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Endogenous estradiol levels are associated with attachment avoidance and implicit intimacy motivation

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ABSTRACT

Estradiol has been linked with attachment and caregiving processes in humans and other mammals; however, relations between estradiol and personality constructs relevant to intimate relationships have not yet been explored. In the present sample of 100 adult participants (52 men, 48 women), we examined endogenous estradiol levels in relation to two personality constructs that predict comfort with and desire for close, intimate relationships—attachment style and implicit intimacy motivation. In both men and women, estradiol levels were predicted by an interaction between a dimension of attachment style—attachment avoidance—and implicit intimacy motivation. Specifically, the highest estradiol levels were observed among participants whose explicit traits support the expression of their implicit motives, that is, those characterized by both low avoidance and high intimacy motivation. Our findings provide novel evidence that endogenous estradiol levels are associated with relationship-relevant personality constructs in theoretically meaningful ways. These findings also highlight the importance of considering interactions between implicit and explicit personality constructs in the study of the biological bases of personality.

Introduction

Estradiol has been associated with the regulation of attachment and caregiving processes in humans and other mammals (Dwyer, 2008; Lévy and Fleming, 2006). Levels of this steroid hormone are highest in females just prior to ovulation (Johnson and Everitt, 2000), when sexual motivation also tends to peak (e.g., Adams et al., 1978). Estradiol rises during pregnancy, peaks around parturition, and then declines following birth (e.g., Storey et al., 2000). The rise of estradiol prior to delivery is thought to be critical for the onset of maternal behavior (Wynne-Edwards and Reburn, 2000). During this period, for instance, pregnant female macaques demonstrate heightened caregiving behavior toward other females' infants, and such behavior is correlated with rising estradiol levels (Maestripieri and Zehr, 1998). Higher prepartum estradiol levels also predict more effective caregiving toward neonates among red-bellied tamarin monkeys (Pryce et al., 1988). In humans, mothers who maintain high levels of estradiol before and after childbirth report feeling more attached to their infants after birth compared to postpartum women with lower levels of estradiol (Fleming et al., 1997).

Although research with males is more limited, estradiol has also been linked with paternal caregiving behavior (Wynne-Edwards, 2001). For instance, following an estradiol inhibitor during adolescence, male hamsters are less attentive to pups during and after birth (Timonin and Wynne-Edwards, 2008). In humans and nonhuman primates, estradiol levels are higher among expectant fathers compared to non-fathers (Berg and Wynne-Edwards, 2001), particularly among those with prior parental experience (Ziegler et al., 2004).

These findings suggest that state levels of estradiol fluctuate in response to both biological processes (e.g., pregnancy) and social contexts (e.g., parental experience). However, many steroid hormones also exhibit some trait-like properties (e.g., testosterone, Sellers et al., 2007), including those that vary over the course of the menstrual cycle in women (e.g., progesterone, Liening et al., 2010). For instance, Chatterton et al. (2004) obtained several estradiol samples from women over a 15-month period and found that correlations among estradiol levels at the same point of the menstrual cycle ranged from .88 to .96. These results indicate considerable rank-order stability of estradiol over time. That is, individuals who had high estradiol levels (relative to the overall sample) at one assessment also tended to have relatively high levels at later assessments. Estradiol also appears to be relatively stable over time in male subjects (Kaneda and Ohmori, 2005).

Thus, differences in estradiol levels may reflect not only state fluctuations, but also more stable trait-like differences. Such findings raise the intriguing possibility that estradiol is associated with other similarly stable constructs, such as human personality traits. Specifically, the links between estradiol and attachment processes described earlier suggest that estradiol may be particularly relevant for

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personality constructs that are associated with interpersonal relationships. Yet, relatively few studies have examined associations between endogenous estradiol levels and personality traits and, to our knowledge, none have investigated associations between estradiol and personality constructs with direct relevance for close relationships. With respect to personality more generally, there is some evidence that estradiol is positively associated with aspects of reward-seeking, risk-taking, and sensation-seeking (Daitzman and Zuckerman, 1980; Vermeersch et al., 2008, 2009). Although these constructs may have some indirect implications for close relationships, they are not measures of interpersonal processes per se.

In sum, despite the established links between estradiol and attachment processes, it is not yet known whether estradiol is associated with more stable relationship-relevant personality variables in humans. In the present study, we examined endogenous estradiol levels in relation to two personality constructs that predict comfort with and desire for close, intimate relationships: attachment style (Shaver and Mikulincer, 2006) and implicit intimacy motivation (McAdams, 1980). These constructs represent two aspects of personality—the first more explicit or conscious and the second more implicit or nonconscious—that play an important role in human attachment processes and may therefore be associated with endogenous estradiol levels. Although extensive research has documented the role of these personality constructs in relationship processes (e.g., Feeney, 2008; McAdams and Constantian, 1983), to our knowledge our study is the first to examine their association with estradiol levels. In addition, previous work demonstrates that explicit and implicit personality constructs interact to predict important life outcomes, such as satisfaction with work and relationships (Winter et al., 1998). By including both implicit and explicit personality measures in the current study, we had the opportunity to further investigate such interactions in relation to biological processes.

Individual differences in adult attachment are generally represented by two independent, continuous dimensions, attachment-related avoidance and anxiety (Shaver and Mikulincer, 2006). Attachment orientations tend to be relatively stable over time (e.g., Fraley, 2002; Kirkpatrick and Hazan, 1994), although, like many personality traits, they can also show some variability across situations (La Guardia et al., 2000). Individuals with high scores on the avoidance dimension report discomfort with close relationships, including both romantic relationships and parent–child relationships (e.g., Edelstein and Shaver, 2004; Rholes et al., 2006). They dislike physical and emotional intimacy (e.g., Brennan et al., 1998b) and report feeling less close to their children (Rholes et al., 1995). As caregivers, avoidant adults maintain distance from relationship partners (Kunce and Shaver, 1994) and report more self-serving motives for helping others (Feeney and Collins, 2003). Observer ratings of behavior further indicate that avoidant individuals are particularly unsupportive when relationship partners are highly distressed (e.g., Edelstein et al., 2004; Fraley and Shaver, 1998). These findings, linking avoidance with impoverished attachment relationships and poor quality caregiving behavior, led us to predict that higher levels of avoidance would be associated with lower estradiol levels.

The anxiety dimension reflects fears of being alone and preoccupation with intimacy and relationship partners (e.g., Davis et al., 2003). Individuals with high scores on the anxiety dimension are hypervigilant to attachment-related concerns (Mikulincer et al., 2002) and easily distressed by even brief separations from relationship partners (e.g., Fraley and Shaver, 1998). Anxious individuals also tend to be insensitive caregivers, although they are likely to be overly involved or intrusive rather than distant (Kunce and Shaver, 1994), and their motivations for caregiving include trying to keep relationship partners from leaving (Feeney and Collins, 2003). Predictions for anxiety in relation to estradiol levels are less clear than those for avoidance. On the one hand, anxious adults are highly attuned to relationships and often overly involved with their partners, which could be associated with higher estradiol levels. On the other hand, anxious individuals show deficits in caregiving—albeit of a different nature than those of avoidant individuals—which could instead be associated with lower estradiol levels. In the present study, we therefore considered the investigation of attachment anxiety in relation to estradiol levels more exploratory.

Assessments of attachment style are based on people's explicit, self-reported orientations toward close relationships. Implicit motives, in contrast, are thought to be inaccessible to conscious awareness and are assessed via indirect rather than self-report measures (Schultheiss and Pang, 2007). In general, implicit motives are defined as driving forces that shape, organize, and energize behavior toward desired goal states (Murray, 1938). Motives are more fluid than traits and therefore tend to be somewhat less stable over time (e.g., Schultheiss et al., 2008); nevertheless, motives measured at one point in time have been shown to predict more distal life outcomes, such as the likelihood of marriage (Winter et al., 1998). Implicit intimacy motivation is specifically characterized by the goal state of warm, close, and communicative exchange with another person (McAdams, 1980). Individuals with high levels of intimacy motivation are thought to be concerned with the quality of specific close relationships, particularly the deepening and broadening of important relationships, as opposed to the quantity of interpersonal relationships or more superficial aspects of relationships in general (McAdams, 1992).

Numerous studies document the significance of implicit intimacy motivation for close relationship processes. For instance, intimacy motivation is positively associated with self-disclosure (Craig et al., 1994; McAdams et al., 1984), an important component of the development of interpersonal intimacy (Reis and Shaver, 1988). People with high levels of intimacy motivation are perceived by others as warmer, more loving, and more sincere than those with lower levels of intimacy motivation (McAdams, 1980). They think more often about close relationships (McAdams and Constantian, 1983), express greater concern with friends' well-being (McAdams et al., 1984), and spend more time interacting with others (McAdams and Constantian, 1983), particularly in dyads (Craig et al., 1994). When asked to recall significant life experiences, individuals with high levels of intimacy motivation are more likely to focus on memories that emphasize relationships and closeness (King and Noelle, 2005; McAdams, 1982). Given that implicit intimacy motivation is linked with a desire for and a focus on close, intimate relationships, in the present study we expected that higher levels of intimacy motivation would be associated with higher estradiol levels.

However, it is also important to note the importance of interactions between implicit and explicit personality constructs (McClelland et al., 1989; Winter et al., 1998). Winter et al. proposed that the behavioral expression of implicit motives is channeled by more explicit traits. That is, whether and how an implicit motive is expressed depends on the extent to which explicit traits support or hinder such expression. In support of this idea, Brunstein et al. (2005) found that implicit and explicit achievement motivation interacted to predict students' performance on a laboratory achievement task: Students characterized by high levels of both implicit and explicit achievement motivation showed the most improvement on a task in which they believed they were doing poorly. For students with low levels of explicit achievement motivation, implicit achievement motivation had little effect on performance. Brunstein et al. interpret these findings as reflecting the ability of explicit desires for achievement to recruit and focus implicit achievement motives in the service of task performance.

Winter et al. (1998) similarly found that implicit motives and explicit traits operated in a synergistic manner to predict important life outcomes. For instance, implicit power motivation interacted with the explicit trait of extraversion (characterized by talkativeness,

sociability, and assertiveness, John and Srivastava, 1999) to predict career outcomes in sample of college-educated women. Highly power-motivated women were more likely to be in careers that involved influence over others (e.g., business, education), but only if they also scored highly on extraversion, a trait that would facilitate the expression of power in interpersonal contexts. In contrast, among less extraverted women, power motivation was unrelated to career choices.

Taken together, these findings suggest that implicit intimacy motivation might be a predictor of relational outcomes primarily among participants whose explicit traits support the expression of intimacy, that is, those with low levels of attachment avoidance. We therefore expected that the association between intimacy motivation and estradiol would be positive only among less avoidant participants. In contrast, intimacy motivation and estradiol levels should be unrelated, or perhaps even negatively related, among individuals whose explicit traits do not support the expression of intimacy, that is, those with high levels of attachment avoidance.

Method

Participants

Participants were 102 undergraduate students (58 men, 44 women; M age = 18.79, SD = 0.89) who received course credit for their participation. Two female participants were tested but excluded because of missing data on the attachment measure, leaving 100 participants for remaining analyses. Seventy participants identified as Caucasian, 16 as Asian American, 4 as African American, and 10 as of mixed or other ethnicities. Women reported being, on average, 17.95 days (SD = 11.60) past the onset of their last menstruation,[1] and 13 women reported being on oral contraceptives. Participants were asked to refrain from eating, drinking, and brushing their teeth for 1 h prior to the beginning of the experimental session.[2] All procedures were approved by the University of Michigan Institutional Review Board.

Procedure

All participants were tested individually. After informed consent was obtained, participants provided a saliva sample that was later used to assess estradiol levels. Participants then completed the Picture Story Exercise (PSE) to assess implicit intimacy motivation, followed by background and demographic questionnaires, which included information about oral contraceptive use and any other medical conditions that might affect hormone levels. Next, participants completed a series of personality questionnaires that included a measure of adult attachment.

Salivary estradiol—collection and assessment

Participants used a stick of sugar-free chewing gum to collect up to 7.5 mL saliva in a sterile polypropylene vial and then discarded the chewing gum. Participants sealed the vials immediately after each collection and the experimenter placed the vials in frozen storage immediately after the experimental session was complete. Samples were freed from mucopolysaccarides and other residuals by three freeze thaw cycles followed by centrifugation. Salivary estradiol levels were assessed with solid-phase Coat-A-Count 125I radioimmunoassays for estradiol (TKE2) from Diagnostic Products Corporation, Los Angeles. To determine salivary estradiol concentrations, we prepared water-based 1:80 dilutions of all standards (with a resulting range of 0.625 to 20 pg/ml) and controls (cf. Schultheiss and Stanton, 2009; see Schultheiss et al., 2003, for validation data). Eight hundred microliters of the saliva samples, standards, and controls were pipetted into antibody-coated tubes and allowed to incubate overnight. Next, 1-mL radio-labeled tracer was added to each tube and allowed to incubate overnight. Finally, tubes were aspirated and counted for 3 min. Assay reliability was evaluated by including control samples with known hormone concentrations in each assay (Bio-Rad Lyphochecks from Bio-Rad Laboratories, Hercules, CA). The assay manufacturer documents that its assay does not cross-react with estrogens in oral contraceptives. Analytical sensitivity (B0 −3 SD) was at 0.05 pg/mL. Pooled saliva samples had an average concentration of 1.9 pg/mL (men) and 2.6 pg/mL (women), and the inter-assay CVs for these measurements was 25% and 12%, respectively. Analytical recovery was 104% on samples of known concentration (0.48 pg/mL). Participants' saliva samples were counted in duplicate and average intra-assay coefficients of variation was 9.77%.

Implicit intimacy motivation

The PSE was used to assess implicit intimacy motivation. Using instructions specified by Schultheiss and Pang (2007), participants were given 5 min to write creative stories in response to eight ambiguous pictures. The stories were then coded for intimacy motivation using the scoring system developed and validated by McAdams (1992). In this system, each story is first coded for the presence or absence of at least one of two indicators of intimacy: (a) an interaction or interpersonal encounter between two or more characters that engenders a positive affective experience, or (b) reciprocal, non-instrumental communication between two or more story characters. If neither indicator is present, that story receives a score of zero for intimacy motivation and no additional intimacy criteria are coded.

If one or both indicators are present, the story is then coded for the presence or absence of eight thematic categories that reflect characteristics of interpersonal intimacy: *psychological growth and coping* (i.e., characters' relationship facilitates self-fulfillment, adjustment, etc.); *commitment or concern* (i.e., characters experience feelings of loyalty, responsibility for one another); *time–space* (i.e., relationships transcend usual boundaries of space and time); *union* (i.e., physical or metaphorical coming together of characters who have been separated); *harmony* (characters are in synchrony with one another); *surrender* (interpersonal relationships are beyond individual control and characters surrender to outside forces); *escape to intimacy* (relationship is used to physically or metaphorically escape to a more positive, peaceful setting); and *connection with the outside world* (characters are physically or metaphorically connected to nature or other metaphysical elements). Each story receives a score of 1 (present) or 0 (absent) for each of the first two indicators and the additional eight categories. Possible intimacy scores therefore range from 0 to 10 for a given story, and scores were summed across the eight stories for each participant.

Three trained coders first evaluated stories from a subset of 20 participants to establish inter-rater reliability ($\alpha = 0.83$). Discrepancies in coding were discussed and stories from the remaining 80 participants were then evaluated by at least one of the three coders. Inter-rater reliability ranged from 0.85 to 0.98 for the additional 25 participants rated by two coders, and ratings were averaged across coders. Participants' eight PSE stories averaged a total of 956.06 words (SD = 278.91) and contained 9.80 total intimacy images (SD = 3.87). Participants' intimacy scores were positively associated with their total PSE word count, $r = 0.47$, $p < 0.01$, so we computed a proportion intimacy variable by dividing the total intimacy scores by the total

[1] Two participants who reported being more than 130 days past onset of their last menstruation are not included in this average or in analyses involving cycle phase.

[2] Twelve participants reported having oral infections or lacerations, which can lead to blood contamination in saliva and subsequent elevations in steroid hormone levels (Schultheiss and Stanton, 2009). Findings excluding these participants were virtually identical to those presented here.

word count (Schultheiss, 2008). The proportion intimacy scores, used in subsequent analyses, are expressed as the amount of intimacy imagery per 1000 words (see Schultheiss and Pang, 2007).

Adult attachment

The Experiences in Close Relationships (ECR) Inventory (Brennan et al., 1998a) was used to assess individual differences in adult attachment. The ECR *avoidance* subscale ($\alpha = 0.91$) reflects an individual's discomfort with closeness. The *anxiety* subscale ($\alpha = 0.90$) reflects an individual's concern about abandonment. Sample items include "I don't feel comfortable opening up to romantic partners" (*avoidance*), and "I often worry that my partner doesn't really love me" (*anxiety*). Participants rate the extent to which they agree with each statement, using a 7-point Likert scale, ranging from 1 (*disagree strongly*) to 7 (*agree strongly*).

Statistical analyses

Salivary estradiol was the dependent variable for subsequent analyses. Attachment avoidance, attachment anxiety, implicit intimacy motivation, and gender were the independent variables. The Statistical Package for the Social Sciences (SPSS, version 16) was used to conduct all analyses. Mean differences were assessed using *t*-tests (two-tailed) and associations were assessed using correlations and multiple regressions.

Results

Descriptive statistics and correlations among the primary study variables are presented in Table 1. Estradiol levels were significantly lower among men, M = 1.82 pg/mL, SD = 0.57, compared to women, M = 2.18 pg/mL, SD = 0.81, $t(98) = 2.62$, $p < 0.05$. Among women, estradiol levels were somewhat lower among those taking oral contraceptives, M = 1.96 pg/mL, SD = 0.58, compared to those who were not, M = 2.29 pg/ml, SD = 0.88, but this difference was not statistically significant, $t(40) = 1.24$, $p = 0.22$. In addition, time of day was negatively correlated with estradiol levels, $r = -0.34$, $p < 0.01$, reflecting a diurnal decline across participants (e.g., Lenton et al., 1978); however, time of day was unrelated to any of the other predictor variables, *p*'s > 0.31.

To examine the unique contributions of and interactions among the personality variables, we regressed estradiol levels on attachment avoidance and anxiety, intimacy motivation, and (dummy-coded) gender. All continuous variables were centered prior to analysis and all two-way interactions were included. Consistent with earlier analyses, men had lower estradiol levels compared to women, $\beta = -0.28$, $p < 0.01$. The hypothesized effect of avoidance approached significance, $\beta = -0.18$, $p = 0.07$, with somewhat lower estradiol levels observed among more avoidant participants. In addition, and consistent with our hypotheses, the interaction between attachment avoidance and intimacy motivation was a significant predictor of estradiol levels, $\beta = -0.30$, $p < 0.01$. As depicted in Fig. 1, at low levels of avoidance, intimacy motivation was positively associated with estradiol levels, $\beta = 0.39$, $p < 0.01$. In contrast, at high levels of avoidance, intimacy motivation was negatively associated with estradiol levels, $\beta = -0.22$, $p = 0.09$, although this relation did not reach statistical significance. Estradiol levels were therefore highest among participants with low avoidance scores and high implicit intimacy motivation. No other effects or interactions were significant in this analysis, *p*'s > 0.24.

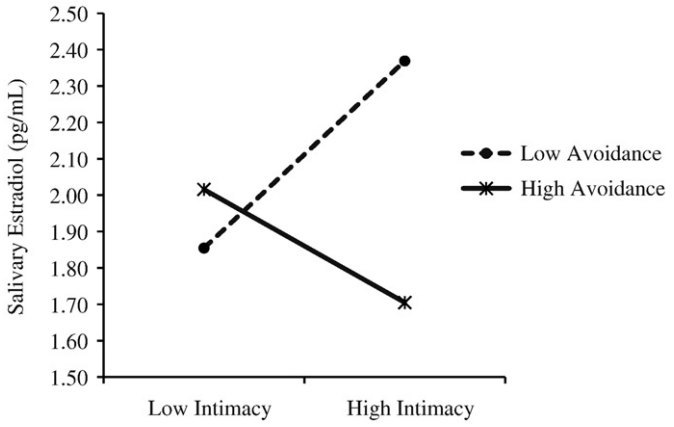

Fig. 1. The relation between attachment avoidance, intimacy motivation, and estradiol levels. Simple slopes are plotted for individuals at one standard deviation above and below the means of attachment avoidance and intimacy motivation (see Aiken and West, 1991).

Including the three-way interactions among the attachment dimensions, gender, and intimacy motivation did not result in a significant increase in the amount of variance explained, $R^2_{change} = 0.04$, $p = 0.39$, indicating that the avoidance × intimacy interaction held for both men and women. In fact, when regression analyses were conducted separately by gender, results were very similar to those presented here and, in particular, the magnitude of the avoidance × intimacy interaction was identical for men and women, *β*'s = −0.39, *p*'s < 0.07.

Results excluding the 13 women on oral contraceptives were also very similar to those from the complete sample, including the significant effects of gender, $\beta = -0.35$, $p < 0.01$ and the avoidance × intimacy interaction, $\beta = -0.34$, $p < 0.01$, although the main effect of avoidance no longer approached significance, $\beta = -0.15$, $p = 0.15$. In addition, including time of day as a covariate did not substantially change any of the findings, including the significant effects of gender, $\beta = -0.26$, $p < 0.01$, the avoidance × intimacy interaction, $\beta = -0.23$, $p < 0.05$, or the main effect of avoidance, $\beta = -0.17$, $p = 0.09$.

Finally, because women's estradiol levels change over the course of the menstrual cycle, we examined the role of cycle phase in our findings. That is, do cycle-related fluctuations in women's estradiol levels underlie the interaction between avoidance and intimacy motivation? To address this question, we included days past last menstruation as a covariate in our regression analysis with the 28 normally cycling women who provided usable day-of-cycle data. Preliminary analyses indicated that the relation between days past last menstruation and estradiol levels best resembled a quadratic function—with estradiol levels rising until approximately day 18 and then declining from that point on—so we included both the linear and quadratic (days^2) terms in our regression. As expected, in this analysis, the days^2 variable was a significant predictor of estradiol levels, $\beta = -0.56$, $p = 0.05$. More importantly, the intimacy × avoidance interaction was significant with these covariates included, $\beta = -0.71$, $p < 0.05$, and was in fact stronger in magnitude than when the covariates were not included, $\beta = -0.67$, $p < 0.05$. Thus, the interaction between avoidance and intimacy motivation could not be explained by women's cycle phase. It is also worth noting that the linear and

Table 1
Descriptive statistics and correlations among study variables.

	1	2	3	4	5
1. Gender					
2. Attachment avoidance	0.00				
3. Attachment anxiety	−0.07	0.06			
4. Proportion PSE intimacy imagery	−0.12	−0.01	0.09		
5. Estradiol levels	−0.26*	−0.14	0.02	0.07	
Mean	–	3.06	3.73	10.46	1.98
Standard deviation	–	0.93	1.00	4.14	0.70

Note. N = 100; gender: 0 = female, 1 = male; proportion PSE intimacy imagery reflects imagery per 1000 words; estradiol levels are reported in pg/mL; *$p < 0.05$.

quadratic day-of-cycle variables were not significantly associated with avoidance and intimacy motivation, p's>0.35, suggesting that these personality variables did not fluctuate over the course of women's menstrual cycles.

Discussion

Findings from the present study contribute to our understanding of the role of estradiol in humans by providing some of the first evidence that endogenous estradiol levels are associated with relationship-relevant personality constructs. Specifically, we found that estradiol was highest among participants with low levels of attachment avoidance and high levels of intimacy motivation. Both of these personality constructs have previously been associated with relationship processes, with avoidance predicting discomfort with closeness (Edelstein and Shaver, 2004) and implicit intimacy motivation predicting a heightened focus on close relationships (e.g., McAdams and Powers, 1981). Although estradiol has also been associated with relationship processes, to our knowledge our study is the first to demonstrate an association between estradiol levels and these particular personality constructs. Moreover, although estradiol levels were higher among women in our study, the interaction between avoidance and intimacy motivation held across gender, consistent with the idea that estradiol is associated with relational processes in both men and women (Wynne-Edwards and Reburn, 2000).

Our findings also make important contributions to the literature on the biological bases of personality and attachment processes. The attachment system is thought to be an evolved, biologically based system (Carter, 1998); however, research linking individual differences in attachment to biological processes generally, and hormones in particular, is still relatively rare, especially in humans (Coan, 2008). Such work has the potential to considerably advance our understanding of attachment processes. For instance, in addition to promoting caregiving behavior, estradiol has been shown to attenuate stress responses (e.g., Del Rio et al., 1994) and to support cognition (e.g., Sherwin, 2006). Perhaps avoidant individuals' lower estradiol levels will ultimately help to explain their difficulties with emotion regulation (Shaver and Mikulincer, 2007) or their poor memory for information about relationships (e.g., Edelstein, 2006).

Although the negative association between attachment avoidance and estradiol levels approached statistical significance in our study, it is important to note that this effect was qualified by an interaction with implicit intimacy motivation. The interaction between these two constructs revealed that, at low levels of avoidance, estradiol was positively associated with intimacy motivation. In contrast, at high levels of avoidance, estradiol was slightly negatively associated with intimacy motivation. Put another way, the highest estradiol levels were observed among participants whose explicit traits supported the expression of their implicit motives, those characterized by both low avoidance *and* high intimacy motivation.

Winter et al. (1998) have argued that explicit personality traits channel the behavioral expression of implicit motives. Our findings provide additional evidence in support of this argument, demonstrating that a biological marker of close relationships is best predicted by the interaction between an explicit trait and an implicit motive. Moreover, despite decades of research on intimacy motivation, the biological correlates of this construct have been largely neglected (Sokilowski and Heckhausen, 2008), particularly in contrast with research on other implicit motives such as power (e.g., Stanton and Schultheiss, 2009). Thus, findings from the current study extend research on implicit motivation into a previously unexplored niche and suggest important ways in which the biological expression of implicit motives may be moderated by explicit personality constructs.

In the current study, attachment anxiety was unrelated to estradiol levels, including in interaction with other personality measures. This may reflect some of the inherent contradictions in anxious individuals' experience: Although anxious individuals are highly concerned with relationships and relationship partners (e.g., Davis et al., 2003), they are nevertheless ineffective caregivers (e.g., Kunce and Shaver, 1994) and generally make unsatisfactory relationship partners (e.g., Campbell et al., 2005). Thus, whereas some aspects of anxiety might be associated with higher estradiol levels, others could reflect the opposite, and this incongruity may underlie the null results obtained in our study.

Because we tested participants at only one point in time, it is difficult to differentiate the contributions of state and trait processes to our effects. Attachment and implicit motives are relatively stable aspects of personality (Fraley, 2002; Schultheiss et al., 2008), but levels of these constructs can nevertheless fluctuate over time and across situations (La Guardia et al., 2000; Schultheiss, 2008). Estradiol similarly demonstrates some trait-like properties (Chatterton et al., 2004), although levels of this hormone also vary over time, particularly among women (Johnson and Everitt, 2000). Thus, the relations among avoidance, intimacy motivation, and estradiol could reflect trait differences in these constructs, or more state-like variations, for instance, if women's menstrual cycle phase affected both their estradiol levels and their feelings about intimacy. However, at least two aspects of our findings argue against a state explanation. First, although we found that women's estradiol levels indeed differed over the course of the menstrual cycle, the interaction between avoidance and intimacy motivation was independent of cycle phase. That is, the interaction between avoidance and intimacy motivation did not fluctuate as a function of menstrual cycle phase, and thus the relation between these constructs and estradiol levels cannot be explained by cycle phase. Second, it is important to note that men's estradiol levels show less daily variability than women's (Lenton et al., 1978) and, in the present study, the interaction between avoidance and intimacy motivation was identical for men and women. These findings also argue against a purely state explanation, although further research on this topic is clearly needed, especially given the relatively small number of normally cycling women in our sample. Future studies could disentangle these issues by assessing estradiol levels and personality variables over multiple time points and across diverse contexts.

It is also difficult to answer questions about causality based on our findings alone. Perhaps variations in the personality constructs we measured resulted from intrinsic differences in endogenous estradiol levels. Alternatively, social context can modulate hormones (van Anders and Watson, 2006), perhaps decreasing estradiol levels over time for those less invested in intimate relationships. In fact, recent experimental evidence suggests that changes in behavior can result in changes in hormone levels (e.g., van Anders et al., 2007). Holt-Lunstad et al. (2008), for instance, found that a supportive-touch intervention among married couples increased both partners' levels of salivary oxytocin, a hormone associated with stress reduction and positive social interactions (Carter et al., 2006). Ultimately, the relationship between hormones and personality is likely to be bidirectional and recursive (Nelson, 2000). Future research could begin to address these issues by experimentally manipulating participants' estradiol levels, state feelings of avoidance or intimacy, or both.

Finally, it is worth noting that, although avoidance and implicit intimacy motivation interacted to predict estradiol levels, these two variables were not significantly correlated with one another. This finding may seem surprising on the surface, given that these two constructs share some conceptual overlap. Yet, the null association is consistent with numerous studies indicating that implicit and explicit motives are typically uncorrelated (e.g., McClelland et al., 1989; Pang and Schultheiss, 2005; Stanton et al., 2010). Why might this be the case? One explanation comes from the different developmental trajectories of these two motivational systems: Implicit motives are thought to develop early in life, supported primarily by nonverbal mechanisms, whereas explicit traits are thought to develop later, and

to be more closely tied to verbal processes (McClelland et al., 1989). In addition, because implicit motives are less accessible to conscious awareness, people are unlikely to draw on them when evaluating their explicit traits.

The statistical independence between traits and motives also necessarily means that, as in our study, some individuals will show concordance between their motives and their traits while others will show discordance. Why do people differ in the extent to which their implicit motives are consistent with their explicit traits? A definitive answer to this question awaits further research; however, Thrash et al. (2007) describe a number of factors that could contribute to consistencies (or lack thereof), including the extent of people's access to their implicit motives, their concern with appearing consistent to others, and their concern with internal consistency. Insofar as people have some conscious access to their implicit motives, are concerned with appearing consistent to others, and are bothered by inconsistencies in their internal experience, implicit motives may be more congruent with explicit traits. Our findings suggest that one such instance of congruence, between attachment avoidance and intimacy motivation, has important implications for estradiol levels. However, our findings cannot speak to the source of such consistencies (or lack thereof), or to the specific role of estradiol in the development of consistencies or inconsistencies. Given the dearth of research addressing these important questions, we believe that this is an area with great potential for future exploration (Stanton et al., 2010).

In conclusion, our findings demonstrate that endogenous estradiol levels are associated with relationship-relevant personality constructs in theoretically meaningful ways. We found that estradiol levels were predicted by an interaction between attachment avoidance and implicit intimacy motivation, two personality constructs that have important implications for close relationship processes. These novel results advance our understanding of the biological bases of personality in humans and suggest many potentially fruitful avenues for future research.

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