social interactions. This survey assessed perceptions of the subjects' confidence, extraversion, self-consciousness, masculinity, nervousness, and self-disclosure using 7-point likert scales. Ratings were standardized within experimenters. Exploratory analyses examined possible associations between these ratings and changes in hormone concentrations.

Hormonal analyses

Saliva samples for Experiment 1 were shipped on dry ice to the Endocrine Core Lab at the California Regional Primate Research Center, Davis, CA. Prior to assay, samples were centrifuged at 3000 rpm for 10 min to separate the aqueous component from mucins and other suspended particles. Salivary concentrations of testosterone were estimated in duplicate using commercial radioimmunoassay kits (Diagnostics Systems Laboratories, Webster, TX). The assay procedures were those outlined in Granger et al. (1999). The assay has a least detectable dose of 1.956 pg/ml. Intra- and inter-assay coefficients of variation (CV) were 6.06 and 4.21, respectively. Mean baseline testosterone concentration was 144.06±10.6 pg/ml and did not differ across experimental groups, $F(2,111)=.10$, $P=.90$. Salivary concentrations of cortisol were estimated in duplicate using commercial radioimmunoassay kits (Diagnostics Products Corp., Los Angeles, CA). Assay procedures were modified to accommodate overall lower levels of cortisol in human saliva relative to plasma as follows: (1) standards were diluted to concentrations ranging from 2.76 to 345 nmol/l; (2) sample volume was increased to 200 µl, and (3) incubation times were extended to 3 h. Serial dilution of samples indicates that the modified assay displays a linearity of .98 and a least detectable dose of 0.548 nmol/l. Intra- and inter-assay CVs were 4.79 and 2.31, respectively. Mean baseline cortisol concentration was 9.74±.55 nmol/l and did not differ across experimental conditions, $F(2,106)=.34$, $P=.72$.

Saliva samples for Experiment 2 were shipped on dry ice to the Biomarkers Core Lab at the Yerkes National Primate Research Center at Emory University, Atlanta, GA. Prior to assay, samples were centrifuged at 3000 rpm for 15 min to separate the aqueous component from mucins and other suspended particles. Salivary cortisol was estimated in duplicate using a commercially prepared EIA kit produced by Diagnostic Systems Laboratories (Webster, TX) using a sample volume of 25 µl. Sensitivity of the assay was .1–10 µg/dl. The intra-assay CV was 8.70, and the inter-assay CVs were 2.91 at .26 µg/dl and 4.39 at 1.94 µg/dl. Mean baseline cortisol concentration was .80±.02 µg/dl and did not differ across experimental groups, $t(90)=.84$, $P=.41$. Salivary testosterone concentrations were estimated in triplicate using a modified version of a Diagnostic Systems Laboratories kit, cat. # DSL-4100 (double antibody RIA). Standards were diluted for greater sensitivity to salivary testosterone, with detectable levels of 1–250 pg/ml. The intra- and inter-assay CVs were 3.41 and 7.49, respectively. Mean baseline testosterone concentration was 101.27±3.37 pg/ml and was greater in the male condition than in the female condition, $t(92)=2.16$, $P<.05$. This difference appears to be an artifact of an uneven distribution of saliva samples across assay batches as more samples from the male condition were in a batch that returned higher control values and differences between conditions were no longer significant when control values were entered as a covariate in an ANCOVA predicting baseline testosterone, $F(1,88)=1.66$, $P=.20$. Baseline differences could not affect within-subject changes in testosterone given that saliva samples from each individual were assayed within the same batches, but statistical analyses that controlled for baseline concentrations were performed in order to ensure that baseline differences were not driving differential testosterone responses across experimental conditions (see Results).

Statistical analyses

The hypothesized increase in testosterone after exposure to women was assessed in both experiments by testing the interaction between time of saliva samples (baseline vs. post-manipulation) and experimental condition (control vs. exposure) using mixed model analyses of variance (ANOVA) with time of saliva sample treated as a repeated measure. Similar tests were performed for exploratory analyses of changes in cortisol. Post hoc pairwise comparisons between individual cells were tested using paired *t*-tests when comparing only two means and Tukey's HSD test (α=.05) when comparing more than two means. Analysis of covariance (ANCOVA) was employed in order to test the effect of baseline testosterone concentrations on change scores in Experiment 2. On the recommendation of a reviewer, categorical measures of the number of subjects who exhibited hormonal increases were also computed; we used a 20% increase over baseline as the criterion for both ease of interpretation and because this value was in most cases over three times the intra-assay CV. Associations between number of subjects exhibiting increases and experimental condition were tested with chi-square statistics. Correlations between subjects' and confederates' ratings of social interactions with hormonal changes (computed as difference scores) were assessed using Pearson's *r* or Spearman's ρ depending on whether the correlated variables were normally distributed. Descriptive statistics appear as mean±SEM. Reported significance levels are all two-tailed.

For each time-point at which saliva was collected, hormone concentrations more than three standard deviations from the respective means were excluded from data analyses. There was one such outlier for testosterone in Experiment 1 and three outliers each for testosterone and cortisol in Experiment 2 (no statistical conclusions were changed by inclusion of the outliers). In addition to these exclusions, insufficient saliva for assay reduced the final sample sizes per time-point to the following: for Experiment 1, $n=113$ for testosterone and $n=110$ for cortisol; for Experiment 2, $n=94$ for testosterone and $n=89$ for cortisol. Hormone concentrations at each time-point were normally distributed after log transformation with the exception of testosterone in Experiment 2 for which a square root transformation was applied to achieve normality. Raw data appear in figures for presentation purposes but statistical tests were performed on the transformed data.

Results

Experiment 1

Testosterone responses

The pattern of testosterone concentrations across saliva samples was very similar across the neutral and flirtatious conditions (Ps>.50 for contrasts between the two groups) and the two conditions were therefore collapsed into a single condition in order to increase the power of subsequent analyses. The effect of social interactions with women on men's testosterone concentrations was then tested with a 2 (experimental group: alone vs. female exposure)×3 (saliva sample: baseline, post-20 min, post-35 min)×3 (timeslot: 1100, 1230, 1400) mixed model ANOVA, with saliva sample a repeated measure. The Huynh–Feldt correction was applied since the sphericity assumption was not met. The hypothesized interaction between experimental group and saliva sample was not confirmed, $F(1.93,206.91)=.58$, $P=.56$ and only the three way interaction between group, saliva sample, and timeslot was significant, $F(3.87,206.91)=4.15$, $P<.01$. This interaction is depicted graphically in Fig. 1. It can be seen that the hypothesized pattern was found only in the 2 PM timeslot and two way interactions between experimental group and saliva sample tested separately for each timeslot confirmed a significant effect only at 2 PM, $F(2,74)=5.69$, $P<.01$ (this interaction was still significant after exclusion of an outlier specific to the 2 PM timeslot, $F(2,72)=3.68$, $P<.05$; Fig. 1 excludes the outlier). The interaction at 2 PM was characterized by a nonsignificant decrease in testosterone across saliva samples in the alone condition versus a significant elevation above baseline at post-35 min among men exposed to women. Across all timeslots, 25% (19/76) of men who spoke with a woman exhibited testosterone increases at least 20% above baseline at post-35 min versus 27% (10/37) of men who sat alone, $\chi^2(1, N=113)=0.05$, $P=.82$; the percentage of subjects exhibiting at least a 20% increase likewise did not differ significantly across conditions within the individual timeslots (Ps>.10). In summary, the repeated measures analyses revealed that speaking with a woman was associated with testosterone increases only among men tested at 14:00 h.

Cortisol responses

Cortisol patterns were virtually identical across the neutral and flirtatious conditions (Ps>.60) and there were no main effects or interaction effects involving timeslot; as such, data analyses were collapsed across these variables. The effect of social interactions on cortisol reactivity was therefore tested with a 2 (experimental group: alone vs. female exposure)×3 (saliva sample: baseline, post-20 min, post-35 min) mixed model ANOVA, with saliva sample a repeated measure. The Huynh–Feldt correction was applied due to violation of the sphericity assumption. The interaction between experimental group and saliva sample was significant, $F(1.32,139.40)=6.47$, $P<.01$. Fig. 2 demonstrates that this interaction was driven by a progressive decline in cortisol from baseline (significant at post-35 min) in the alone condition versus a significant increase at post-20 min followed by a return to baseline among men exposed to women. Forty-two percent (31/74) of men who spoke with a woman exhibited cortisol increases at least 20% above baseline at post-20 min versus only 22% (8/36) of men in the alone condition, $\chi^2(1, N=110)=4.09$, $P<.05$.

Survey responses

On average, the women confederates were rated as moderately attractive by the male participants: mean=4.88±.13 for the physical attractiveness composite variable, mean=3.54±.18 for long-term mate attractiveness, mean=4.09±.19 for short-term mate attractiveness. Evidence for the effectiveness of the neutral vs. flirtatious behavior manipulation was mixed: perceived positivity of the conversation was higher in the flirtatious condition (mean=5.51±.09) than in the neutral condition

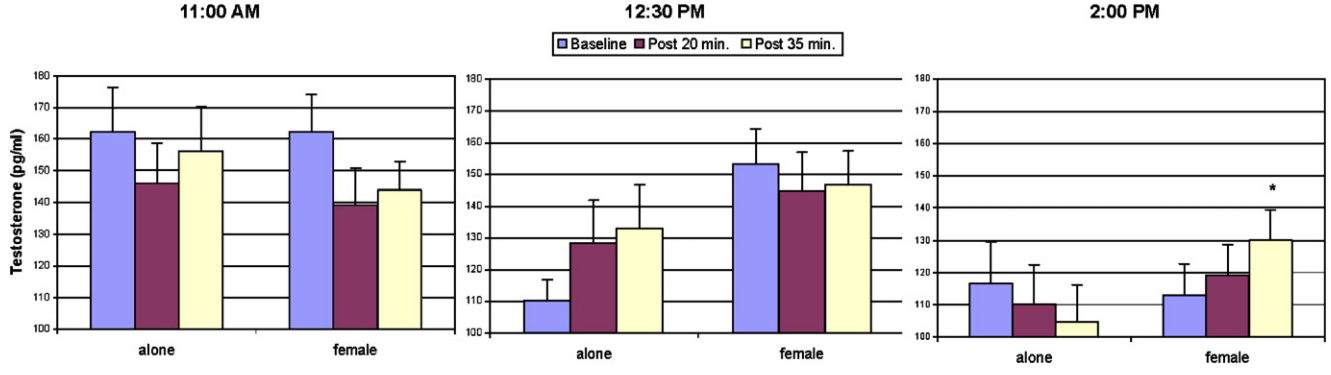

Fig. 1. Salivary testosterone concentrations (measured at baseline and at 20 and 35 min after the onset of the waiting room manipulation) depicted by experimental condition and time of day. Values are mean±SEM. *$P<.05$ for the within-subject pairwise contrast with baseline testosterone.

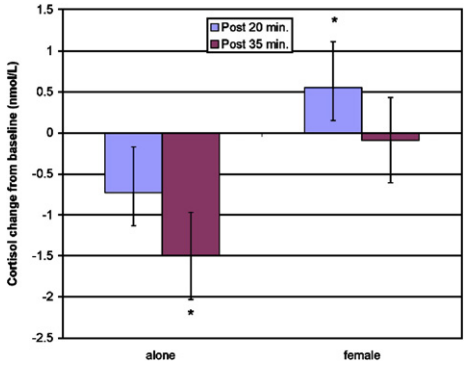

Fig. 2. Baseline cortisol concentrations subtracted from concentrations measured at 20 min (Post 20 min) and 35 min (Post 35 min) after the onset of the waiting room manipulation and depicted by experimental condition. Values are mean±SEM. *P<.05 for the within-subject pairwise contrast with baseline cortisol.

(mean=5.14±.14), $t(74)=2.19$, $P<.05$ but men in the flirtatious condition (mean=4.97±.14) did not perceive that the confederates liked them more than did men in the neutral condition (mean=4.68±.13), $t(74)=1.55$, $P=.13$.

There were no significant correlations between changes in either cortisol or testosterone from baseline (at either post-20 or post-35 min) and participants' background characteristics (relationship status, sexual experience). Likewise, hormonal changes were uncorrelated with subjects' ratings of the conversations/confederates, with the exception of one marginal trend: subjects' ratings of how much the confederates liked them were positively associated with changes in cortisol from baseline to 20 min, $\rho(73)=.22$, $P<.06$. Finally, the confederates' ratings of subjects' display behaviors and polite interest were not correlated with changes in hormone concentrations; confederates' ratings of subjects' arousal were negatively correlated with changes in cortisol from baseline at both 20 min, $\rho(73)=-.25$, $P<.05$ and 35 min, $\rho(71)=-.23$, $P<.05$.

Experiment 2

Testosterone responses

The effect of interacting with a woman vs. a man on men's testosterone concentrations was tested with a 2 (experimental group: male experimenter vs. female experimenter)×2 (saliva sample: baseline vs. post-test) mixed model ANOVA, with saliva sample a repeated measure. The hypothesized interaction was confirmed, $F(1,92)=7.40$, $P<.01$. As predicted, testosterone concentrations were significantly elevated above baseline in the female experimenter condition, paired-$t(45)=3.29$, $P<.01$ (baseline mean=93.98±4.89 pg/ml; post-test mean=103.10±5.59 pg/ml) but were unchanged in the male experimenter condition, paired-$t(47)=.14$, $P=.89$ (baseline mean=108.25±4.48 pg/ml; post-test mean=107.89±4.63 pg/ml). The effect of experimental group on testosterone responses remained significant when baseline testosterone was entered as a covariate in an ANCOVA predicting testosterone change scores, $F(1,91)=4.88$, $P<.05$. Unlike Experiment 1, timeslot (13:30, 14:45, 16:00 h) did not significantly interact with the other two factors when tested in a 2×2×3 mixed model ANOVA (Ps>.40). Finally, 28% (13/46) of men in the female condition experienced testosterone increases greater than 20% above baseline as opposed to 10% (5/48) of subjects in the male condition, $\chi^2(1, N=94)=4.83$, $P<.05$.

Cortisol responses

The effect of sex of experimenter on cortisol responses was also tested with a 2 (experimental group: male experimenter vs. female experimenter)×2 (saliva sample: baseline vs. post-test) mixed model ANOVA, with saliva sample a repeated measure. The interaction between experimental group and saliva sample was significant, $F(1,87)=6.15$, $P<.05$. Within conditions, cortisol concentrations exhibited a nonsignificant increase above baseline in the female condition, paired-$t(41)=1.18$, $P=.24$ (baseline mean=0.82±.04 μg/dl; post-test mean=0.88±.04 μg/dl) and a significant decline from baseline in the male condition, paired-$t(46)=2.49$, $P<.05$ (baseline mean=0.78±.03 μg/dl; post-test mean=0.70±.03 μg/dl). Consistent with the testosterone data, time of day did not significantly interact with the other factors (Ps>.30). Thirty-eight percent (16/42) of men in the female condition experienced cortisol increases at least 20% above baseline versus 11% (5/47) of men in the male condition, $\chi^2(1, N=89)=9.28$, $P<.01$.

Correlations between hormonal measures

Significant effects of the experimental manipulation on both testosterone and cortisol responses raise the possibility that these were correlated reactions. Change in testosterone was in fact significantly correlated with change in cortisol across the full sample, $r(89)=.25$, $P<.05$. However, this correlation was driven by the male experimenter condition, $r(47)=.31$, $P<.05$ and was not found in the female condition, $r(42)=.14$, $P=.37$.

Survey responses

Although subjects in Experiment 2 did not rate the women experimenters for attractiveness, three out of the four women were also confederates in Experiment 1. Aggregated ratings of these three confederates in Experiment 1 were as follows: mean=5.10±.20 for physical attractiveness, mean=3.70±.24 for long-term mate attractiveness, and mean=4.45±.23 for short-term mate attractiveness. As was the case in Experiment 1, subjects' relationship status was not significantly associated with changes in hormone concentrations. The effects of sexual experience on hormonal responses could not be tested due to the clerical error that entailed that this question was asked only of men currently in relationships as almost all of these men reported having sexual experience. Number of sex partners did not correlate with hormone changes within this same subsample of participants.

The women experimenters' ratings of men's display behaviors were marginally correlated with changes in testosterone concentrations from baseline, $\rho(46)=.26$, $P=.08$. The polite interest and arousal scales did not correlate with changes in testosterone, nor did any of the three behavioral scales correlate significantly with changes in cortisol. Table 1 presents

Table 1
Correlations between absolute changes in hormone concentrations and experimenters' ratings of subjects' behaviors

	Confidence	Extraversion	Self-consciousness	Masculinity	Nervousness	Self-disclosure
Female experimenter						
Change testosterone	.24	.38*	−.17	−.03	.08	.35*
Change cortisol	.07	−.12	.13	−.09	−.06	.16
Male experimenter						
Change testosterone	.16	−.05	−.25	.31*	−.05	−.24
Change cortisol	−.11	−.24	.04	−.02	.03	−.30

Note. Pearson correlation coefficients appear within the cells; although some variables were not normally distributed, results were very similar when computed with rank-order correlations.
* $P<.05$.

correlations between changes in endocrine variables and the more global ratings of subjects' behaviors that were completed by both the male and female experimenters. It can be seen that two variables that are conceptually related to the display scale – extraversion and self-disclosure – were both positively correlated with changes in testosterone in the female condition. Only ratings of subjects' masculinity were correlated with changes in testosterone in the male condition. Finally, none of the rating variables in either condition was significantly correlated with changes in cortisol.

Discussion

The present experiments represent the most extensive tests to date in humans of possible hormonal responses to social interactions with members of the opposite sex. The results provide evidence that men are more likely to exhibit increases in testosterone after interactions with women than after sitting alone or interacting with other men, though positive effects were restricted to subjects tested during the afternoon. Not all men who interacted with women experienced testosterone increases, though, and correlational analyses in Experiment 2 revealed that men who were rated more extraverted and self-disclosing during interactions with confederates tended to show the most positive changes in testosterone (see Roney et al., 2003 for a similar finding). These patterns suggest possible coordination between behavioral and hormonal responses to potential mates, though much more evidence is needed before accepting such a conclusion. The present studies also appear to provide the first evidence of reactive cortisol increases in men after social interactions with women. Changes in cortisol were generally uncorrelated with ratings of men's behavior (a negative correlation between change in cortisol and women's ratings of men's arousal in Experiment 1 did not replicate in Experiment 2) and it is thus unclear whether cortisol responses may be associated with particular behavioral patterns.

The restriction of positive effects to the 2 PM timeslot in Experiment 1 was not predicted a priori, but the results of Experiment 2 confirmed reactive testosterone increases when all subjects were tested in the afternoon. Men's testosterone exhibits a strong circadian pattern in which concentrations are highest near waking and decline across the day (Dabbs, 1990; Gupta et al., 2000) and the endogenous tendency for steep decline during morning hours may impede the ability to detect reactive changes during those times. Consistent with this, previous studies have reported stronger correlations between testosterone and behavioral variables when testosterone was measured in the afternoon vs. morning (e.g., Book et al., 2001; Gray et al., 2004), and one study of rhesus macaques found testosterone increases among males given access to females at 14:00 h but not among males given access at 10:00 h (Herndon et al., 1981). Time of day may thus be an important moderator of hormonal reactions to mating stimuli among primates.

Although the function of rapid testosterone increases is not entirely clear, the broader context provided by previous human research suggests interesting possibilities. Various studies have reported positive correlations between testosterone and personality characteristics such as disinhibition, self-confidence, assertiveness, extraversion, and sensation-seeking (Aluja and Torrubia, 2004; Dabbs et al., 1991; Daitzman et al., 1978; Daitzman and Zuckerman, 1980; Gerra et al., 1999). Likewise, studies have suggested that higher testosterone individuals are generally more focused on maintaining personal power (Schultheiss et al., 1999), status (Josephs et al., 2003), and dominance (for reviews, see Archer, 2006; Booth et al., 2006; Mazur and Booth, 1998), and other research provides evidence that such characteristics may enhance men's mate attractiveness (e.g., Sadalla et al., 1987). Testosterone increases after interactions with potential mates might therefore promote more assertive and status-seeking behaviors that could improve prospects for successful mate attraction. Such effects could be mediated through relatively rapid effects of testosterone on risk-aversion, furthermore, as studies in rodents have shown anxiolytic effects of exogenous testosterone within 30 min of injection (Aikey et al., 2002) and injection studies in humans have found reduced fear responses within a few hours of testosterone administration (Hermans et al., 2006; van Honk et al., 2005). Future research could more directly address these ideas by testing whether testosterone reactions to interactions with women are associated specifically with changes in behavioral and/or psychological measures of risk-aversion, assertiveness, and status-seeking.

The robust effects of the experimental manipulations on men's cortisol concentrations suggest potentially novel interpretations of socially mediated cortisol reactivity. Cortisol increases have been widely interpreted as markers of stress

reactions in response to threatening stimuli (for a review, see Dickerson and Kemeny, 2004). It is not clear that the present results should be assimilated to such an interpretation, though, as men's changes in cortisol from baseline were uncorrelated with their ratings of the stressfulness of their conversations with women but were positively correlated with their ratings of how much the women confederates liked them (Experiment 1). This at least presents the possibility that the observed cortisol increases were triggered by interpretations of the interactions as positively valenced social opportunities rather than as negatively valenced social threats. In principle, cortisol-mediated energy mobilization may be just as functional for facilitating forms of courtship effort as it is in facilitating responses to threatening events. In any case, the fact that interactions with women produced clear effects on men's cortisol concentrations in both experiments suggests that adrenal activation may be a basic but heretofore unknown component of men's reactions to encounters with potential mates.

Effects of the experimental manipulation on both testosterone and cortisol responses in Experiment 2 raise the possibility that common mechanisms could have generated both outcomes. Adrenal activation could directly produce cortisol increases, for instance, but also lead to testosterone elevations via the peripheral conversion of adrenal androgens. Although testosterone and cortisol responses were correlated in the male exposure condition of Experiment 2 (perhaps reflecting circadian decline in both hormones), there was no such correlation in the female exposure condition, thus suggesting that these are dissociable reactions. Other research casts doubt on an adrenal mechanism causing testosterone changes, furthermore, as ACTH injections do not typically result in testosterone elevations in human males (Iannotta, 1987; Kicman et al., 1999; Veglio et al., 1988; cf. Reinberg et al., 1981). If these are in fact dissociable responses, then questions arise as to what predicts which responses individuals will exhibit in specific circumstances. Future research could address such questions of eliciting conditions, answers to which could in turn shed light on the potential functions of the two types of hormonal responses.

In summary, the present studies add to the evidence that encounters with women can produce rapid endocrine responses in young men. The primary goal of this research was to test the existence of such responses, but there are clearly many unanswered questions and broad opportunities for new avenues of research. It is still unclear, for instance, precisely what stimulus characteristics tend to trigger these reactions. Experiment 1 failed to find evidence that variations in women's proceptive behaviors would differentially affect hormonal responses, though the effectiveness of this manipulation was unclear and future research could attempt either stronger behavioral manipulations or systematic variation of the perceived physical attractiveness of confederates. Likewise, there are potentially interesting questions regarding individual difference variables that may predict which men tend to exhibit hormonal responses—we found no evidence that relationship status made a difference, for example, but a host of other personality and experiential variables could be tested. Finally, as discussed above, further investigations of the behavioral correlates of changes in hormones will be crucial for testing ideas about the functions of these effects. These unanswered questions notwithstanding, the similarities between the hormonal responses reported here and those seen in many nonhuman species support the possibility that phylogenetically conserved brain mechanisms may play important roles in the regulation of men's reactions to social encounters with potential mates.

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