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ABSTRACT

Despite progress in understanding the social neuroendocrinology of close relationship processes, most work has focused on negative experiences, such as relationship conflict or stress. As a result, much less is known about the neuroendocrine implications of positive, emotionally intimate relationship experiences. In the current study, we randomly assigned 105 dating or married couples to a 30-minute semi-structured discussion task that was designed to elicit either high or low levels of closeness. Participants provided pre- and post-task saliva samples (to assess cortisol and testosterone) and post-task reports of self-disclosure, closeness, attraction, positive and negative affect, and stress. Participants found the discussion conditions comparably positive and enjoyable, but those in the high-closeness condition reported that they disclosed marginally more and felt marginally closer to their partners than those in the low-closeness condition. Participants also showed larger increases in cortisol and testosterone during the high (versus low) closeness discussion, and self-reported disclosure mediated these increases in cortisol and testosterone. Self-reported closeness and other theoretically plausible mediators, such as sexual attraction and excitement, did not mediate changes in either hormone. Taken together, the current findings contribute to our understanding of neuroendocrine changes associated with emotionally intimate relationship experiences. We consider possible explanations for the hormone changes we observed and offer directions for future research on the neuroendocrine implications of close relationship experiences.

1. Introduction

Closeness is a central feature of fulfilling intimate relationships across the lifespan (Mashek and Aron, 2004). People whose romantic relationships are characterized by greater closeness—feelings of connectedness, shared understanding, self-disclosure, and responsiveness—generally report higher relationship satisfaction and lower likelihood of break-up or divorce (e.g., Berscheid et al., 1989; Weinberger et al., 2008). Closeness may also confer benefits in other important life domains, including reduced risk of mortality (Brown et al., 2003). The links between closeness and these beneficial inter- and intrapersonal outcomes are not yet fully understood; however, physiological changes that occur during intimate interactions may provide one potential pathway. To begin to understand these processes, research is needed to assess how people physiologically respond to close relationship experiences. In the current study, we examine two steroid hormones, cortisol and testosterone, that have been linked with close relationship processes and thus may be sensitive to experiences that elicit feelings of closeness (e.g., Edelstein and Chin, 2018).

In brief, close relationship experiences that elicit feelings of nurturance are thought to lead to *decreases* in cortisol and testosterone, whereas close relationship experiences that elicit feelings of excitement or sexual attraction are thought to lead to *increases* in these hormones. Cortisol is considered a "stress" hormone that is particularly responsive to challenging interpersonal interactions and threat of evaluation by others (Dickerson and Kemeny, 2004). People in established romantic relationships tend to have lower levels of cortisol compared to people who are single or in the early stages of a romantic relationship (Maestripieri et al., 2013; Mercado and Hibel, 2017), suggesting that cortisol may decrease as a function of being in a committed relationship. Cortisol also tends to decrease in response to supportive interactions with close others (Maestripieri et al., 2013; Malina et al., 2019), further suggesting that nurturance and closeness lead to a down regulation of cortisol. In contrast, cortisol tends to increase in response to interactions with attractive potential partners and as a function of thinking about a partner (real or imagined; López et al., 2009; Roney et al., 2007). Taken together, these findings suggest that cortisol may increase in response to the (potentially exciting) early stages of a relationship but decrease

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when relationships are more established and/or supportive.

Similar to cortisol, people who are single have higher testosterone compared to those in established romantic relationships (van Anders and Watson, 2006). Among those in committed relationships, lower testosterone is also associated with higher romantic relationship quality for both partners (Edelstein et al., 2014). These findings suggest that higher testosterone may be beneficial for romantic relationship initiation, whereas lower testosterone may be beneficial for maintaining ongoing relationships (Roney and Gettler, 2015). In a similar vein, testosterone is theorized to decrease in response to more nurturant and caregiving close relationship experiences (van Anders et al., 2011; Wingfield et al., 1990), but to increase in response to experiences with (potential) partners that involve excitement or sexual intimacy (Roney and Gettler, 2015; Roney et al., 2007; van Anders et al., 2011).

The overarching goal of the current study was to examine the neuroendocrine implications of closeness by assessing changes in cortisol and testosterone following a closeness-inducing interaction between romantic partners. We used a procedure designed to experimentally manipulate closeness in the lab, known as the "fast-friends" task (Aron et al., 1997). This discussion task consists of 36 questions that progressively increase in levels of self-disclosure compared to a "small-talk" control discussion that is designed to be comparably positive, and similar in structure, but to elicit less self-disclosure. This task has been used with both unacquainted dyads (e.g., Ketay et al., 2017; Smith et al., 2009; Sprecher, 2021) and romantic couples (e.g., Slatcher, 2010; Stanton et al., 2017; Welker et al., 2014). In general, compared to control conditions, the fast-friends task tends to increase closeness between unacquainted individuals (Ketay et al., 2017; Sprecher, 2021) and enhance relationship functioning (e.g., closeness, passionate love) between those in already established relationships (Slatcher, 2010; Stanton et al., 2017; Welker et al., 2014). These psychological changes are thought to be driven by greater self-disclosure in the fast-friends versus control conditions (Aron et al., 1997).

To our knowledge, only a handful of studies have investigated neuroendocrine changes as a function of the fast-friends task (Ketay et al., 2017; Page-Gould et al., 2008; Smith et al., 2009). In one notable exception, Ketay et al. (2017) measured cortisol and testosterone changes in unacquainted same-sex dyads who were randomly assigned to a high-closeness (fast-friends) or a low-closeness control condition in which participants took turns giving directions, playing word games, and reading short passages. Participants showed significant pre- to post-task decreases in cortisol and testosterone in the control condition, and significant pre- to post-task decreases in cortisol in the high-closeness condition; there were no significant changes in testosterone in the high-closeness condition. Because hormone levels tend to decline over the course of the day (Dabbs Jr, 1990), the null effects for testosterone in the high-closeness condition could reflect an overall *increase* in testosterone, consistent with the idea that the task may have elicited feelings of excitement. Together, these findings point to normative decreases in cortisol regardless of the closeness manipulation and decreases in testosterone only in the low-closeness control condition.

It is important to note, however, that the low-closeness control task used by Ketay et al. (2017) differed in structure and content from their high-closeness (fast-friends) task, in that it involved not only minimally intimate conversation but also different kinds of conversation (e.g., playing word games versus taking turns asking and answering questions). Thus, it is difficult to attribute any hormone changes (or lack thereof) to one specific difference between the tasks, such as self-disclosure per se. A direct comparison of the fast-friends and small-talk tasks would provide greater insight into the potential mechanisms underlying changes in hormones as a function of the closeness induction specifically.

It is also unclear, based on this initial study of unacquainted dyads, whether similar hormone changes would be observed among those in romantic relationships. Insofar as people in romantic relationships experience closeness as more nurturant, they might be more likely to show cortisol and testosterone *decreases*; however, insofar as they experience closeness as more exciting or sexual, they might be more likely to show cortisol and testosterone increases (van Anders et al., 2013). To this end, we also assessed psychological outcomes during the fast-friends versus small-talk tasks. In general, we expected that participants would disclose more personal information, feel closer to their partner, and feel more attracted to their partner during the fast-friends versus small-talk task. We focused on these variables as potential mediators of hormone changes. We did not expect participants to report any differences in positive affect, negative affect, or stress across tasks. Further, we expected that, regardless of condition, insofar as people experienced the interaction task as nurturant, they would show decreases in cortisol and/or testosterone; insofar as they experienced the task as exciting or sexual, we expected that they would show increases in cortisol and/or testosterone.

2. Materials and methods

2.1. Participants

Our sample included 105 couples (90 heterosexual couples, 11 lesbian couples, and four gay male couples; a total of 112 women and 98 men) who responded to advertisements on the University of Michigan campus, in the community, and online (e.g., Facebook). To be eligible, participants had to be between 18 and 40 years old (because of age-related changes in hormones; Leifke et al., 2000), speak and read English fluently, and be in a romantic relationship for at least three months. Smokers, people taking any hormonal medication (e.g., hormonal birth control), and pregnant women were not eligible. Of these couples, we excluded 13 women who reported being on hormonal medication at the time of the study (despite assenting to our eligibility criteria during our pre-screening process). We were also missing testosterone data for one participant and excluded cortisol data for three participants because they had unacceptably high measurement error (above 15% coefficient of variation). In all these cases, we removed participants who were missing cortisol or testosterone data prior to analyses but kept their partner's data. Thus, in total we had cortisol data for 194 people and testosterone data for 196 people. We were also missing self-report data for one female participant due to technical difficulties.

Women in the current sample ranged in age from 18 to 40 years, $M = 23.50$, $SD = 4.79$; men ranged in age from 18 to 40 years, $M = 24.03$, $SD = 5.04$. Participants self-reported their race/ethnicity as 66% Caucasian, 15% Asian, 7% African-American, 4% multi/bi-racial, 3% Hispanic/Latino, 3% Indian/Pakistani, 1% American-Indian, and 1% other. Twenty percent of couples were married, 65% percent of couples were living together, and 7% of couples had children. Relationship length ranged from three months to 19.5 years, $M = 33.32$ months, $SD = 40.19$ months.

2.2. Procedure

All procedures were reviewed and approved by the University of Michigan Institutional Review Board. Couples who were interested in the study followed a link to an online survey, which they were instructed to complete independently from their partner. Informed consent was obtained during this initial online survey and participants were told they could withdraw from the study at any time without penalty. After providing informed consent and confirming eligibility, participants completed a battery of personality questionnaires (e.g., Big Five), which were collected for other purposes and thus not included in the present report (data on cortisol, testosterone, and the Big Five are published in Sundin et al., 2021). Once both partners completed the initial survey, they were invited to schedule a lab session together.

In the lab, couples were seated in armchairs located in a section of our lab designed to resemble a living room. A research assistant

randomly assigned them to one of two discussion conditions, modeled closely after the fast-friends and small-talk tasks developed by Aron et al. (1997). Couples in both conditions took turns answering 36 questions, which were divided into three sets of 12 questions. They were allotted 10 min per set for a total 30-minute discussion. Couples in the *high-closeness* (fast-friends) discussion condition answered questions that were designed such that levels of self-disclosure progressively increased within and between sets. For example, a question at the beginning of the task was, "Given the choice of anyone in the world, whom would you want as a dinner guest?" and a question later in the task was, "What does love and affection mean to you?".

Couples in the *low-closeness* (small-talk) discussion condition answered questions that were designed to be engaging but involve minimal focus on the partner or relationship and elicit minimal self-disclosure (Aron et al., 1997). For example, a question at the beginning of the task was, "When did you last walk for an hour?" and a question later in the task was, "Do you subscribe to any magazines?" After the discussion task, participants completed a post-task survey and then were debriefed and compensated $15 USD each.

2.3. Measures

Once couples completed the discussion task, they returned to the computers to complete a post-task survey, which included two single-item measures that assessed their ***current state and feelings*** (i.e., "How attracted are you to your partner right now?" and "How stressed do you feel right now?") and two single-item measures that assessed their ***feelings about the task*** (i.e., "How much would you like to do the task again?" and "How enjoyable did you find this activity?") on a scale of 1 (*not at all*) to 7 (*extremely*).

Closeness was measured using the single-item Inclusion of the Other in the Self Scale (IOS; Aron et al., 1997). Participants selected one out of seven pairs of circles labeled *Self* and *Other* that overlap to various degrees, creating a 7-point interval scale, that best described their relationship.

Positive and negative affect were assessed using the Positive and Negative Affect Scale (PANAS; Watson et al., 1988), a 20-item measure of affect with two-subscales: positive (10 items; $\alpha = 0.86$) and negative (10 items; $\alpha = 0.76$) affect. Participants were asked to rate the extent to which they presently felt each emotion (e.g., "Excited", "Upset") on a scale of 1 (*not at all*) to 5 (*extremely*).

Self-disclosure was assessed with three questions ($\alpha = 0.80$, used by Stanton et al., 2017) that measured how much participants disclosed[1] personal information during the discussion (i.e., "I disclosed information about my innermost self" and "I disclosed personally important experiences and events" and "I openly expressed my feelings about my partner") on a scale ranging from 1 (*not at all*) to 9 (*very much*).

2.4. Salivary cortisol and testosterone collection and assessment

Because hormone levels are most stable in the afternoon to evening hours (Schultheiss and Stanton, 2009), all couples had their lab session scheduled between 12:00 PM to 8:00 PM to control for circadian changes in hormones. Participants were instructed to refrain from eating, drinking (except for water), chewing gum, or brushing their teeth for one hour prior to the scheduled session. Approximately 10 min after arrival, couples were instructed to provide their first (pre-task) saliva sample.

Participants then provided their second (post-task) saliva samples 10 min after the end of the discussion.[2] Steroid hormones such as cortisol and testosterone generally peak 15 min after the onset of an eliciting stimulus (Schultheiss and Stanton, 2009), so we used this time to capture the peak of the closeness-inducing manipulation (i.e., 25 min into the discussion). This time frame is similar to that used in prior research with both cortisol and testosterone (Edelstein et al., 2019; Ketay et al., 2017).

We collected saliva samples in 50 mL polypropylene tubes (Fisherbrand™ Nonsterile Polystyrene Culture Tubes) and instructed participants to fill the tube to the marked line (1.5 mL) by passively drooling into the tube through a straw. All samples were frozen at −20 °C until assayed, and the mean duration of sample storage at −20 °C before assays was 244 days for cortisol and 88 days for testosterone. Samples were analyzed by enzyme immunoassay using a commercial kit from Salimetrics Incorporated. Water-based dilutions of all standards and controls were prepared to determine salivary cortisol and testosterone concentrations. Samples were assayed in duplicate and the mean levels for each sample were utilized for analysis. Controls were used to assess assay reliability. The inter-assay coefficient of variation (CV) for low and high controls were 12.43% and 11.26%, respectively, for cortisol, and 17.50% and 11.99%, respectively, for testosterone. The intra-assay CV was 6.63% for cortisol and 6.87% for testosterone. Both inter- and intra-assay CVs are comparable to similar studies conducted in our lab and are in the normal range for published hormone studies (Edelstein et al., 2019; Ketay et al., 2017). Analytic sensitivity (B_0 – 2 SD) for the two hormonal assays is < 0.007 ug/dL for cortisol and 1 pg/mL for testosterone.

To maximize the use of all available data, hormone values that were larger than three standard deviations above or below the mean for each gender were winsorized (i.e., replaced with values corresponding to three standard deviations above or below the mean for that particular variable; Edelstein et al., 2014). Six people with cortisol levels greater than three standard deviations above the mean for their gender, and four people with testosterone values larger than three standard deviations above the mean for their gender were replaced using this approach.

To examine changes in hormones as a function of the discussion task, we computed percent change scores (i.e., ((Time 2 – Time 1)/Time 1) x 100), a commonly used method of assessing short-term hormone changes (van Anders et al., 2012). Percent change scores account for baseline differences in hormone levels and are generally preferred to difference scores, which can be difficult to interpret when there are large individual and/or gender differences in baseline hormone levels (van Anders et al., 2009). Testosterone change was normally distributed but cortisol change was positively skewed, kurtosis = 4.37, skewness = 28.14, so we log transformed the cortisol variable for subsequent analyses.

2.5. Statistical analyses

The Statistical Package for the Social Sciences (SPSS, version 27) was

[1] Our first 43 couples inadvertently received disclosure items focused on disclosure to their partners in the past 10 days, as opposed to during the task specifically. For the remaining 62 couples, we added items assessing how much they disclosed during the task. Thus, we are missing data from 43 couples (86 individuals) on this variable. People who did and did not self-report disclosure during the task did not differ on any of our key variables, including cortisol change, testosterone change, or post-task closeness (IOS), $t_{\text{cortisol change}}(192) = -0.38$, $p = 0.70$, $d = 0.05$; $t_{\text{testosterone change}}(194) = -0.31$, $p = 0.75$, $d = 0.04$; $t_{\text{post-task closeness}}(194) = 1.65$, $p = 0.10$, $d = 0.24$.

[2] We initially ran 34 couples and collected their second saliva sample after they completed the post-task survey. However, because some people took slightly longer than others to complete the post-task survey, we collected the second saliva sample for the remaining 71 couples at 10 min post-discussion, regardless of when they completed their survey. Post-task cortisol and testosterone as well as cortisol and testosterone change were not significantly different between people who provided their saliva after completing the post-task survey versus those who provided saliva at 10 min post-discussion, $t_{\text{post-task cortisol}}(194) = -0.07$, $p = 0.94$, $d = 0.01$; $t_{\text{post-task testosterone}}(194) = -1.33$, $p = 0.19$, $d = 0.21$; respectively; $t_{\text{cortisol change}}(192) = 0.97$, $p = 0.33$, $d = 0.15$; $t_{\text{testosterone change}}(194) = 0.65$, $p = 0.51$, $d = 0.10$.

used to conduct all analyses. For our preliminary analyses, mean differences were assessed using independent samples *t*-tests (two-tailed) and associations were assessed using bivariate correlations. For our main analyses, we used multilevel modeling (MLM) procedures recommended for dyadic data to account for the statistical interdependence between partners (i.e., SPSS Mixed; Kenny et al., 2006); we report unstandardized beta coefficients for these analyses. Importantly, MLM allows for inclusion of all participants when some data are missing (e.g., those whose hormone data were excluded prior to analysis; Singer and Willett, 2003).

Given that our sample includes both opposite- and same-sex couples,[3] we employed the factorial method, an extension of the actor-partner interdependence model (APIM) by West et al. (2008) for assessing three different types of dyads: male-female, male-male, and female-female. This method provides separate main effects for actor gender (i.e., women compared to men) and partner gender (i.e., people partnered with women compared to people partnered with men).

For all models, we included effect-coded condition (−1 = low-closeness discussion, 1 = high-closeness discussion), actor gender (−1 = women, 1 = men), and partner gender (−1 = women, 1 = men) as predictor variables. We also included the two-way interactions between actor gender and condition and between partner gender and condition. The interaction of actor and partner gender in this model tests whether the actor gender effects depend on whether one is in a relationship with a same- or opposite-sex partner (i.e., whether the couple's gender make up, or sexual orientation of the couple, moderated the outcome variables). However, our results were unchanged when we included the interaction between actor and partner gender, so we excluded this interaction variable from further models for simplicity. Additionally, because all four of our gay male couples were (by chance) randomly assigned to the low-closeness condition, we could not examine whether any effects of the manipulation differed for same- versus opposite-sex couples, a point we return to in the discussion section.

Outcomes included post-task self-reports for psychological variables[4] and percent changes in cortisol and testosterone. To decompose two-way interactions involving actor or partner gender, we used the two-intercept approach, which tests the simple slopes for each level of the differentiating variable (Kenny et al., 2006) and allowed us to determine whether the effect of our dependent variable was stronger for women or men (or people partnered with women versus men). Results for our models were also unchanged when we included time of day, time elapsed since waking, weight, or relationship length; none of the main effects for the other variables were statistically significant (p's > 0.11), so we excluded them from further models for simplicity.

3. Results

3.1. Preliminary analyses

We report mean pre- and post-task cortisol and testosterone for women and men in Table 1. Pre- and post-task cortisol was highly correlated for women, $r_{women} = 0.59$, $p < 0.01$, and men, $r_{men} = 0.67$, $p < 0.01$; and pre- and post-task testosterone were also highly correlated for women, $r_{women} = 0.83$, $p < 0.01$, and men, $r_{men} = 0.82$, $p < 0.01$, indicating significant rank-order stability in hormones from before to after the discussion task. Men's and women's cortisol levels did not differ significantly at pre-task, $t(193) = -0.68$, $p = 0.49$, $d = 0.10$, or post-task, $t(194) = -1.80$, $p = 0.07$, $d = 0.26$; as expected, men had significantly higher testosterone levels than women at both pre-task, $t(146) = -13.42$, $p < 0.001$, $d = 1.92$, and post-task, $t(141) = -15.76$, $p < 0.001$, $d = 2.26$.[5] Given presumed links between cortisol and self-reported stress, we also examined bivariate correlations between post-task stress and pre-task cortisol, post-task cortisol, and cortisol change by condition. We did not find that post-task stress was significantly correlated with any of our cortisol variables in either the low-closeness ($r_{pre\text{-}task\ cortisol} = 0.20$, $p = 0.07$, $r_{post\text{-}task\ cortisol} = 0.17$, $p = 0.12$, $r_{cortisol\ change} = -0.04$, $p = 0.70$) or high-closeness ($r_{pre\text{-}task\ cortisol} = -0.01$, $p = 0.92$, $r_{post\text{-}task\ cortisol} = 0.15$, $p = 0.13$, $r_{cortisol\ change} = 0.14$, $p = 0.15$) condition.

Table 1
Descriptive statistics for cortisol and testosterone across low- and high-closeness discussion.

	Low-closeness discussion, *M* (*SD*)		High-closeness discussion, *M* (*SD*)	
	Pre-task	Post-task	Pre-task	Post-task
Cortisol				
Women	0.14 (0.09)	0.11 (0.07)	0.13 (0.05)	0.13 (0.08)
Men	0.15 (0.09)	0.14 (0.08)	0.14 (0.08)	0.15 (0.08)
Testosterone				
Women	90.21 (42.31)	81.50 (41.16)	91.35 (26.09)	87.15 (28.89)
Men	195.41 (63.79)	205.18 (67.34)	184.07 (64.30)	210.85 (71.17)

Note. Cortisol is measured in ug/dL and testosterone is measured in pg/mL. Low-closeness discussion $n_{women} = 45$, $n_{men} = 46$; high-closeness discussion $n_{women} = 54$, $n_{men} = 52$.

3.2. Psychological outcomes following the discussion task

First, we conducted multilevel modeling analyses to examine (1) post-task psychological outcomes as a function of the task and (2) whether outcomes differed by gender. As shown in Tables 2 and 3, and as expected, people reported that they disclosed marginally more and felt marginally closer to their partners in the high- versus low-closeness condition.

We did not find any significant effects of condition for post-task positive affect, negative affect, attraction to partner, or stress, $b = -0.05$, $t(100) = -0.80$, $p = 0.42$; $b = 0.02$, $t(99) = 0.68$, $p = 0.50$; $b = 0.14$, $t(101) = 1.45$, $p = 0.15$; $b = 0.16$, $t(100) = 1.56$, $p = 0.12$. There was not a significant difference across the low- and high-closeness

Table 2
Descriptive statistics for psychological variables across low- and high-closeness discussion.

	Low-closeness discussion, *M* (*SD*)		High-closeness discussion, *M* (*SD*)	
	Pre-task	Post-task	Pre-task	Post-task
Disclosure	–	5.03 (1.46)	–	5.67 (1.17)
Closeness	4.91 (1.44)	5.08 (1.42)	5.21 (1.06)	5.50 (1.08)
Positive Affect	3.07 (0.66)	3.41 (0.80)	2.78 (0.69)	3.32 (0.77)
Negative Affect	1.43 (0.39)	1.21 (0.28)	1.36 (0.34)	1.22 (0.28)
Attracted	5.77 (1.15)	5.87 (1.15)	5.49 (1.23)	6.17 (0.93)
Stress	3.59 (1.73)	1.97 (1.18)	3.39 (1.73)	2.20 (1.37)

Note. Disclosure represents self-disclosure during the task (measured at post-task only). Closeness is measured using the Inclusion of the Other in the Self Scale. $n_{low\text{-}closeness} = 48$ couples, $n_{high\text{-}closeness} = 57$ couples.

[3] We also re-ran all analyses excluding same-sex couples. All effects reported here were consistent when same-sex couples were excluded (albeit weaker in magnitude in some cases).

[4] We also ran all multilevel models using residualized change scores (similar to Stanton et al., 2017) and percent change scores as the dependent variable to account for baseline self-reports; the majority of our effects were consistent with those reported for post-task psychological reports.

[5] Because Levene's test for equality of variances was violated for the analysis of men and women's testosterone levels at pre- and post-task, $F(1, 194) = 27.89$, $p < 0.001$, $F(1, 194) = 37.30$, $p < 0.001$, respectively, we computed a *t*-statistic not assuming homogeneity of variance.

Table 3
Post-task psychological reports as a function of the low- and high-closeness discussion.

	Estimate	*SE*	*df*	*t*
Disclosure				
Intercept	5.29	0.15	55.45	34.84***
Condition	0.29	0.15	55.45	1.93‡
Actor Gender	-0.33	0.20	60.84	-1.61
Partner Gender	-0.22	0.21	63.61	-1.05
Actor Gender*Condition	-0.14	0.20	60.84	-0.70
Partner Gender*Condition	-0.13	0.21	63.61	-0.65
Closeness				
Intercept	5.28	0.10	101.21	52.48***
Condition	0.19	0.10	101.21	1.90‡
Actor Gender	-0.06	0.15	118.91	-0.40
Partner Gender	-0.01	0.15	120.90	-0.09
Actor Gender*Condition	-0.15	0.15	118.91	-1.01
Partner Gender*Condition	-0.09	0.15	120.90	-0.60

Note. Closeness is measured using the Inclusion of the Other in the Self Scale. Estimate = unstandardized regression coefficients. Condition: −1 = low-closeness, 1 = high-closeness, actor gender: −1 = women, 1 = men, partner gender: −1 = women, 1 = men. $n_{\text{low-closeness}} = 48$ couples, $n_{\text{high-closeness}} = 57$ couples.
‡ $p = 0.06$.
*** $p < 0.001$.

conditions in self-reported task enjoyment or desire to do the task again, $b = -0.07$, $t(102) = -0.83$, $p = 0.41$; $b = -0.07$, $t(102) = -0.56$, $p = 0.57$, respectively, suggesting that our tasks were comparable across these dimensions. There was, however, a significant interaction between condition and partner gender associated with self-reported stress, $b = 0.40$, $t(117) = 2.58$, $p < 0.01$. We ran a two-intercept model to decompose this interaction, which revealed that people partnered with men reported significantly greater stress in the high- versus low-closeness condition, $b = 0.56$, $t(105) = 2.74$, $p < 0.01$. The effect of condition on stress was not significant among people partnered with women, $b = -0.22$, $t(111) = -1.33$, $p = 0.19$.

3.3. Changes in hormones following the discussion task

We next conducted multilevel modeling analyses to examine (1) cortisol and testosterone changes following the high- versus low-closeness tasks and (2) whether hormone changes differed by (actor and partner) gender.[6] As shown in Table 4 and the first bar graph in Fig. 1, people showed significantly larger increases in cortisol in the high- versus low-closeness conditions. Across conditions, men showed larger cortisol increases compared to women.

As shown in Table 4 and the second bar graph in Fig. 1, effects for testosterone were similar to those obtained for cortisol, such that people showed significantly larger increases in testosterone in the high- versus low-closeness condition. Further, across conditions, men showed larger testosterone increases compared to women.

We further examined whether post-task changes in cortisol and testosterone were influenced by baseline hormones levels by including baseline cortisol and testosterone as covariates in each respective model. In the model for cortisol change, we found that all effects reported earlier were virtually identical; in addition, baseline cortisol was significantly negatively associated with cortisol change, such that people who had lower baseline cortisol showed greater increases in cortisol across conditions, $b = -1.03$, $t(159) = -3.23$, $p < 0.01$. Similarly, in the model for testosterone change, we found that all effects reported earlier were virtually identical; in addition, baseline testosterone was significantly negatively associated with testosterone change, such that people who had lower baseline testosterone showed greater increases in testosterone across conditions, $b = -0.10$, $t(178) = -3.26$, $p < 0.01$.

Next, we explored the interaction of testosterone and cortisol following the Dual Hormone Hypothesis, which suggests that effects of

[6] Following Ketay et al., we also examined whether baseline cortisol and testosterone predicted self-reported closeness in our sample of romantic couples. We did not find any significant associations between baseline cortisol or testosterone and self-reported post-task closeness in either the fast-friends or small-talk condition.

Table 4
Hormone changes as a function of the low- and high-closeness discussion.

	Estimate	*SE*	*df*	*t*
Cortisol				
Intercept	1.80	0.02	99.34	82.62***
Condition	0.06	0.02	99.34	2.78**
Actor Gender	0.10	0.03	123.95	3.09**
Partner Gender	0.06	0.03	125.52	1.95†
Actor Gender*Condition	0.01	0.03	123.95	0.24
Partner Gender*Condition	0.03	0.03	125.52	1.04
Testosterone				
Intercept	3.35	1.63	98.80	2.05*
Condition	4.39	1.63	98.80	2.69**
Actor Gender	10.44	2.37	117.65	4.40***
Partner Gender	1.83	2.39	119.46	0.77
Actor Gender*Condition	3.11	2.37	117.65	1.31
Partner Gender*Condition	2.88	2.39	119.46	1.20

Note. Cortisol and testosterone are percent change values, cortisol is log transformed. Estimate = unstandardized regression coefficients. Condition: −1 = low-closeness, 1 = high-closeness, actor gender: −1 = women, 1 = men, partner gender: −1 = women, 1 = men. $n_{\text{low-closeness}} = 48$ couples, $n_{\text{high-closeness}} = 57$ couples.
† $p = 0.05$.
* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.

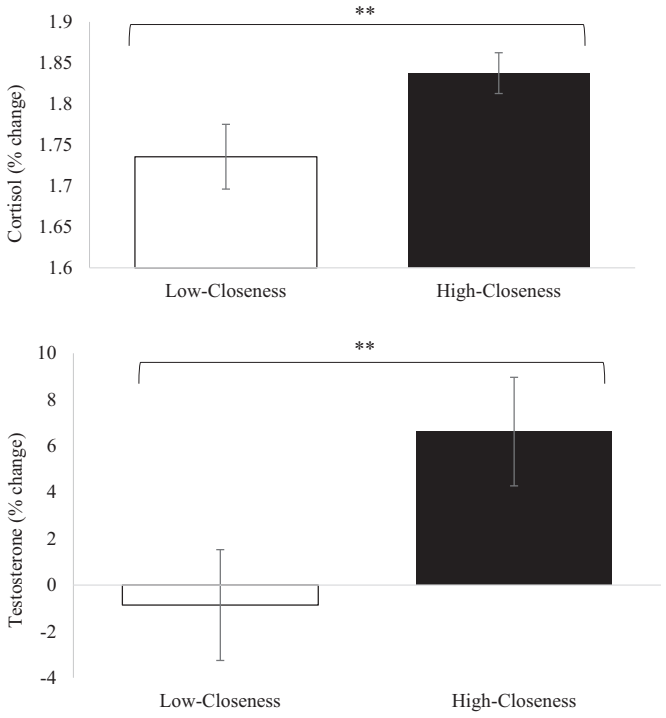
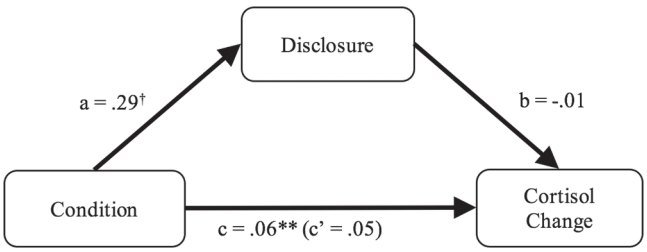
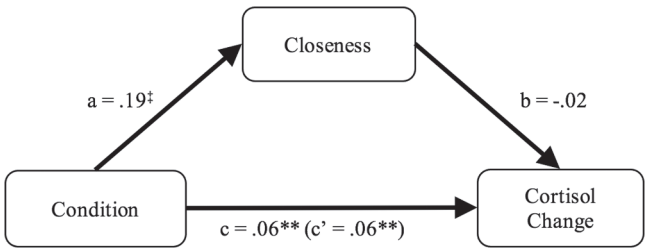
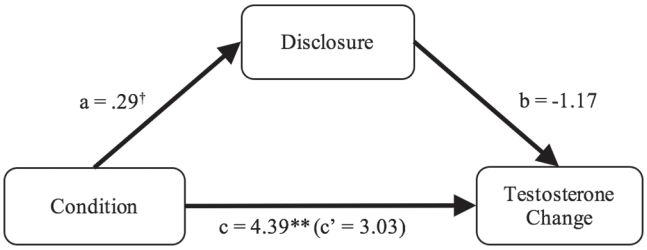


Fig. 1. Cortisol change bars for the low- and high-closeness conditions are both significantly different from zero, $t(88) = 43.93$, $p < 0.001$; $t(104) = 73.77$, $p < 0.001$, respectively. The testosterone change bar for the high-closeness condition is significantly different from zero, however the testosterone change bar for the low-closeness condition was not significantly different from zero, $t(104) = 2.83$, $p < 0.01$; $t(90) = -0.36$, $p = 0.72$, respectively. $n_{\text{low-closeness}} = 48$ couples, $n_{\text{high-closeness}} = 57$ couples. Error bars represent standard errors. **$p < 0.01$.







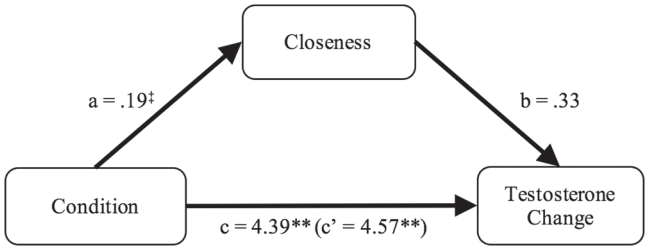


Fig. 2. Self-reported disclosure during the task helps to explain the association between condition and cortisol change and between condition and testosterone change. $n_{\text{low-closeness}} = 48$ couples, $n_{\text{high-closeness}} = 57$ couples. Estimates are unstandardized regression coefficients. The regression slope in parenthesis indicates the relationship between condition and hormone changes controlling for disclosure. $^{\dagger}p = 0.05$, $^{**}p < .01$.

Fig. 3. Self-reported closeness, measured by the Inclusion of the Other in the Self Scale, during the task does not significantly mediate the association between condition and cortisol change (3a) or between condition and testosterone change (3b). $n_{\text{low-closeness}} = 48$ couples, $n_{\text{high-closeness}} = 57$ couples. Estimates are unstandardized regression coefficients. The regression slope in parenthesis indicates the relationship between condition and hormone changes controlling for closeness. $^{\ddagger}p = .06$, $^{**}p < .01$.

testosterone are more pronounced among people who have lower baseline cortisol (Mehta and Prasad, 2015). Consistent with the Dual Hormone Hypothesis, we found a negative association between baseline cortisol and testosterone change, such that people who had lower levels of cortisol showed greater increases in testosterone across conditions, $b = -77.73$, $t(168) = -3.64$, $p < 0.001$.

Finally, given that relationship length can influence hormone levels (Maestripieri et al., 2013), we included relationship length (centered and log transformed due to skewness) as a control variable as well as the interaction between relationship length and condition to each model predicting cortisol and testosterone changes. We found that neither relationship length nor the interaction between relationship length and condition were significantly associated with cortisol change, $b = -0.04$, $t(97) = -0.79$, $p = 0.43$; $b = -0.03$, $t(97) = -0.69$, $p = 0.49$, respectively, or testosterone change, $b = -1.41$, $t(96) = -0.41$, $p = 0.68$; $b = 3.43$, $t(96) = 1.00$, $p = 0.32$, respectively, and all the effects reported earlier were virtually identical with these variables included.

3.4. Do psychological reports account for hormone changes?

Next, we explored whether psychological reports during the task would account for (i.e., mediate) cortisol and testosterone changes between the low- and high-closeness conditions. Given that the experimental manipulation was centered around self-disclosure with the purpose of enhancing closeness, we were first interested in assessing whether disclosure and closeness during the task explained cortisol and testosterone increases. We were also interested in assessing excitement and attraction as potential mediators, given that theoretical and experimental work suggests that excitement and sexual intimacy are associated with higher cortisol and testosterone, respectively.

We began by examining whether self-reported disclosure during the task mediated the effect of condition on cortisol change following West et al.'s (2008) approach for mediation with the actor-partner interdependence model. As displayed in the first diagram in Fig. 2, and consistent with our previous analyses, the total effect of condition on cortisol change was significant (path c). The effect from condition to self-reported disclosure (the mediator) was marginally significant (path a), and the effect from disclosure to cortisol change, controlling for condition, was not significant (path b). Finally, the direct effect of condition on cortisol change was no longer significant (reduced from $p = 0.007$ to $p = 0.065$) when controlling for disclosure (path c′). Based on conventional practice and recommendations (Rucker et al., 2011), even with a non-significant path b, these analyses suggest that people's reports of how much they disclosed during the task may help to explain the effect of condition on cortisol increases.

We ran the same mediation analyses to examine whether self-reported disclosure during the task mediated the effect of condition on testosterone change. As displayed in the second diagram in Fig. 2, and consistent with our previous analyses, the total effect of condition on testosterone change was significant (path c). The effect from condition to self-reported disclosure (the mediator) was marginally significant (path a), and the effect from disclosure to testosterone change, controlling for condition, was not significant (path b). Finally, the direct effect of condition on testosterone change was no longer significant (reduced from $p = 0.008$ to $p = 0.18$) when controlling for disclosure (path c′), and therefore, similar to cortisol above, disclosure may also help to explain the effect between condition and testosterone increases.

We then examined whether reported self-reported post-task closeness might account for differences in hormone changes across conditions. These analyses indicated that greater post-task closeness did not explain the larger cortisol or testosterone increases in the high- versus low-closeness condition (see Fig. 3).

Finally, we also explored whether self-reported post-task excitement (using the single PANAS item) and attraction to partner during the task could account for the cortisol and testosterone changes. These variables did not significantly mediate the larger cortisol or testosterone increases in the high- versus low-closeness condition.

4. Discussion

In the current study, we assessed changes in cortisol and testosterone during high- (fast-friends) versus low-closeness (small-talk) discussions. We found that people showed larger increases in cortisol and

testosterone in the high-closeness discussion with their romantic partner compared to people in the low-closeness discussion. Across conditions, men showed larger cortisol and testosterone increases compared to women. We also found that self-reported disclosure during the task helped to explain the cortisol and testosterone increases, such that people who were in the high-closeness discussion disclosed more personal and important information to their partners, which led to testosterone and cortisol increases. These findings contribute novel information about neuroendocrine changes associated with positive, emotionally intimate experiences between romantic partners.

Both women and men in the current study showed larger increases in cortisol during the high-closeness versus low-closeness task. In contrast, Ketay et al. (2017) found significant cortisol *decreases* among unacquainted same-sex pairs in both their high- and low-closeness tasks. One critical difference between their study and ours is that Ketay et al.'s participants were previously unacquainted, whereas ours were in established romantic relationships. Perhaps Ketay et al.'s participants saw the interaction as an opportunity to make a friend which would enhance their support network, which led to cortisol decreases, whereas couples in the current study might have experienced excitement given the novelty and intimacy of the high-closeness discussion, which led to cortisol increases. There is some evidence that people show cortisol increases when they have interactions with potential partners (i.e., unacquainted members of the opposite-sex; e.g., Roney et al., 2010) or have novel conversations about marriage with their partners (Loving et al., 2009b). Exciting and novel experiences stimulate the release of neurotrophin nerve growth factor (NGF; Aloe et al., 1994), which is a biological marker related to social bonding (Emanuele et al., 2006). Further, increases in NGF can stimulate the HPA axis (Laurent et al., 2014). Consistent with this biological connection, the experience of falling in love, a relationship transition that is regarded as exciting and novel, is associated with increases in NGF and cortisol (Emanuele et al., 2006; Marazziti and Canale, 2004). Further, other work suggests that people show increases in cortisol when they think about when they met or fell in love with their partner (Loving et al., 2009a). Thus, future research might examine the effect of NGF on the HPA axis or assess whether it is excitement and/or novelty that elicits cortisol increases. Future research might also consider oxytocin, a hormone that is generally associated with social bonding and intimacy. People who are in newer relationships typically show higher levels of oxytocin compared to people who are single (Liu et al., 2012; Schneiderman et al., 2012), suggesting that oxytocin may also increase during particularly novel and exciting close relationship experiences. Therefore, it is plausible that positive, emotionally intimate relationship experiences that are interpreted as novel and/or exciting may also increase oxytocin levels.

Both women and men in the current study also showed larger increases in testosterone during the high- versus low-closeness control task. To our knowledge, only one study has examined changes in testosterone during these tasks: Ketay et al. (2017) found significant testosterone decreases among unacquainted same-sex dyads during their low-closeness control task (i.e., giving directions, playing word games, reading short passages) but no significant testosterone changes during their high-closeness (fast-friends) task. Given diurnal declines in testosterone (Dabbs Jr, 1990), their findings may suggest a testosterone increase during the high-closeness task for the same-sex dyads in their study, which would be consistent with our findings for established romantic couples. Our findings of a testosterone increase during high- versus low-closeness discussions might suggest that people interpret close and emotionally intimate experiences with an established romantic partner similarly to sexually intimate experiences. We did not find that participants reported feeling significantly more attracted to their partners in the high- versus low-closeness task; however, it is worth noting that attraction was assessed using a single item, which is necessarily less reliable than multi-item measures (e.g., Emons et al., 2007). Our single item also did not distinguish between emotional and sexual attraction, which may have implications for testosterone change. Future studies might examine this distinction to better understand whether close relationship experiences between established romantic partners promote sexual attraction and/or sexual intimacy, and whether these factors contribute to testosterone increases.

We also found that self-reported disclosure during the discussion helped to explain the cortisol and testosterone increases in the high- versus low-closeness task. That is, people in the high-closeness task were marginally more likely to report that they revealed personal and important information about themselves to their partners, which in turn, was associated with larger increases in cortisol and testosterone changes in the high-closeness condition specifically. These findings suggest that something about self-disclosure—a critical difference between the two experimental conditions—may elicit increases in both hormones, perhaps increasing participants' feelings of novelty, excitement, or engagement with the task. We note that only half of our sample completed items related to how much they disclosed during the task specifically, which likely limited power in these analyses; however, we did not find that people who did and did not complete these disclosure items differed in any of our key variables.

It is also worth noting that, although participants felt closer to their partners during the high- versus low-closeness task, this difference was fairly small in magnitude and only marginally significant. Perhaps in part because of the size of this effect, self-reported closeness did not account for differences in cortisol and testosterone changes between conditions. Although the experimental task is known to manipulate closeness, at least among unacquainted dyads, people in established relationships (particularly those willing to participate in research studies) may have fairly high levels of closeness to begin with, raising the possibility of ceiling effects. In fact, participants in our study reported pre-task closeness levels around 5 on a 7-point scale, which may have limited the extent to which meaningful changes could occur in a relatively short period of time. Our use of a single-item measure of closeness, the Inclusion of the Other in the Self Scale (Aron et al., 1997), which does not distinguish between emotional and physical closeness, may have also limited variability in our study. Future research might consider additional measures that are more specific to people's experiences in this task, such as how understood one felt by their partner or how much one felt their *partner* disclosed to them.

Future research might also benefit from consideration of genetic variability, such as genetic polymorphisms that can affect hormone responses and/or individual differences in approaches to closeness (DeRijk and de Kloet, 2005; Fraley et al., 2013). Higher levels of a dopamine D2 receptor gene known as DRD2, for instance, have been linked with both reward mechanisms in the brain and "love styles" (i.e., eros, ludus, storge, pragma, agape, and mania; Bonci and Hopf, 2005; Emanuele et al., 2007). Insofar as genetic variation contributes to individual differences in both relationship orientations and physiological responses during intimate interactions, understanding such variations could provide valuable information about people's responses to closeness and intimacy.

Our findings also extend prior research by examining gender differences in cortisol and testosterone changes following partner discussions. In the current study, men showed larger increases in cortisol and testosterone across conditions compared to women. The presence of an opposite-sex confederate can elicit cortisol and testosterone increases in heterosexual men (e.g., Roney et al., 2007; Roney et al., 2003), although men may also show testosterone increases insofar as they perceive other men to be in competition with them (Kivlighan et al., 2005). Thus, the (heterosexual) men in our study may have shown larger cortisol and testosterone increases across conditions due to the presence of a female research assistant (who explained all task procedures but was not in the room during the lab session). We chose to keep the gender of our research assistants constant to minimize such effects across couples, but such a design makes it impossible to know whether research assistant gender might have contributed to any changes in men's (or women's) hormones. It is also worth noting that there were no significant

interactions between condition and participant gender; therefore, it is not the case that men responded to the two tasks differently than women, but perhaps to the lab context. Future research might explore this issue more systematically by including both male and female research assistants.

To our knowledge, our study is the first to assess both romantic partners' hormone changes during the fast-friends task, and one of very few to assess testosterone changes specifically in couples during lab interactions. One advantage of this approach is that we were able to standardize the discussion such that couples answered similar questions in the same lab space. One disadvantage of this approach was that, perhaps, people felt less comfortable having emotionally intimate discussions with their partner in the lab, or that couples felt stressed because they were asked to discuss topics they might not engage in normally. Future studies might examine hormone changes following spontaneous partner interactions in more naturalistic settings, which could reduce couples' discomfort or stress and provide a more realistic measure of hormone changes in response to closeness.

Another strength of our study is that we measured both cortisol and testosterone changes which allowed us to test the Dual Hormone Hypothesis. The Dual Hormone Hypothesis suggests that effects of testosterone are more pronounced among people who have lower baseline cortisol (Mehta and Prasad, 2015). Consistent with this hypothesis, we found that people with lower baseline cortisol levels showed larger testosterone responses in both conditions. Future studies might also take a multisystem approach, ideally including multiple hormones such as cortisol and testosterone, to better understand neuroendocrine changes associated with positive, emotionally intimate close relationship experiences.

Our findings are nevertheless restricted in that we collected saliva samples at only two time points—once pre-task and once at approximately 10 min post-task—which limits our understanding of the trajectory of hormone changes throughout the task and during the recovery period. Thus, future research might benefit from collecting additional samples after each 10-minute set of the discussion task and at 20, 30, 45, and even 60 min after the task, given that hormone responses can occur as delayed as 21–40 min after exposure (Dickerson and Kemeny, 2004). These additional samples could elucidate individual differences in hormone changes and hormone trajectories during close relationship experiences and recovery (i.e., return to baseline) associated with closeness and disclosure.

Another limitation is that, with only 14 same-sex couples, we did not have enough statistical power to test differences between opposite- and same-sex couples. Further, all four of our gay male couples, by chance, were randomly assigned to the low-closeness condition, which precluded our ability to examine whether interactions between actor gender, partner gender, and condition predicted cortisol and testosterone changes. Although this diversity in our sample is a strength, future studies with larger samples of same-sex couples could help to assess whether cortisol and testosterone changes might differ for people who do not identify as heterosexual and/or are partnered with someone of the same gender.

Future studies might also benefit from collecting more diverse samples in terms of geographic location or cultural orientation. We are not aware of research examining cultural differences in cortisol or testosterone changes in the lab, but there is some evidence for country-related variability in cortisol responses as a function of cultural values (Miller and Kirschbaum, 2019). Future studies with larger and more geographically or culturally diverse samples would help to assess whether our findings generalize to people beyond our sample of couples from the Midwest United States.

Finally, concerns have been raised about using immunoassays which can produce unstable or inflated estimates in lower concentrations of cortisol and testosterone (e.g., Prasad et al., 2019; Welker et al., 2016). Future work should consider more highly powered hormone measurement techniques, such as liquid chromatography-tandem mass spectrometry, which can more reliably and accurately detect differences in lower concentrations of these hormones, particularly for women who generally have lower testosterone (Keevil et al., 2014).

5. Conclusions

Our findings demonstrated that both men and women showed cortisol and testosterone increases during a closeness-inducing discussion with their romantic partner. We additionally shed light on a potentially important mechanism of such changes, in that people also reported that they disclosed to a greater extent during the high- versus low-closeness task and disclosure accounted for cortisol and testosterone increases. Future research will be necessary to better understand these changes, including the extent to which they replicate during naturally occurring close relationship experiences, using multiple measures of cortisol and testosterone over time, and in larger and more diverse samples. Nevertheless, the current findings advance our understanding of the neuroendocrine changes and underlying processes associated with closeness-inducing relationship experiences in humans.

Declaration of Competing Interest

The authors declare that they have no competing financial interests or personal relationships that could have influenced the work reported in this manuscript.

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References

Aloe, L., Bracci-Laudiero, L., Alleva, E., Lambiase, A., Micera, A., Tirassa, P., 1994. Emotional stress induced by parachute jumping enhances blood nerve growth factor levels and the distribution of nerve growth factor receptors in lymphocytes. Proc. Natl. Acad. Sci. U. S. A. 91, 10440–10444.

Aron, A., Melinat, E., Aron, E.N., Vallone, R.D., Bator, R.J., 1997. The experimental generation of interpersonal closeness: a procedure and some preliminary findings. Pers. Soc. Psychol. Bull. 23, 363–377.

Berscheid, E., Snyder, M., Omoto, A.M., 1989. The relationship closeness inventory: assessing the closeness of interpersonal relationships. J. Pers. Soc. Psychol. 57, 792–807.

Bonci, A., Hopf, F.W., 2005. The dopamine D2 receptor: new surprises from an old friend. Neuron 47, 335–338.

Brown, S.L., Nesse, R.M., Vinokur, A.D., Smith, D.M., 2003. Providing social support may be more beneficial than receiving it: results from a prospective study of mortality. Psychol. Sci. 14, 320–327.

Dabbs Jr, J.M., 1990. Salivary testosterone measurements: reliability across hours, days, and weeks. Physiol. Behav. 48, 83–86.

DeRijk, R., de Kloet, E.R., 2005. orticosteroid receptor genetic polymorphisms and stress responsivity. Endocrine 28, 263–269.

Dickerson, S.S., Kemeny, M.E., 2004. Acute stressors and cortisol responses: a theoretical integration and synthesis of laboratory research. Psychol. Bull. 130, 355–391.

Edelstein, R.S., van Anders, S.M., Chopik, W.J., Goldey, K.L., Wardecker, B.M., 2014. Dyadic associations between testosterone and relationship quality in couples. Horm. Behav. 65, 401–407.

Edelstein, R.S., Chin, K., 2018. Hormones and close relationship processes: Neuroendocrine bases of partnering and parenting. In: Schultheiss, O.C., Mehta, P.H. (Eds.), Routledge International Handbook of Social Neuroendocrinology. Routledge, Abingdon, UK, pp. 281–297.

Edelstein, R.S., Chin, K., Saini, E.K., Kuo, P.X., Schultheiss, O.C., Volling, B.L., 2019. Adult attachment and testosterone reactivity: fathers' avoidance predicts changes in testosterone during the strange situation procedure. Horm. Behav. 112, 10–19.

Emanuele, E., Brondino, N., Pesenti, S., Re, S., Geroldi, D., 2007. Genetic loading on human loving styles. Neuroendocrinol. Lett. 28, 815–821.

Emanuele, E., Politi, P., Bianchi, M., Minoretti, P., Bertona, M., Geroldi, D., 2006. Raised plasma nerve growth factor levels associated with early-stage romantic love. Psychoneuroendocrinology 31, 288–294.

Emons, W.H., Sijtsma, K., Meijer, R.R., 2007. On the consistency of individual classification using short scales. Psychol. Methods 12, 105–120.
Fraley, R.C., Roisman, G.I., Booth-LaForce, C., Owen, M.T., Holland, A.S., 2013. Interpersonal and genetic origins of adult attachment styles: a longitudinal study from infancy to early adulthood. J. Pers. Soc. Psychol. 104, 817–838.
Keevil, B., MacDonald, P., Macdowall, W., Lee, D., Wu, F., Team, N., 2014. Salivary testosterone measurement by liquid chromatography tandem mass spectrometry in adult males and females. Ann. Clin. Biochem. 51, 368–378.
Kenny, D.A., Kashy, D.A., Cook, W.L., 2006. Dyadic Data Analysis. Guilford Press, New York, NY.
Ketay, S., Welker, K.M., Slatcher, R.B., 2017. The roles of testosterone and cortisol in friendship formation. Psychoneuroendocrinology 76, 88–96.
Kivlighan, K.T., Granger, D.A., Booth, A., 2005. Gender differences in testosterone and cortisol response to competition. Psychoneuroendocrinology 30, 58–71.
Laurent, H.K., Laurent, S.M., Granger, D.A., 2014. Salivary nerve growth factor response to stress related to resilience. Physiol. Behav. 129, 130–134.
Leifke, E., Gorenoi, V., Wichers, C., Von Zur Mühlen, A., Von Büren, E., Brabant, G., 2000. Age-related changes of serum sex hormones, insulin-like growth factor-1 and sex-hormone binding globulin levels in men: cross-sectional data from a healthy male cohort. Clin. Endocrinol. (Oxf.) 53, 689–695.
Liu, J.C., Guastella, A.J., Dadds, M.R., 2012. Effects of oxytocin on human social approach measured using intimacy equilibriums. Horm. Behav. 62, 585–591.
López, H.H., Hay, A.C., Conklin, P.H., 2009. Attractive men induce testosterone and cortisol release in women. Horm. Behav. 56, 84–92.
Loving, T.J., Crockett, E.E., Paxson, A.A., 2009a. Passionate love and relationship thinkers: experimental evidence for acute cortisol elevations in women. Psychoneuroendocrinology 34, 939–946.
Loving, T.J., Gleason, M.E., Pope, M.T., 2009b. Transition novelty moderates daters' cortisol responses when talking about marriage. Pers. Relatsh. 16, 187–203.
Maestripieri, D., Klimczuk, A.C., Seneczko, M., Traficonte, D.M., Wilson, M.C., 2013. Relationship status and relationship instability, but not dominance, predict individual differences in baseline cortisol levels. PLoS One 8, 84003.
Malina, A., Głogiewicz, M., Piotrowski, J., 2019. Supportive social interactions in infertility treatment decrease cortisol levels. Front Psychol. 10, 2779.
Marazziti, D., Canale, D., 2004. Hormonal changes when falling in love. Psychoneuroendocrinology 29, 931–936.
Mashek, D.J., Aron, A., 2004. Handbook of Closeness and Intimacy. Lawrence Erlbaum Associates, Mahwah, NJ.
Mehta, P.H., Prasad, S., 2015. The dual-hormone hypothesis: a brief review and future research agenda. Curr. Opin. Behav. Sci. 3, 163–168.
Mercado, E., Hibel, L.C., 2017. I love you from the bottom of my hypothalamus: the role of stress physiology in romantic pair bond formation and maintenance. Soc. Personal. Psychol. Compass 11, e12298.
Miller, R., Kirschbaum, C., 2019. Cultures under stress: a cross-national meta-analysis of cortisol responses to the Trier Social Stress Test and their association with anxiety-related value orientations and internalizing mental disorders. Psychoneuroendocrinology 105, 147–154.
Page-Gould, E., Mendoza-Denton, R., Tropp, L.R., 2008. With a little help from my cross-group friend: reducing anxiety in intergroup contexts through cross-group friendship. J. Pers. Soc. Psychol. 95, 1080–1094.
Prasad, S., Lassetter, B., Welker, K.M., Mehta, P.H., 2019. Unstable correspondence between salivary testosterone measured with enzyme immunoassays and tandem mass spectrometry. Psychoneuroendocrinology 109, 104373.
Roney, J.R., Gettler, L.T., 2015. The role of testosterone in human romantic relationships. Curr. Opin. Psychol. 1, 81–86.
Roney, J.R., Mahler, S.V., Maestripieri, D., 2003. Behavioral and hormonal responses of men to brief interactions with women. Evol. Hum. Behav. 24, 365–375.
Roney, J.R., Lukaszewski, A.W., Simmons, Z.L., 2007. Rapid endocrine responses of young men to social interactions with young women. Horm. Behav. 52, 326–333.
Roney, J.R., Simmons, Z.L., Lukaszewski, A.W., 2010. Androgen receptor gene sequence and basal cortisol concentrations predict men's hormonal responses to potential mates. Proc. R. Soc. B 277, 57–63.
Rucker, D.D., Preacher, K.J., Tormala, Z.L., Petty, R.E., 2011. Mediation analysis in social psychology: current practices and new recommendations. Soc. Personal. Psychol. Compass 5, 359–371.
Schneiderman, I., Zagoory-Sharon, O., Leckman, J.F., Feldman, R., 2012. Oxytocin during the initial stages of romantic attachment: relations to couples' interactive reciprocity. Psychoneuroendocrinology 37, 1277–1285.
Schultheiss, O.C., Stanton, S.J., 2009. Assessment of Salivary Hormones. Guilford Press, New York, NY.
Singer, J.D., Willett, J.B., 2003. Applied Longitudinal Data Analysis: Modeling Change and Event Occurrence. Oxford University Press, New York, NY.
Slatcher, R.B., 2010. When Harry and Sally met Dick and Jane: creating closeness between couples. Pers. Relatsh. 17, 279–297.
Smith, A.M., Loving, T.J., Crockett, E.E., Campbell, L., 2009. What's closeness got to do with it? Men's and women's cortisol responses when providing and receiving support. Psychosom. Med. 71, 843–851.
Sprecher, S., 2021. Closeness and other affiliative outcomes generated from the Fast Friends procedure: a comparison with a small-talk task and unstructured self-disclosure and the moderating role of mode of communication. J. Soc. Pers. Relatsh. 1–20.
Stanton, S.C.E., Campbell, L., Pink, J.C., 2017. Benefits of positive relationship experiences for avoidantly attached individuals. J. Pers. Soc. Psychol. 113, 568–588.
Sundin, Z.W., Chopik, W.J., Welker, K.M., Ascigil, E., Brandes, C.M., Chin, K., Ketay, S., Knight, E.L., Kordsmeyer, T.L., McLarney-Vesotski, A.R., Prasad, S., Reese, Z.A., Roy, A.R.K, Sim, L., Stern, A.R.K, Carré, J.M., Edelstein, R.S., Mehta, P.H., Slatcher, R.B., Tackett, J.L., 2021. Estimating the associations between Big Five personality traits, testosterone, and cortisol. Adapt. Hum. Behav. Physiol. 1–34.
van Anders, S.M., Brotto, L., Farrell, J., Yule, M., 2009. Associations among physiological and subjective sexual response, sexual desire, and salivary steroid hormones in healthy premenopausal women. J. Sex. Med. 6, 739–751.
van Anders, S.M., Edelstein, R.S., Wade, R.M., Samples-Steele, C.R., 2013. Descriptive experiences and sexual vs. nurturant aspects of cuddling between adult romantic partners. Arch. Sex. Behav. 42, 553–560.
van Anders, S.M., Goldey, K.L., Kuo, P.X., 2011. The steroid/peptide theory of social bonds: integrating testosterone and peptide responses for classifying social behavioral contexts. Psychoneuroendocrinology 36, 1265–1275.
van Anders, S.M., Tolman, R.M., Volling, B.L., 2012. Baby cries and nurturance affect testosterone in men. Horm. Behav. 61, 31–36.
van Anders, S.M., Watson, N.V., 2006. Social neuroendocrinology. Hum. Nat. 17, 212–237.
Watson, D., Clark, L.A., Tellegen, A., 1988. Development and validation of brief measures of positive and negative affect: The PANAS scales. J. Pers. Soc. Psychol. 54, 1063–1070.
Weinberger, M.I., Hofstein, Y., Whitbourne, S.K., 2008. Intimacy in young adulthood as a predictor of divorce in midlife. Pers. Relatsh. 15, 551–557.
Welker, K.M., Baker, L., Padilla, A., Holmes, H., Aron, A., Slatcher, R.B., 2014. Effects of self-disclosure and responsiveness between couples on passionate love within couples. Pers. Relatsh. 21, 692–708.
Welker, K.M., Lassetter, B., Brandes, C.M., Prasad, S., Koop, D.R., Mehta, P.H., 2016. A comparison of salivary testosterone measurement using immunoassays and tandem mass spectrometry. Psychoneuroendocrinology 71, 180–188.
West, T.V., Popp, D., Kenny, D.A., 2008. A guide for the estimation of gender and sexual orientation effects in dyadic data: an actor-partner interdependence model approach. Pers. Soc. Psychol. Bull. 34, 321–336.
Wingfield, J.C., Hegner, R.E., Dufty, A.M., Ball, G.F., 1990. The "challenge hypothesis": theoretical implications for patterns of testosterone secretion, mating systems, and breeding strategies. Am. Nat. 136, 829–846.