ESTROGENS AND RELATIONSHIP JEALOUSY

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The relation between sex hormones and responses to partner infidelity was explored in two studies reported here. The first confirmed the standard sex difference in relationship jealousy, that males (n = 133) are relatively more distressed by a partner's sexual infidelity and females (n=159) by a partner's emotional infidelity. The study also revealed that females using hormone-based birth control (n = 61) tended more toward sexual jealousy than did other females, and reported more intense affective responses to partner infidelity (n = 77). In study two, 47 females were assessed four times across one month. Patterns of response to partner infidelity did not vary by week of menstrual cycle, but significant relations between salivary estradiol level and jealousy responses were obtained during the time of rising and high fertility risk. The implications, at least for females, are that any evolved psychological, affective, or behavioral dispositions regarding reproduction-related relationships are potentially moderated by estradiol, and that the use of synthetic hormones may disrupt this relation.

KEY WORDS: **Infidelity; Relationship jealousy; Sex differences; Sex hormones**

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Human paternal investment and female-female competition over this investment make human reproductive dynamics unusual, in comparison with those of other mammalian species (Andersson 1994; Clutton-Brock 1989; Darwin 1871; Geary 2000; Geary and Flinn 2001; Trivers 1972). In addition to creating a resource over which females compete, human paternal investment results in extensive costs to males who have been cuckolded (Daly et al. 1982; Geary 1998). It has been hypothesized that these reproductive dynamics resulted in the evolution of a sex difference in the pattern of relationship jealousy (Buss et al. 1992; Daly et al. 1982; Symons 1979). To reduce cuckoldry risk and thus increase the likelihood that parental efforts will be directed toward one's biological offspring, an evolved sensitivity of males to a partner's sexual infidelity has been hypothesized. For females, a partner's emotional infidelity is hypothesized to be relatively more distressing than his sexual infidelity. This is because maternity is certain and because a male partner's attentiveness and emotional investment in the relationship are cues to the likelihood that he will maintain the relationship and invest in any future offspring. If the male develops an emotional attachment to another female, then this is a potential threat to the relationship and thus any future paternal investment.

Empirical studies conducted in the United States, China, and a number of European nations have generally confirmed these predictions and have typically been interpreted as support for this evolution-based model (Buss et al. 1992; Buunk et al. 1996; Geary et al. 1995; Wiederman and Kendall 1999; but see DeSteno and Salovey 1996; Harris 2000; Harris and Christenfeld 1996). Across all of these studies, males, more so than females, indicate that a partner's sexual infidelity is relatively more distressing than a partner's emotional infidelity. Females, more so than males, indicate that a partner's emotional infidelity is more distressing than a partner's sexual infidelity.

Although the empirical result is well established, several issues remain to be addressed. First, females who are using hormone-based birth control do not show the same pattern of sexual behavior and mate preferences as females who are not using these synthetic hormones (e.g., Chavanne and Gallup 1998; Gangestad and Thornhill 1998). The implication is that the use of synthetic hormones may disrupt many of the affective, psychological, and behavioral systems that influence the dynamics of reproduction-related relationships. Because relationship jealousy is an integral part of the suite of variables that influence reproduction-related relationships, the possibility that the use of synthetic hormones disrupts naturally occurring patterns of relationship jealousy needs to be explored. In other words, if female responses to relationship jealousy covary with the use of synthetic hormones, then previous studies that have combined---in unknown proportions--- females who are and are not using these hormones may not

have provided an accurate assessment of naturally occurring sex differences in this area. The first study reported here was designed to address this issue. The second study assessed whether patterns of relationship jealousy vary across the menstrual cycle, and are related to salivary levels of estradiol for females who are not taking synthetic hormones.

HORMONE-BASED BIRTH CONTROL

The most common hormone-based birth control method used in the United States includes synthetic forms of estradiol and progesterone (i.e., progestin) administered by means of either oral contraceptive or implant (Ferin et al. 1993). The biochemical structure of these synthetic hormones differs from that of human 17-beta estradiol---the estrogen that appears to be the most biologically active across the menstrual cycle---and progesterone, and the sites and mechanisms of biological action may differ as well. In fact, many forms of progestin are derived from testosterone and can have androgenic effects. The use of hormone-based birth control thus has the potential to change females' psychological and social behavior in ways that differ from the influence of natural estrogens or progesterone (e.g., Gangestad and Thomhill,1998).

FEMALE SEXUALITY AND THE MENSTRUAL CYCLE

Females who are not taking hormone-based birth control exhibit, as a group, systematic changes in cognition, sexual behavior, and mate preferences during the second week of the menstrual cycle, that is, during the time of rising and high fertility risk (Bellis and Baker 1990; Chavanne and Gallup 1998; Gangestad and Thornhill 1998; Kimura 1999; Penton-Voak and Perrett 2000; Penton-Voak et al. 1999; Thornhill and Gangestad 1999; Wedekind et al. 1995; Wilcox et al. 2000). Bellis and Baker found that females who engage in an extra-pair copulation are most likely to do so during the time of high fertility risk and are less likely to use a contraceptive than during copulations with their long-term social partner. The pattern suggests that the extra-pair copulation may be with a more fit male and that the long-term partner may be cuckolded if pregnancy occurs.

In keeping with this view, sensitivity to and rated attractiveness of male pheromones increases during this time as well. Gangestad and Thornhill (1998) found that the scent of facially symmetric males (as assessed through scent on their shirts, without the male) was rated as more attractive and sexy than was the scent of less symmetric males, but only during the time of rising and high fertility risk (see also Thornhill and Gangestad

1999). Similarly, Penton-Voak and colleagues have found that females rate masculine faces, those with a more prominent jaw, as more attractive during the second week of the menstrual cycle than at other points in the cycle (Penton-V oak and Perrett 2000; Penton-Voak et al. 1999). Scent, facial symmetry, and a masculine jaw bone may, in turn, be proximate cues to male genetic fitness, including immunocompetence (Folstad and Karter 1992; Shackelford and Larsen 1997; Wedekind et al. 1995).

This pattern is consistent with the position that females have an evolved sensitivity to proximate cues of male fitness, but a sensitivity that is only expressed during times of rising and high fertility risk, that is, during the second week of the menstrual cycle. The pattern also suggests that female sexuality can involve a mixed social and reproductive strategy, whereby the female's social partner---the male providing paternal investment---may not be the father of her offspring (Bellis and Baker 1990; Gangestad and Simpson 1990, 2000; Gangestad and Thornhill 1998; Geary 1998). In this view, females are generally attentive to the relationship with the social partner and thus maintain his investment (Geary 2000), becoming sensitive to the cues of a more fit male only during the brief period of rising and high fertility risk. In this way, the risk of her partner detecting cuckoldry is reduced, given the relatively brief period during which she is attracted to and potentially sexually responsive to other males.

The systematic changes in female sexual behavior and mate preferences across the menstrual cycle suggest that females' responses to a partner's sexual infidelity or emotional infidelity may also vary across the menstrual cycle and with estradiol levels. One proposal is that during the time of rising and high fertility risk, females will be especially sensitive to cues that are predictive of their social partners' continued investment-that is, they should show more distress in response to a partner's emotional infidelity (Gaulin et al. 1997). An alternative possibility is that females are more sensitive to sexual cues in general during the time of rising and high fertility risk and thus might respond more intensely to a partner's sexual infidelity. The one study that tested this hypothesis did, indeed, find that females were more likely to report that a partner's emotional infidelity was more distressing than his sexual infidelity during the time of rising and high fertility risk and the opposite pattern during menstruation (Gaulin et al. 1997). Gaulin and his colleagues also estimated females' estradiol and progesterone levels, based on reported day in menstrual cycle, and found that estradiol, but not progesterone, estimates were positively correlated with a tendency toward emotional jealousy. However, this study compared two groups of females who were at different points in the menstrual cycle, rather than testing the same females at different points in the cycle. The second study described below attempted to replicate this result but with the use of a within-subjects design, that is, by assessing the same females four

times across one month. The second study also extended Gaulin and colleagues' research through examination of the relation between females' responses to partner infidelity and salivary estradiol levels, rather than estimated estradiol levels based on day in cycle.

STUDY ONE

Sex differences in patterns of distress and reported affective responses to a partner's sexual or emotional infidelity were assessed in the first study, as were differences between females taking hormone-based birth control and those who were not. The latter comparison is important because it is not known if the use of synthetic estradiol and progestin influences the jealousy responses of females. As noted, many forms of progestin are derived from testosterone and could thus result in more male-like responses to partner infidelity, whereas the elevated levels of synthetic estradiol may work in the opposite manner.

Subjects

The initial subject pool consisted of 398 general psychology students from the University of Missouri, but the sample was restricted to the 292 students who reported having had sexual intercourse at least once in their lifetime. The restriction was imposed to reduce potential differences in the sexual relationships of females who are taking some form of hormone-based birth control and those who are not. Of these 292 subjects, 159 were female and 133 were male. The respective mean ages of the females and males were 19.1 years (s.d. = 1.0) and 19.6 years (s.d. = 1.5). Owing to restricted variability in the age of the sample, the sex difference was statistically, though not practically, significant ($p < .0001$).

Procedure

Assessment measures. All subjects were administered a battery of cognitive and psychological measures. The focus of the current study is on surveys of relationship jealousy, sexual activity, and use of birth control.

The first jealousy item was based on research by Buss and colleagues (Buss et al. 1992) and asked subjects to "imagine that their most recent sexual partner had become interested in someone else and told you about it right now. What would distress or upset you more right now?" Subjects then selected one of the options below:

A. If your partner told you he or she had formed a deep emotional attachment to another person.

B. If your partner told you he or she had passionate sex with another person.

Following completion of the above item and to obtain a more nuanced assessment of reactions to partner infidelity, subjects were asked to first imagine that their partner had developed a deep emotional attachment to another person and then respond, based on how they would feel today, to four items that assessed their affective reactions to this scenario (Geary et al. 1995). For the first item, the subjects rated the relative degree of hurt feelings or anger on a 5-point scale, ranging from -2 (much more hurt than angry) to 2 (much more angry than hurt); for the analyses, this item was rescaled from 1 (much more hurt than angry) to 5 (much more angry than hurt). For the next three items, the intensity of their hurt feelings, anger, and jealous feelings, respectively, was rated on a 1 (not hurt/ angry / jealous) to 5 (extremely hurt/ angry /jea10us) scale. The subjects then completed the same four items, after imagining their partner having passionate sex with another person.

All subjects were asked to indicate the number of times they had had sex in the past week and to describe their relationship with the person with whom they last had sex using one of the following choices: (a) someone you just met; (b) a casual friend or acquaintance; (c) someone you are dating, but not seriously; (d) a steady boyfriend or girlfriend/ dating seriously; or (e) your fiancé/spouse. These items were included as a means to control for the possibility that responses to the partner infidelity items may be more strongly related to the nature of the most recent reproduction-related relationship than to biological sex (i.e., being male or female) or hormone use per se. The females were also asked to indicate whether or not they were currently using a form of hormone-based birth control.

Administration. The battery was administered once to each subject, according to standard instructions and in groups of up to 50 subjects. The session took about 1 hour to complete.

Results

Sex differences. There was no sex difference in the proportion of males (40%) or females (37%) who had had sexual intercourse during the past week ($F(1,268) < 1$, $p > .50$). There was, however, a significant sex difference in the nature of the relationship with their last sexual partner [$\chi^2(4) = 11.61$, $p < .05$]. As shown in Table 1, a higher proportion of males reported that their last sexual relationship was with someone they had just met or with an acquaintance, whereas a higher proportion of females reported that their last sexual relationship was with a serious boyfriend or with a fiancé/ spouse.

Table 1. Sex Differences in the Nature of Most Recent Sexual Relationship

	Percentage	
Nature of Relationship	*Male*	*Female*
Just met	11	4
Acquaintance	19	11
Dating, not serious	12	14
Dating, serious	57	65
Fiancé/ Spouse	2	6

Note: The first column does not total to 100, owing to rounding.
χ^2 (4) = 11.61, P < .05

As with previous studies, most of the males (73%) indicated that their partner's sexual infidelity was more distressing than their partner's emotional infidelity, whereas most of the females (63%) indicated the opposite pattern b:2(1) = 37.36, P < .001]. Mean scores for the reported affective responses to the imagined emotional and sexual infidelity items are shown in Table 2. The first item, relative degree of hurt/anger, was submitted to a 2 (sex) by 2 (infidelity status: emotional or sexual, based on response to the basic partner infidelity item) analysis of variance (ANOVA). The three other items (degree of hurt feelings, anger, and jealous feelings) were first submitted to a 2 (sex) by 2 (infidelity status) multivariate analysis of

Table 2. Sex Differences in Reported Emotional Reactions to Partner Infidelity

	Male		*Female*	
Item	*Mean*	*s.d.*	*Mean*	*s.d.*
EMOTIONAL INFIDELITY				
Hurt/Anger	2.37	1.12	1.68	0.90
Hurt	3.38	1.36	3.97	1.27
Angry	2.89	1.33	3.15	1.27
Jealous	3.02	1.37	3.52	1.21
SEXUAL INFIDELITY				
Hurt/Anger	3.59	1.19	3.32	1.38
Hurt	3.37	1.37	3.92	1.25
Angry	3.64	1.38	4.07	1.16
Jealous	3.20	1.39	3.33	1.37

Note: Hurt/Anger scores range from 1 (Much more hurt than angry) to 5 (Much more angry than hurt). All other scores range from 1 [Not hurt (angry, jealous) at all] to 5 [Extremely hurt (angry, jealous)].

variance (MANOVA). Significant effects were followed up with 2 by 2 ANOVAs.

For imagined emotional infidelity, both females and males reported more intense hurt feelings than anger, but females reported relatively more intense hurt feelings than did males (F(l,284) = 26.46, p < .0001). For imagined sexual infidelity, both females and males reported more intense anger than hurt feelings, with no sex difference in this respect (F(l,287) = 2.62, p >.10). The MANOVAs revealed a significant main effect for sex for both imagined emotional infidelity (F(3, 282) = 4.11, p < .01) and imagined sexual infidelity (F(3,283) = 6.42, p < .001), but the main effects for infidelity status and the sex by infidelity status interactions were not significant (p values>.05). Follow-up ANOVAs revealed that in response to imagined emotional infidelity, females reported more intense hurt feelings (F(l,284) = 9.68, p < .01) and jealous feelings (F(l,284) = 8.05, p < .01) than did males. In response to imagined sexual infidelity, females reported more intense hurt feelings (F(l,285) = 16.18, p < .0001) and anger (F(l,285) = 9.80, p < .01) than did males.

*Relationshi*p *commitment*. Because the nature of the last sexual relationship varied from "just met" to "fiancé/spouse," it could be determined if jealousy reactions differed with respect to the degree of relationship commitment.

Infidelity status (i.e., emotional versus sexual) was not related to the nature of the last sexual relationship for either males [χ^2 (4) = 6.56, p> .10] or females [χ^2(4) = 4.99, p > .25]. The same pattern was found when this variable was dichotomized into uncommitted ("just met," "acquaintance," "dating, not serious") versus committed ("dating serious," "fiancé/spouse") relationships: males [χ^2 (1) 2.19, p > .10], females [χ^2 (1) <1, p> .25].

However, responses to the affective intensity items were correlated with the nature of last sexual relationship; the latter was coded as a continuous variable in terms of degree of commitment [1 (just met) to 5 (fiancé/spouse)]. The nature of this relationship was significantly correlated with seven of the eight imagined infidelity items and the same pattern of correlations was evident for both males and females (thus the male and female samples were combined). For their partner's imagined emotional infidelity, being in a more committed relationship was associated with feeling relatively more hurt than anger (r(255) = - .21, p < .001) and with more intense overall levels of hurt feelings (r(257) = .45, p < .001), anger (r(257) = .25, p < .001), and jealous feelings (r(257) = .33, P < .001). For their partner's imagined sexual infidelity, being in a more committed relationship was not correlated with degree of hurt/anger (r(257) = - .01, p > .50) but was associated with more intense overall levels of hurt feelings (r(257) = .44, p < .001), anger (r(257) = .38, p < .001), and jealous feelings (r(257) = .25, p < .001).

Finally, to determine if the sex difference in the nature of the last relationship was related to the sex differences in intensity of affective responses to partner infidelity, all of the significant effects described in the previous section were reanalyzed using the last relationship variable as a covariate (i.e., in an analysis of covariance, ANCOVA). The results revealed that all of these effects remained significant (p values <.05), with one exception. For imagined sexual infidelity, the sex difference in terms of intensity of reported anger no longer reached the conventional significance level, although the effect was close to this level (F(I,254) = 3.73, p = .055).

Hormone status. Of the 159 females, 61 indicated the use of some form of hormone-based birth control, 77 reported that they did not use this form of birth control, and the remaining subjects did not respond to this item and were thus excluded from the subsequent analyses.

A higher proportion of females using hormone-based birth control reported a sexual relationship during the past week (48%) than did females not using hormone-based birth control (23%) (F(1,123) = 9.23, p < .01). As shown in Table 3, a higher percentage of females not using hormone-based birth control reported that their last sexual relationship was with someone they had just met or with an acquaintance, whereas a higher percentage of females using hormone-based birth control reported that their last sexual relationship was with a serious boyfriend [χ^2 (4) = 12.44, p < .05].

Response to the infidelity item varied with use or lack of hormone-based birth control, although the difference did not reach the conventional significant level [χ^2 (1) = 3.05, p = .08; Φ= .15]. The majority (70%) of females not using hormone-based birth control indicated that the emotional infidelity of their partner was more distressing than their partner's sexual infidelity, whereas only about one-half (56%) of the females using a hormone-based birth control responded in the same way.

Table 3. Hormone-Status Differences in the Nature of Most Recent Sexual Relationship

	Percentage	
Nature of Relationship	Hormone	No Hormone
Just met	0	8
Acquaintance	3	13
Dating, not serious	15	17
Dating, serious	78	53
Fiancé/ Spouse	3	8

Note: Columns do not total to 100, owing to rounding.
χ^2 (4) = 12.44, p < .05

Table 4. Differences in Reported Emotional Reactions to Partner Infidelity across Birth-control Status

	Hormone		*No Hormone*	
Item	*Mean*	*s.d.*	*Mean*	*s.d.*
EMOTIONAL INFIDELITY				
Hurt/Anger	1.58	0.77	1.73	0.99
Hurt	4.39	1.04	3.62	1.35
Angry	3.39	1.04	2.91	1.31
Jealous	3.90	1.04	3.32	1.25
SEXUAL INFIDELITY				
Hurt/Anger	3.30	1.45	3.43	1.35
Hurt	4.30	1.07	3.57	1.34
Angry	4.36	1.00	3.84	1.25
Jealous	3.72	1.20	3.04	1.43

Note: Hurt/Anger scores range from 1 (Much more hurt than angry) to 5 (Much more angry than hurt). All other scores range from 1 [Not hurt (angry, jealous) at all] to 5 [Extremely hurt (angry, jealous)].

Mean scores among females for the reported affective responses to the imagined emotional and sexual infidelity items are shown in Table 4. As with the sex differences analyses, the relative hurt/anger items were analyzed by means of a 2 (hormone status) by 2 (infidelity status) ANOVA, and the remaining items by means of a 2 (hormone status) by 2 (infidelity status) MANOVA. There were no significant main effects or interactions for the relative hurt/anger items (p values > .10). For imagined emotional infidelity, the MANOV A reveal significant main effects for hormone status [$F(3,129) = 4.94$, $p < .01$] and infidelity status [$F(3,129) = 4.33$, $p < .01$], but a nonsignificant interaction [$F(3,129) = 2.37$, $p > .05$]. For imagined sexual infidelity, the main effect for hormone status was significant [$F(3,130) = 4.12$, $p < .01$], but infidelity status [$F(3,130) < 1$] and the interaction [$F(3,130) < 1$] were not.

For imagined emotional infidelity, follow-up ANOVAs revealed that females using hormone-based birth control reported more intense hurt feelings [$F(1,131) = 14.60$, $p<.001$], anger [$F(1,131) = 9.72$, $p < .01$], and jealous feelings [$F(1,131) = 6.97$, $p < .01$] than did females not using hormone-based birth control. The same pattern was found for imagined sexual infidelity: hurt feelings [$F(1,132) = 10.48$, $p < .01$], anger [$F(1,132) = 5.87$, $p < .05$], and jealous feelings [$F(1,132) = 8.66$, $P < .01$]. For imagined emotional infidelity, the significant main effect for infidelity status was because of emotionally jealous females, regardless of hormone status, reporting more intense hurt feelings [$F(1,131) = 4.96$, $p < .05$] and anger [$F(1,132) = 13.03$, $p < .001$] than sexually jealous females.

Finally, because sexual activity during the previous week and the nature of the last sexual relationship varied with hormone status, all of the significant hormone-status effects were reanalyzed using the sexual activity and sexual relationship variables as covariates. The results revealed that three of the six hormone-status effects were now nonsignificant (p values > .10): intensity of anger and jealous feelings for imagined emotional infidelity, and intensity of anger for imagined sexual infidelity. Females using hormone-based birth control still reported more intense hurt feelings for imagined emotional infidelity [F(l,113) = 5.86, p < .05] and for imagined sexual infidelity [F(l,113) = 4.20, p < .05]. Females using hormone-based birth control also reported more intense jealous feelings in response to imagined sexual infidelity, but the effect did not quite reach the conventional significance level [F(l,113) = 3.646, p = .059].

Reexamining the sex differences. Because use of hormone-based birth control covaried with responses to several infidelity items, the sex differences analyses were redone, comparing males with females who were not using hormone-based birth control. As with the initial analysis, the majority of males (73%) indicated that their partner's sexual infidelity was more distressing than their partner's emotional infidelity, whereas the majority of females (70%) indicated the opposite pattern [χ^2 (1) = 36.93, p< .001].

However, nearly all of the significant sex differences in affective responses to imagined partner infidelity were no longer significant. For relative degree of hurt/ anger, females reported relatively more intense hurt feelings than did males for imagined emotional infidelity [F(l,204) = 15.76, p < .0001], but not for imagined sexual infidelity [F(l,205) < 1]. The MANOVA for imagined sexual infidelity revealed nonsignificant effects for sex [F(3,201) = 2.07, p > .10], infidelity status [F(3,201) < 1], and the interaction [F(3,201) < 1]. The MANOVA for imagined emotional infidelity revealed nonsignificant main effects for sex [F(3,200) = 1.83, p > .10] and infidelity status [F(3,200) = 2.12, p > .05], but the interaction was significant [F(3,200) = 4.86, p < .01]. Follow-up ANOVAs revealed a significant interaction for reported intensity of anger [F(l,202) = 9.78, p < .01]. Emotionally jealous females reported more intense anger (mean = 3.25, s.d. = 1.16) to imagined emotional infidelity than did sexually jealous females (mean = 2.13, s.d. = 1.29) [F(l,72) = 13.84, p < .001], but no such difference was found for males [F(l,130) < 1].

Discussion

The standard sex difference in relative distress to a partner's sexual or emotional infidelity was replicated (e.g., Buss et al. 1992). The initial sex differences analysis also indicated that females reported more intense affective responses to partner infidelity, emotional and sexual, than did

males. However, nearly all of the sex differences in reported affective intensity disappeared when males were compared with females who were not using hormone-based birth control. The one effect that remained robust was the standard sex difference, that is, the tendency of males to be relatively more distressed by their partner's sexual infidelity and females to be relatively more distressed by their partner's emotional infidelity. In any case, whether the infidelity was emotional or sexual, in comparison with infidelity of a casual partner, both males and females reported more intense affective distress to a committed partner's infidelity. In other words, even with a sex difference in relative distress to a partner's sexual or emotional infidelity, females and males were similar in that the intensity of affective responses to partner infidelity varied directly with the degree of relationship commitment to that partner, whether the infidelity was emotional or sexual.

Jealousy patterns and intensity of affective responses to partner infidelity also varied across the groups of females who were and were not using synthetic hormones as a form of birth control. For all significant effects, females using synthetic hormones reported more intense affective responses than did other females, and many of these effects remained significant when sexual activity levels and nature of the last sexual relationship were statistically controlled. Moreover, in comparison with other females, a larger proportion of females using synthetic hormones indicated that the sexual infidelity of their most recent partner was more distressing than their partner's emotional infidelity. Even though the latter result did not reach conventional levels of significance, it is consistent, when combined with the affective differences, with the more general finding that use of birth control disrupts behaviors associated with reproduction-related relationships (e.g., Gangestad and Thornhill 1998). Future work will be needed to explore the relation between use of synthetic hormones and the dynamics of reproduction-related relationships. For instance, does the use of progestin result in a more masculine pattern of relationship jealousy? Do the different types of synthetic birth control result in different patterns of response to partner infidelity?

For now, the implication is that combining females who are and are not using hormone-based birth control may lead to an underestimation of the sex difference in relative distress to a partner's sexual or emotional infidelity, and may lead to an overestimation of the magnitude of the sex difference in intensity of affective responses to infidelity.

STUDY TWO

The goal of the second study was to explore further the potential relation between sex hormones and relationship jealousy and to do so with an at-

tempt to replicate two of Gaulin and colleagues' findings (1997): that females show more distress to a partner's emotional infidelity at the time of rising and high fertility risk than during menstruation, and that high levels of estradiol are associated with a tendency toward emotional jealousy. The current study differed in two important respects from that of Gaulin and his colleagues. First, a within-subjects rather than a between-subjects design was used in the current research. In this way, the same females were compared across a single menstrual cycle, as contrasted with Gaulin et al.'s comparison of two groups of females who were at different points in their cycle. Second, rather than estimating estradiol levels based on day in cycle, salivary estradiol levels were assessed and correlated with female responses to partner infidelity. If the hypothesis offered by Gaulin and colleagues is correct, then high estradiol levels should be positively related to a bias toward emotional, as contrasted with sexual, jealousy.

Subjects

The subjects were 57 female general psychology students from the University of Missouri who reported themselves to be menstruating regularly and were not using any form of hormone-based birth control. Potential subjects were identified through their responses to a pre-testing questionnaire administered to all students enrolled in general psychology at the university. Females who met the selection criteria were contacted by means of electronic mail and invited to participate in the study. To increase sample size, the study one constraint of having had sexual intercourse at least once in their lifetime was removed.

Of these 57 females, five were not included in the analyses because after beginning the study they either reported irregularities in their menstrual cycles (which could indicate pregnancy) or they missed more than one testing session. Five additional subjects were discarded because they did not provide sufficient saliva for assay for two or more sessions. The remaining 47 subjects attended at least three testing sessions and provided at least three usable saliva samples. Of these, 31 provided usable samples for all four testing sessions and 16 provided usable samples for three sessions. Because the missing data for these 16 subjects were distributed across the four sessions, the degrees of freedom differ across some of the analyses reported below. Of the 47 subjects, 16 reported that they had never had sexual intercourse. These subjects were instructed to respond to items in terms of their most recent committed relationship.

Procedure

Assessment measures. The same battery of measures used in the first study was administered. The following analyses focused on the same items and responses to a menstrual cycle questionnaire. The questionnaire included

items on length of cycle (average number of days), regularity of cycle length, and number of days since the first day of their last menstrual period (calendars were provided to facilitate the answering of these items).

Administration. The subjects were tested in groups of no more than 20. As each subject arrived, she was asked to be seated at a designated place, which had the materials for saliva collection and the battery of measures. Subjects were read standardized directions and the order of questionnaires and timing of saliva collection was kept uniform across all sessions.

For the saliva collection, participants removed any gum and rinsed their mouths with water before beginning the testing session. After 20 minutes, subjects were asked to stop filling out the questionnaires and saliva collection began. Subjects were instructed to salivate into a polypropelene funnel connected to a cryovial. The cryovials were premarked with the participant's subject number. The sample was unstimulated and the participants allowed all saliva to be collected without interruption for a period of three minutes. During the saliva collection, and in order to facilitate salivation, subjects were invited to imagine something good to eat or to imagine the smell of something good to eat. Samples were frozen within the hour.

Estradiol assay. All samples were assayed by an independent laboratory (Salimetrics, State College, PA) for salivary estradiol using a double antibody radioimmunoassay developed at the Penn State Behavioral Endocrinology Laboratory (see Shirtcliff et al. 2000). Shirtcliff and colleagues found that salivary and plasma estradiol levels were significantly correlated (r = .60) and that independent assays of the same salivary sample yielded estradiol values that varied between 6.5 and 9%. The same procedure described by Shirtcliff et al. was used for the current study.

Saliva samples were thawed, vortexed, and centrifuged at 1,500x g for twenty minutes. Three hundred microliters of the samples was pipetted into the appropriate tubes. One hundred microliters of antiserum dilution was added to all tubes. All tubes were then vortexed and incubated for four hours at room temperature. One hundred microliters of the x3 estradiol [125I] tracer dilution was added to all tubes. Tubes were again vortexed and incubated overnight at 4°c. Afterwards, 500 J.lI of precipitating reagent was added to all tubes. All tubes were then vortexed and incubated for 20 minutes at room temperature. Finally, the tubes were centrifuged at 1,500x g for 20 minutes at room temperature, aspirated or decanted, and counted for two minutes on a counter (LKB Clinigamma).

Data alignment. To enable the assessment of week in cycle effects, subjects' data were aligned based on time in cycle. The subjects provided up to four estimates, one for each testing session, for the number of days since

the first day of their last menstrual period. It was assumed that the smallest of these values was the most accurate, as this represents the shortest lag between the beginning of the subject's most recent menstrual period and a testing session. The associated testing session was designated as cycle week one, the following session as week two, and so forth. If the smallest value was provided for the fourth testing session, then this session was designated as week one, and the first session (which should correspond to the second week of their previous cycle) as week two.

Results

Cycle alignment. Across sessions (unaligned time of measurement), the mean estimate for subjects' length of cycle ranged between 28.0 (s.d. = 5.8) and 28.9 (s.d. = 3.0) days; estimates did not vary across sessions [$F(3,l11) = 1.47$, $P > .10$]. The mean numbers of reported days since the first day of the last menses are shown in Table 5 for session and week in cycle (aligned). A repeated measures ANOV A confirmed that days since last menstrual cycle did not vary across sessions [$F(3,117) = 1.79$, $p > .10$] but did vary across cycle weeks [$F(3,117) = 430.35$, $p < .001$]. Moreover, the means for cycle weeks show a pattern consistent with the alignment objective, that is, to assess subjects during week one of the cycle, week two of the cycle, and so forth.

As can be seen in two righthand columns of Table 5, estradiol levels (pg/ml) show the same pattern, that is, no variation across sessions [$F(3,96) = 2.40$, $p > .05$], and significant changes across cycle weeks [$F(3,102) = 14.56$, $p < .001$].1 The pattern across cycle weeks is generally consistent with typical estradiol fluctuations, that is, low levels early in the

Table 5. Day in Menstrual Cycle and Estradiol Levels

	Day Since Beginning of Cycle		*Estradiol Levels (pg/ml)*	
Time	*Mean*	*s.d.*	*Mean*	*s.d.*
WEEK IN CYCLE				
Week 1	5	3	0.30	0.36
Week 2	12	4	0.61	0.53
Week 3	18	5	0.78	0.58
Week 4	26	6	0.68	0.49
TIME OF MEASUREMENT				
Session 1	16	10	0.63	0.55
Session 2	13	8	0.54	0.49
Session 3	14	9	0.57	0.54
Session 4	17	9	0.66	0.49

cycle, which then rise and finally decline toward the end of the cycle (e.g., Ferin et al. 1993; Laessle et al. 1990). Day in cycle means and standard deviations for week two and week three suggest that for many subjects, peak estradiol levels would have likely occurred between the cycle week two and cycle week three assessments (Ferin et al. 1993). Still, for most of the subjects, cycle week two will represent the follicular phase of the cycle, that is, the time of rising and high fertility risk.

Cycle, sex, and jealousy. Across weeks, between 58% and 63% of the subjects reported that a partner's emotional infidelity was more distressing than his sexual infidelity, a pattern that did not differ across cycle weeks [χ^2 (3) < 1, $p > .50$]. Mean scores across cycle weeks for responses to the imagined emotional and sexual infidelity items are shown in Table 6.[2] These scores were subjected to repeated measures ANOVAs, which revealed only one significant cycle effect: reported intensity of anger in response to a partner's imagined sexual infidelity [$F(3,105) = 2.72$, $p < .05$]. However, given the multiple ANOVAs, and an inconsistent pattern across cycle weeks, this one effect is not considered further.

Estradiol, sex, and jealousy. The relation between estradiol levels and responses to the partner infidelity items was assessed by means of a repeated measures ANOVA. In the first analysis, responses to the basic infidelity item, across each of the four weeks, served as the within-subjects factor, and estradiol level for each of the four weeks served as the independent variables. The results revealed a significant effect for the week two estradiol variable [$F(1,25) = 4.89$, $p < .05$], but nonsignificant effects for the week one

Table 6. Differences in Reported Emotional Reactions to Partner Infidelity across Cycle Week

	Week 1		*Week 2*		*Week 3*		*Week 4*	
Item	*Mean*	*s.d.*	*Mean*	*s.d.*	*Mean*	*s.d.*	*Mean*	*s.d.*
EMOTIONAL INFIDELITY								
Hurt/Anger	1.94	0.93	1.80	0.98	1.85	1.00	2.00	1.11
Hurt	4.03	1.07	4.13	1.08	4.12	0.82	3.93	1.23
Angry	3.15	1.23	2.97	1.11	3.09	1.01	3.20	1.27
Jealous	3.79	1.14	3.67	1.20	3.73	1.04	3.57	1.22
SEXUAL INFIDELITY								
Hurt/Anger	3.76	1.00	3.57	1.11	3.76	1.01	3.68	1.06
Hurt	3.64	1.17	3.67	1.14	3.88	1.11	3.78	1.11
Angry	4.24	0.93	3.87	1.29	4.00	1.10	4.22	1.01
Jealous	3.58	1.23	3.59	1.27	3.67	1.22	3.63	1.35

Note: Hurt/Anger scores range from 1 (Much more hurt than angry) to 5 (Much more angry than hurt). All other scores range from 1 [Not hurt (angry, jealous) at all] to 5 [Extremely hurt (angry, jealous)].

[$F(1,25) = 1.84$, $p > .10$], week three [$F(1,25) = 1.65$, $p > .10$], and week four [$F(1,25) < 1$] estradiol variables. The within-subjects effect of week (i.e., changes in infidelity response across weeks) and the interactions between week and the estradiol variables were nonsignificant (p values> .20). Follow-up analyses indicated that higher week two estradiol levels were associated with a greater tendency toward sexual, as contrasted with emotional, jealousy during cycle week two [$F(1,30) = 4.37$, $p < .05$] and cycle week three [$F(1,29) = 4.21$, $p < .05$]. The follow-up analyses included the estradiol variables for weeks one, three, and four and thus the week two effects are estimated while controlling for estradiol levels at all other weeks.

The same analytic technique was used to assess the relation between the estradiol variables and affective responses to the imagined emotional and sexual infidelity of a partner. The results revealed significant main effects for the cycle week two estradiol variable for relative degree of hurt/ anger in response to a partner's imagined emotional [$F(1,26) = 7.91$, $p < .01$] and sexual [$F(1,26) = 7.34$, $p < .05$] infidelity, as well as a significant effect for the cycle week one estradiol variable for hurt/anger in response to imagined emotional infidelity [$F(1,26) = 5.29$, $p < .05$]. Follow-up analyses indicated that high week two estradiol levels were related to relatively more anger than hurt in response to a partner's emotional infidelity as reported during cycle weeks two and four, and to relatively more hurt than anger in response to a partner's sexual infidelity as reported during weeks two and four (p values < .05). Follow-up analyses also revealed that high week one estradiol levels were associated with relatively more hurt than anger in response to partner's imagined emotional infidelity as reported during cycle weeks two and four.

Finally, there were no significant within-week correlations between the estradiol variable and the reported frequency of sexual activity or the sexual relationship variable (r values - .27 to .10, p values> .10).

Discussion

For each of the four cycle weeks, the majority of females reported that the emotional infidelity of their partner was relatively more distressing than his sexual infidelity, that is, jealousy status did not vary across cycle week. Moreover, there was no consistent pattern in the intensity of affective responses to a partner's imagined sexual or emotional infidelity across cycle weeks. The set of findings did not confirm the results of Gaulin and colleagues (1997). The different methods used in Gaulin and colleagues' study (a between-subjects design) and the current study (a within-subjects design) may account for the different findings; a resolution must await future research.

In any case, the most interesting result is the finding of a consistent relation between salivary estradiol levels and jealousy responses during

cycle week two, a relation that held when estradiol levels for the three other cycle weeks were statistically controlled. Females with a high absolute levels of estradiol during cycle week two tended to report more distress to a partner's imagined sexual infidelity than to his emotional infidelity during this week and the following week (i.e., week three), a finding that is the opposite of that reported by Gaulin et al. (1997). Females with high week two estradiol levels also reported relatively more anger than hurt, and less intense hurt feelings, in response to a partner's emotional infidelity, but relatively more hurt than anger in response to a partner's sexual infidelity. Cycle week one estradiol levels were also related to responses to the hurt/anger item for imagined emotional infidelity, but week one estradiol levels were not related to responses on the basic infidelity item (i.e., tendency toward emotional or sexual jealousy). At this time, a strong interpretation of the specific pattern of relation between cycle week two estradiol levels and responses to the infidelity items is probably premature, in the absence of a replication and given the differences between this study and that of Gaulin and colleagues (1997).

Nonetheless, it appears that estradiol levels during the time of rising and high fertility risk---even when controlling for estradiol levels at other times in the cycle---may result in some changes in the intensity of affective responses to partner infidelity and may bias females toward greater sensitivity to a partner's potential sexual infidelity. However, the latter response may be related to heightened sexual interest during this time in the cycle, rather than to a change in bias toward one type of partner infidelity or the other (Harris 2000; Wood 1994). Either way, the finding of a consistent relation between week two estradiol levels and responses to partner infidelity is consistent with previous findings of changes in female sexual behavior and mate preferences during this time (Bellis and Baker 1990; Gangestad and Thornhill 1998; Penton-Voak and Perrett 2000; Penton-Voak et al. 1999; Thornhill and Gangestad 1999). It appears that patterns of sexual and relationship jealousy can be added to the suite of psychological and sexual behavior changes that occur during the time of rising and high fertility risk for females.

CONCLUSION

The current research adds to the literature on relationship jealousy in several ways. The most interesting and potentially important findings were that female responses to partner infidelity appear to covary with the use or lack of synthetic hormones and with naturally occurring changes in estradiol. The finding that females using hormone-based birth control were more prone than other females to sexual than emotional jealousy and

reported more intense affective responses to partner infidelity has implications for the interpretation of previous research in this area and for future studies. With respect to previous studies, the standard practice of combining groups of females who are using hormone-based birth control with those who are not may have resulted in an underestimation of the magnitude of the sex difference in tendency toward sexual or emotional jealousy, and an overestimation of the sex difference in intensity of affective responses to partner infidelity. The results also indicate that in future studies, investigators should ascertain whether or not female subjects are using hormone-based birth control and assess whether or not patterns of relationship jealousy, and many other reproduction-related constructs, covary with hormone use. Further research will also be needed to determine if different forms of hormone-based birth control (e.g., those that include synthetic estradiol versus those that do not) are differentially related to responses to partner infidelity.

The second study reported here was the first to use a within-subjects design to assess the relation between week in menstrual cycle, estradiol levels, and patterns of response to imagined partner infidelity. The most intriguing result was that responses to partner infidelity were related to estradiol levels and primarily, although not entirely, during the time of rising and high fertility risk, a pattern that is in keeping with studies of female sexual behavior and mate preferences (Bellis and Baker 1990; Chavanne and Gallup 1998; Gangestad and Thornhill 1998; Penton-Voak and Perrett 2000; Penton-Voak et al. 1999; Thornhill and Gangestad 1999; Wedekind et al. 1995). It appears that during the time of rising and high fertility risk, high estradiol levels are associated with changes in relative degree of hurt/anger to different forms of partner infidelity (i.e., emotional or sexual), and to "a tendency toward greater distress over a partner's sexual infidelity than emotional infidelity.

The pattern across studies suggests that for females the expression of any evolved psychological, emotional, or behavioral dispositions regarding issues of sexuality and relationships is potentially moderated by estradiol levels, and that the use of synthetic hormones may disrupt this relation. Of course, the former pattern may have resulted from other hormonal changes (e.g., ratio of estradiol/progesterone), but it is of sufficient interest to merit further research in this area, as well as to merit studies of the potential relation between estradiol levels and changes in female mate preferences across the menstrual cycle.

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NOTES

1. Two estradiol. values were more than 2 standard deviations higher than the next highest value for the same session or week. These values were replaced with the next highest value for the session or week.

2. Of the 32 potential correlations between sexual experience (i.e., comparing subjects who had sexual intercourse with virgins) and responses to the imagined emotional and sexual infidelity items, only one was significant: virgins reported more intense anger to emotional infidelity during cycle week two than did other females [$r(44) = .29$, $p < .05$]. The range of correlations was - .15 to .29, with the median being .09 [$r(43) = .09$, $p > .25$]. On the basis of these null findings, all subjects, regardless of sexual experience, were used in all subsequent analyses.

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