Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

Effects of Ovarian Hormones on Women's Sexuality Across Ovulatory Cycle: The In-pair Conception Hypothesis

Sojung Baek
Pennsylvania State University
Nancy Williams
Pennsylvania State University
Mark Shriver
Pennsylvania State University
Alexis Hacker
Pennsylvania State University
Kevin Rosenfield
David Puts
dap27@psu.edu

Pennsylvania State University

Research Article

Keywords: libido, ovulatory cycle, ovarian hormones, sexual desire, sociosexual orientation

Posted Date: November 19th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-11612347/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License

Additional Declarations: No competing interests reported.

Effects of Ovarian Hormones on Women's Sexuality Across Ovulatory Cycle: The In-pair Conception Hypothesis

Authors: Sojung Baek, Nancy I. Williams, Mark Shriver, Alexis Hacker, Kevin Rosenfield, David A. Puts

Abstract

Purpose: Perhaps the most debated questions in human behavioral endocrinology concern fluctuations in women's mating motivations across the ovulatory cycle. What is the nature of these patterns, and what are their evolutionary functions? To address these questions, we investigated relationships between daily urinary ovarian hormone concentrations and sexual desire, as well as moderation by relationship status and partner attractiveness, across an entire menstrual cycle.

Methods: Sixty-eight naturally cycling women provided daily urine samples across one full menstrual cycle alongside daily responses on the Sexual Desire Inventory (SDI) and a version of the Revised Sociosexual Orientation Inventory (SOI-R) modified for daily use. 1,935 samples were assayed for estrone-3-glucuronide, E1G; pregnanediol-3-glucuronide, PdG. Three complementary approaches including multilevel models, 5-day rolling area-under-the-curve models, and continuous-time structural equation modeling were used to test hormone effects and moderation by relationship status (single/uncommitted vs. committed) and partner attractiveness.

Results: Across all three approaches, higher E1G and estrogen-to-progesterone ratio, and lower PdG, predicted greater SDI scores, and relationships between ovarian hormones and both SDI and SOI-R scores were strongest among committed women and at higher partner attractiveness.

Conclusion: Convergent evidence thus indicates stronger hormonal upregulation of sexual desire during the fertile phase of the menstrual cycle within existing partnerships with attractive men. We therefore propose the *in-pair conception hypothesis* – that women possess a precisely calibrated motivational system that functions to increase mating effort during the fertile cycle phase under conditions that would have been advantageous to ancestral reproduction.

Keywords: libido, ovulatory cycle, ovarian hormones, sexual desire, sociosexual orientation

1. INTRODUCTION

Most mammalian females exhibit classic estrus, a distinct phase of the ovulatory cycle characterized by heightened sexual proceptivity and, often, conspicuous physical changes that increase attractiveness to males (Dixson, 1998). Across primates, variation in estrus expression and the visibility of fertility cues has important implications for social organization, including group structure and mating systems (Furuichi, 2023; Marlowe & Berbesque, 2012; Schaik et al., 1999). Humans differ from this pattern in two notable respects: extended sexuality, or sexual activity outside the fertile window, and concealed estrus, or reduced external cues of fertility (Thornhill & Gangestad, 2008). These features have been argued to facilitate pair bonding and cooperative parenting, both of which are central to human social life (Bolin et al., 2021; Strassmann, 1981).

Sexuality, a psycho-behavioral system that regulates the timing and context of sexual behavior, encompasses adaptive design that shapes which targets are perceived as sexually attractive or aversive, when and how attraction is expressed, and the conditions under which it is expressed or suppressed (Gangestad et al., 2022). Women's sexuality is shaped in part by cyclic variation in ovarian hormones. Several evolutionary accounts make distinct predictions about

hormone-linked variation in women's sexuality. The *dual sexuality hypothesis* proposes that unrestricted *sociosexuality* (interest in uncommitted sex) should increase when conception is possible (Gangestad et al., 2022; Thornhill & Gangestad, 2008), under conditions of relatively high estradiol and low progesterone (Shirazi et al., 2019) among women whose primary partners are low in sexual attractiveness (Haselton & Gangestad, 2006; Pillsworth & Haselton, 2006). In contrast, the *motivational priorities hypothesis* predicts a broader reallocation toward mating effort during the fertile window, such that sexual motivation should increase more generally rather than only short-term or extra-pair mating motivation (Roney, 2018; Roney & Simmons, 2013). The *between-cycle account* is conceptually related but proposes that selection primarily favored heightened sexual motivation during ancestrally rare fertile months, when ovulation was not suppressed by pregnancy or lactation (Roney, 2009). Under this account, within-cycle shifts may arise as a secondary consequence rather than as the primary target of selection. Lastly, the *spandrel account* treats within-woman shifts as byproducts of mechanisms that evolved to regulate between-woman differences in reproductive condition, rather than as adaptations specifically designed for cycle contingent shifts in mating psychology (Havliček et al., 2015).

Recent evidence for associations between ovarian hormones and aspects of sexuality remains heterogeneous across studies. Multiple longitudinal studies have reported higher general sexual desire when progesterone is low and, in some cases, when estradiol is relatively high, with evidence for midcycle increases in general desire, in-pair desire, and some sexual behaviors (Arslan et al., 2021; Jones et al., 2018; Marcinkowska et al., 2023; Schleifenbaum et al., 2024; van Stein et al., 2019). Findings for sociosexuality are more mixed. Some studies report modest within-cycle associations, particularly for sociosexual desire and attitudes, with estradiol showing positive and progesterone showing negative associations, or with effects concentrated in sociosexual desire

compared to general desire (Marcinkowska et al., 2021; Shirazi et al., 2019). Other studies, however, find no reliable effects of conception risk on sociosexual attitudes or desires and no cycle shifts in sociosexual orientation, suggesting limited robustness across samples and measures (Jones et al., 2018; Thomas et al., 2021; van Stein et al., 2019). For broader sexuality related outcomes, a recent large moderator-based study suggest that midcycle increases can extend to both in-pair and extra-pair desire (Arslan et al., 2021), although on preregistered diary study could not distinguish the extra-pair increase from non-ovulatory change (Schleifenbaum et al., 2024). Evidence for moderation by partner attractiveness is mixed: one large diary study found none (Arslan et al., 2021), whereas others report moderation of women's extra-pair sexuality (Dinh et al., 2022; Dobson et al., 2026). Evidence for systematic shifts in mate preference is weak (Stern et al., 2021). Taken together, the strongest recent evidence concerns cyclic changes in sexual desire, whereas evidence for sociosexuality, mate preferences, and strategically targeted extrapair motivation remains mixed and often more modest in magnitude (Marcinkowska et al., 2021, 2023; Stern et al., 2021; Stern & Penke, 2022).

A growing methodological literature has exposed critical validity limitations in the approaches commonly used to characterize menstrual cycle phase in behavioral research. Calendar-based counting procedures show poor validity against hormonally confirmed fertile windows, with coefficients rarely exceeding .40–.55 across simulations of 58,000+ cycles (Gangestad et al., 2016), and are further undermined by inter-individual variability in follicular phase length (Fehring et al., 2006). An analysis of over 4,000 daily hormonal measurements across 102 cycles further demonstrated that fewer than 40% of analyzed cycles conform to the timing pattern that LH-test-based phase assignment implicitly assumes (Marcinkowska, 2020). This work

has established that even supplementing counting with a single positive LH result is insufficient to reliably assign sessions to the peri-ovulatory phase.

Direct hormone assay has not sufficiently resolved these problems. Arslan et al., (2023), pooling raw data from eight menstrual cycle studies encompassing more than 1,200 participants and 9,500 time points, found that cycle phase strongly predicted serum estradiol but poorly predicted salivary estradiol, which was biased upward relative to serum-based expectations. Imputing population-average serum hormone changes from confirmed cycle phase was suggested to yield more valid estimates than salivary immunoassay. Relatedly, a recent study tested three widely used phase-determination strategies against a 35-day daily hormone criterion in 96 participants, finding that counting methods, published hormone ranges, and two-timepoint change scores all produce substantial misclassification, with Cohen's kappa values ranging from −.13 to .53 (Gloe et al., 2023). Together, these findings indicate that the field's predominant measurement toolkit systematically attenuates within-person hormone–behavior associations, undermining both statistical power and replicability. Critically, however, this body of work also identifies a clear methodological path forward: dense, daily, within-person hormone sampling anchored to biologically verified cycle events.

The present study capitalizes on these methodological advances by employing a daily urinary hormone protocol across 68 naturally-cycling women for an entire cycle to examine within-person variation in sexuality across the menstrual cycle. Urinary metabolites of estradiol (E1G) and progesterone (PdG) are not only reliable non-invasive substitutes for salivary hormones, but they also track serum profiles with established fidelity (Munro et al., 1991), enable real-time identification of follicular growth, ovulation, and luteal adequacy (Blackwell et al., 1998; De Souza et al., 2010; O'Connor et al., 2006), and support the algorithmic cycle characterization

validated in foundational methodological work (Baird et al., 1991, 1995; Usala et al., 2022). The present study seeks converging evidence throughout multiple analytic approaches: 1) regression based on multi-level modeling, 2) regression based of area-under-the-curve (AUC) modeling, and 3) continuous-time structural equation modeling (CT-SEM). By generating continuous, individual-level E1G and PdG hormonal trajectories, this study aims to provide some of the most methodologically rigorous evidence to date on within-person endocrine correlates of women's sexuality.

2. METHODS

2.1 Participants

Data were collected from 2022 until 2025. Participants were recruited from The Pennsylvania State University, University Park Campus and the Centre County area of Pennsylvania via online and paper flyers. A total of 68 women were enrolled, ranging in age from 18 to 34 years (M = 22.32, SD = 4.18). All participants provided written informed consent prior to participation, and the research protocol was approved by Penn State Institutional Review Board (STUDY00013693). Demographic information collected included age, ethnicity, education, relationship status, and partner attractiveness. Inclusion criteria required that participants: (a) identified as female and predominantly or exclusively heterosexual (Kinsey score 0–2), (b) reported regular menstrual cycles with cycle lengths between 25 and 35 days for the past 6 months, (c) were between 18 and 35 years of age, (d) had a BMI within the healthy to overweight range (18.5–29.9 kg/m^2), (e) had not used hormonal contraceptives within the past 3 months, (f) were not currently pregnant or breastfeeding, (g) had no reported heavy smoking or alcohol use, (h) had no physician-confirmed diagnosis of an eating disorder (anorexia nervosa or

bulimia nervosa), (i) were not taking medications known to affect ovarian hormone levels (e.g., antidepressants, antipsychotics), (j) had no history of medical conditions or surgeries affecting ovarian function, and (k) had no course of antibiotics within the past 6 months (Williams et al., 2019). See Table 1 for details.

Table 1. Frequency Distribution of Age, Ethnicity, and Education

Variable	*n*	%
Age (valid *n* = 68)		
18	8	11.8
19	17	25.0
20	11	16.2
21	4	5.9
22	2	2.9
23	2	2.9
24	5	7.4
25	2	2.9
27	7	10.3
28	2	2.9
29	3	4.4
30	3	4.4
31	1	1.5
34	1	1.5
Ethnicity (valid *n* = 67)		
Black, African, or African American	12	17.9
East Asian	7	10.4
Hispanic or Latino	7	10.4
Middle Eastern	1	1.5
South Asian	5	7.5
Southeast Asian	4	6.0
White, European, or European American	29	43.3
Other	2	3.0
Education (valid *n* = 67)		
High school diploma or equivalency (GED)	40	59.7
Associate degree (junior college)	1	1.5
Bachelor's degree	11	16.4
Master's degree	14	20.9
Doctorate	1	1.5

Relationship status (valid *n* = 67)		
Single	29	43.3
Uncommitted	3	4.5
Committed	35	52.2

Note. % = valid percent, excluding missing values; Singles and uncommitted were merged as one category in the analysis.

2.2 Procedure

Study procedures comprised four sequential components (Table 2): eligibility screening, laboratory check-in, Phase 1, and Phase 2. Eligible participants attended a laboratory check-in, during which they provided written informed consent, completed a demographic survey, and received study materials. Phase 1 began the day following check-in, independent of cycle phase, and consisted of daily at-home online surveys. Phase 1 served to remove any practice or order effects in daily survey responding across cycle phases by effectively randomizing the start of participation relative to cycle phase, thus preventing systematically confounding day of participation with day of the cycle, while facilitating data collection across an entire cycle. Phase 1 concluded at the onset of participants' next menstrual period, at which point Phase 2 began. Phase 2 spanned one complete ovarian cycle from the onset of the cycle (i.e., start of the period) until the start of the next period, and included both daily online surveys and daily first-morning urine sample collection. Participants visited the laboratory weekly to drop off samples.

During the laboratory check-in survey, participants indicated their relationship status (single, uncommitted, committed) and rated their perceived partner attractiveness on a 0 - 100 scale. Participants who were single were instructed to nominate a male acquaintance, in whom they are sexually interested and/or considered a potential partner. The daily at-home sexual desire inventories in Phase 1 and Phase 2 then referred to whichever partner (or nominated acquaintance) had been identified at the check-in survey.

Table 2. Study Procedures

Eligibility Screening	Lab Check-in	Data Collection		Sample Processing	Hormonal Assay
		Phase 1	Phase 2		
Screening eligibility	Consent Instructions Study materials Check-in survey	Daily at-home online survey (practice)	Daily at-home online survey Daily urine sample collection Weekly sample drop-off	Aliquoting and preparing samples for hormonal assay	Enzyme-linked immunosorbent assay; E1G, PdG

2.3 Urine Collection and Hormone assay

Urine samples were assayed for three urinary hormone metabolites: estrone-3-glucuronide (E1G), pregnanediol-3-glucuronide (PdG), and luteinizing hormone (LH). E1G and PdG reflect daily fluctuations in ovarian estrogen and progesterone, respectively, while LH captures the preovulatory surge (Munro et al., 1991). Together, these metabolites enable identification of cycle phase, confirmation of ovulation, and quantification of cumulative hormonal exposure across the cycle (De Souza et al., 2010; Williams et al., 2019).

Participants collected a first-morning void sample on each day of Phase 2 and stored samples in their home freezer until weekly laboratory drop-off visits. Upon receipt, samples were transferred to a −20 °C laboratory freezer. After a participant completed her full cycle, samples were thawed by laboratory personnel, aliquoted, and returned to −20 °C storage. Once data collection was complete for the study, aliquots were thawed a final time and assayed in batch. Samples thus underwent two freeze–thaw cycles prior to assay.

Microtiter plate competitive enzyme immunoassays were used to measure the urinary metabolites E1G and PdG using the techniques of Munro et al., 1991. E1G (R522-2) and PdG

(R13904) assays utilized a polyclonal capture antibody supplied by Coralie Munro at the University of California Davis (Davis, CA, USA). The competitors for these assays are E1G or PdG conjugated to horseradish peroxidase (E1G-HRP and PdG-HRP, respectively). An end-point substrate color reaction is developed with azino-bis-ethylbenzthiazoline sulfonic acid and peroxidase. E1G and PdG standards (Sigma) were used for the standard curve, and high and low internal controls from in-house samples were used. Intra-assay CVs, calculated as the mean CV of duplicate high and low controls, were 4.7% and 3.9% for PdG and 4.5% and 7.7% for E1G. Inter-assay CVs were 18.5% and 17.6% for PdG and 15.2% and 14.6% for E1G. All urine samples were corrected for specific gravity to account for hydration status. Specific gravity has been reported to perform as well as creatinine correction for adjusting urinary hormone concentrations (Miller et al., 2004). Specific gravity measurements were taken with a digital urine specific gravity refractometer (Atago AL-10S; Atago U.S.A. Inc., Bellevue, WA).

2.4 Materials

The Revised Sociosexual Orientation Inventory (SOI-R; Penke & Asendorpf, 2008) measures tendency to engage in sexual activities and relationships without commitment, and the Sexual Desire Inventory (SDI; Spector et al., 1996) measures subjects' partner-directed, self-directed, extra-pair, and general levels of desire to engage in sexual activities. The original SOI demonstrated two-month test-retest reliability of r = .94 (Simpson & Gangestad, 1991), and the SOI-R attitude subscale showed good one-year retest stability (Penke & Asendorpf, 2008). Importantly, the standard SOI-R items assess individual differences in sociosexual attitudes, which may render the instrument less sensitive to the kind of day-to-day within-person fluctuation that daily diary designs are best suited to detect (Marcinkowska et al., 2021). To address this, item

instructions were modified to measure daily state-level variations, so that participants anchored their responses to *"the past 24 hours,"* temporally aligning the both inventories with the 12-24-hour metabolic lag inherent in urinary hormone assessment (Blackwell et al., 1998).

2.5 Data treatment

2.5.1 Hormonal predictors

Raw E1G and PdG values exhibited pronounced positive skew characteristic of urinary hormone metabolites and were natural log-transformed prior to all analyses. The log-transformed values were then within-person mean-centered by subtracting each participant's cycle mean, isolating daily fluctuations from stable individual baselines. The resulting within-person deviations were standardized by the sample-wide standard deviation by computing across all observations and participants, placing E1G, PdG, and all other predictors on a common metric. This way, a one-unit change reflects a sample-wide-SD increase in daily hormone level relative to each woman's own mean. The log estrogen-to-progesterone ratio (log E:P) was computed as the ratio of log E1G minus log PdG on each observation day and subjected to the same within-person centering and sample-wide standardization procedure. All analyses used this sample-wide standardization.

2.5.2 Cycle characteristics

To determine eligibility, we utilized cycle characteristics in all 68 participants, including cycle length, E1G and PdG profiles, the presence of menses, and ovulatory status, i.e. ovulatory, anovulatory, etc. (Williams et al., 2019). The day of ovulation was determined using the algorithm of Baird and colleagues (1991, 1995) and luteal transition day using the algorithm of Usala et al. (2022). Seven cycles that were missing substantial data, precluding accurate cycle classification,

were categorized as incomplete but still included in the analysis. Two cycles were classified as anovulatory and excluded from the analysis. The final sample included 66 individuals with 1847 daily measurements. Detailed classification criteria and frequency of classification are shown in Table 3.

Table 3. Classification of Cycles and Frequency

Cycle	Category Definition	Cycle & Phase Lengths	Frequency
Optimal Ovulatory	• E1G > 35ng/mL • PdG peak 5µg/mL AND ± 1d sum of > 10µg/mL	• Cycle: 21–35 days • Luteal phase: ≥10 days	49
Ovulatory LPD Inadequate	• E1G: > 35 ng/mL • PdG: peak > 2.5 µg/mL AND < 5 µg/mL AND/OR ± 1d sum of < 10µg/mL	• Cycle: 21–35 days • Luteal phase: ≥10 days	6
Ovulatory LPD Short	• E1G: > 35 ng/mL • PdG: peak > 5 µg/mL AND/OR ± 1d sum of > 10µg/mL	• Cycle: 21–35 days • Luteal phase: < 10 days	0
Ovulatory LPD Inadequate and Short	• E1G: > 35 ng/mL • PdG: peak > 2.5 µg/mL AND < 5 µg/mL AND/OR ± 1d sum of < 10µg/mL	• Cycle: 21–35 days • Luteal phase: < 10 days	0
Anovulatory	• E1G: suppressed (< 35 ng/mL) • PdG: peak < 2.5 µg/mL	• Cycle: 21–35 days	1
Oligomenorrheic Ovulatory	• E1G: > 35 ng/mL • PdG: peak > 2.5 µg/mL	• Cycle: 36–89 days	4
Oligomenorrheic Anovulatory	• E1G: suppressed (< 35 ng/mL) • PdG: peak < 2.5 µg/mL	• Cycle: 36–89 days	1
Amenorrheic	• E1G: suppressed (< 35 ng/mL) • PdG: suppressed (< 2.5 µg/mL)	• Cycle: ≥ 90 days	0
Short Ovulatory	• E1G: > 35 ng/mL • PdG: peak > 2.5 µg/mL	• Cycle: < 21 days	0
Short Anovulatory	• E1G: suppressed (< 35 ng/mL) • PdG: peak < 2.5 µg/mL	• Cycle: < 21 days	0

Note. E1G: estrone-1-glucuronide; PdG: pregnanediol glucuronide; LPD: luteal phase defect, a PdG criterion applied to the luteal phase.

2.6 Analytic Models

To characterize the association between daily ovarian hormone levels and sexual outcomes from complementary analytic perspectives, we conducted three sets of analyses. First, we estimated multilevel models (MLMs) regressing each outcome on single-day, within-person-

centered hormone levels, to allow direct comparison with the discrete approaches used in prior published work in this area. Second, because hormonal influences on behavior may not be limited to same-day concentrations but could instead reflect sustained or accumulated exposure across multiple preceding days, we constructed 5-day rolling area-under-the-curve (AUC) measures of within-person hormone exposure and entered these as predictors in a second set of MLMs to test whether cumulative recent hormone exposure, rather than any single day's level, better predicted the outcomes. Third, to move beyond an a priori fixed accumulation window and instead directly model the underlying temporal dynamics linking hormones and behavior, we estimated continuous-time structural equation models (CT-SEM), which formally characterize the persistence of each process (i.e., how quickly hormone and outcome levels revert toward their own process means) and the strength and direction of their reciprocal influence over time, allowing effects at any time interval to be derived from a single fitted model rather than assumed in advance. Together, these three approaches situate our findings within the existing literature, test for cumulative effects of hormone exposure, and characterize the dynamic, bidirectional temporal structure of hormone–behavior coupling.

A priori statistical power was estimated using Monte Carlo simulation in the simr package (Green & MacLeod, 2016), based on the pre-planned design of $k = 60$ participants completing 25 daily observations across one full menstrual cycle ($n = 1{,}500$ person-days; realized $n = 1{,}473$–$1{,}787$ depending on outcome and analytic approach) prior to the data collection. Details on power analysis along with multilevel reliability analysis and missing data treatment strategy can be found in the Supplementary Materials.

2.6.1 Multilevel Modeling

Multilevel models (MLMs) were estimated using the `lmer` function in the *lme4* package (Bates et al., 2015) with REML estimation, treating daily observations nested within participants as the two-level structure. Random intercepts were included for each participant to account for stable between-person differences in baseline sexual desire and sociosexuality; residual variance was left to capture within-person day-to-day fluctuations. Models including random slopes for hormone predictors produced singular fit, likely reflecting the relatively high model complexity given the number of parameters being estimated relative to the number of participants; random intercept-only structures were therefore retained as the more parsimonious specification. Moderation by relationship status (single/uncommitted vs. committed) and by standardized partner attractiveness ratings was tested by entering the interaction terms (hormone × moderator) alongside their constituent main effects. Simple slopes and marginal means were decomposed using the *emmeans* package (Lenth & Piaskowski, 2017); pairwise contrasts were Tukey-adjusted, and conditional hormone slopes were evaluated at −1 SD, mean, and +1 SD of continuous moderators using `emtrends`.

2.6.2 Area-Under-the-Curve Modeling

To index cumulative within-person hormone exposure, we computed a rolling 5-day area under the curve (AUC) for each hormone and observation day using the trapezoidal rule. Rolling window approaches are standard in daily diary hormone research on emotional eating, reducing noise from pulsatile hormone release and capturing delayed hormone-behavior associations (Klump et al., 2013; Mikhail et al., 2021). Prior work has used rolling 5-day means (Klump et al., 2013; Mikhail et al., 2021), which implicitly assume equal spacing between observations. However, this assumption can easily be violated when participants miss collection days. The

trapezoidal method corrects for this by weighting each adjacent pair of observations by the actual elapsed time between them, AUC = $\Sigma[(x_i + x_{i+1})/2 \cdot (t_{i+1} - t_i)]$, producing unbiased cumulative exposure estimates under irregular sampling (Allaway et al., 2015). To our knowledge, this is the first application of trapezoidal rolling AUC to ovarian hormone predictors with sexuality outcome measures. We used a 5-day rolling window, however, to buffer against missing samples. The ±2 day width also roughly matches the typical error in estimating ovulation day and captures the ~2-day lag reported between estradiol and sexual desire (Roney & Simmons, 2013).

Specifically, a minimum of three valid observations per window was required to calculate the rolling 5-day AUC for both E1G and PdG. Hormone values were log-transformed before integration, both to normalize skewed urinary metabolite distributions and to ensure predictor comparability across all three analytic approaches employed in this study (MLM, AUC, CT-SEM). AUC series were then within-person mean-centered to isolate cycle-level fluctuations from stable individual baselines and divided by the sample-wide standard deviation, placing all indices on the same metric as the MLM and CT-SEM predictors; a one-unit change reflects a one-*SD* increase in cumulative within-person hormone exposure relative to each woman's own mean.

2.6.3 Continuous-time Structural Equation Modeling

Here, we treat estradiol and progesterone as hormones that do not act on sexual desire on a single fixed timescale. Both hormones act through rapid, non-genomic membrane-mediated signaling occurring within minutes as well as classical genomic signaling that unfolds over hours to days, and these two modes are interdependent rather than separable (Lösel & Wehling, 2003).

This dual-timescale action has been directly linked to sexual behavior: progesterone's facilitation of sexual receptivity is attributed partly to non-genomic mechanisms (Delville, 1991), and rapid, minute-to-minute fluctuations in brain estrogen availability produce corresponding rapid shifts in sexual behavior in animal models (Taziaux et al., 2007). Human research further suggests that a woman's current hormonal state reflects the trajectory of recent fluctuations, not just same-day levels, and that capturing these dynamics is important for behavioral hormone research (Gloe et al., 2023), particularly given that hormone–behavior associations are often strongest at the within-person level (Mikhail et al., 2025). Standard discrete regression, which assumes a single fixed time point, cannot capture this multi-timescale, interdependent process. CT-SEM instead estimates these dynamics directly and evaluates them across any interval of interest, offering mechanistically precise characterization of how E1G and PdG fluctuations shape sexual desire over subsequent hours and days.

We estimated a series of continuous-time structural equation models (CT-SEM) using the *ctsem* package (version 3.x) in R (Driver et al., 2017; Voelkle et al., 2018). Unlike conventional discrete-time (DT) approaches, which assume a system's states exist only at the specific, evenly spaced intervals at which it happened to be sampled, CT-SEM treats the underlying process as continuously evolving at all points in time, with observed measurements representing snapshots of that ongoing process. This is formalized through a stochastic differential equation in which a drift matrix captures the system's temporal dynamics: auto-effects describe how quickly each variable reverts toward its own process mean following a perturbation with a larger auto-effect indicating a less stable, slower-reverting process. Auto-effects on the diagonal describe how quickly each variable returns toward its own process mean following a perturbation: more negative auto-effects indicate faster return (lower persistence), and values closer to zero indicate slower

return (greater persistence). Cross-effects on the off-diagonal capture how one variable's state shapes the future trajectory of another. Because dynamics are parameterized in continuous rather than discrete time, effects for any time interval, including lags not directly observed in the sampling schedule, can be derived from a single fitted model, rather than requiring a separate model for each lag of interest as in standard discrete-lag regression (Crewther et al., 2021).

For each outcome, a separate three-variable CT-SEM was estimated including two hormone processes, log-transformed within-person-centered, and sample-wide standardized E1G and PdG, and the respective outcome. The DRIFT matrix was specified to allow all auto-effects, the two focal hormone-to-outcome cross-effects (E1G → Outcome; PdG → Outcome), as well as between-hormone cross-effects and reciprocal paths from the outcome to each hormone. SDI-self and SDI-other were square-root transformed to reduce positive skew, as in the multilevel models; SOI-desire and SOI-attitudes were entered as means of sample-wide z-scored items without further transformation. Models were estimated using maximum a posteriori (MAP) optimization with default weakly informative priors (optimize = TRUE, priors = TRUE), and uncertainty was quantified using 95% posterior credible intervals (CIs) derived from 1,000 posterior samples, with parameters whose 95% CI excluded zero considered to show reliable evidence of a nonzero effect.

Because maximum a posteriori estimation of these models can converge to different solutions depending on starting values, each model was estimated from four starting points (the ctsem default and the outcome auto-effect initialized at −0.05, −0.3, and −1.5), and the solution with the highest log-posterior was retained. For each non-default start, a model with the outcome auto-effect fixed at that value was estimated first, and its estimates served as starting values for the full model. To assess whether the data identified the temporal profile of hormone effects, the SDI models were re-estimated with the outcome auto-effect fixed at seven values from −0.03 to

−4, and model fit was compared (Supplementary Figure S8). Fixed values whose log-likelihood fell within 1.92 units of the best-fitting value (the conventional 95% profile-likelihood threshold) were considered equally supported by the data. Discrete-time implied lagged effects at lags of 1–5 days were then derived from the retained continuous-time parameters using ctStanDiscretePars and averaged across all 1,000 posterior samples (k = 66; n = 1,787 observations).

3. RESULTS

3.1 Multilevel modeling

3.1.1 Main Effects of Estrogen and Progesterone

Within-person fluctuations in E1G and PdG predicted daily SDI-self and SDI-other (Table 4). On days when E1G was relatively higher, participants reported greater SDI-self and greater and SDI-other. Conversely, on days when PdG was relatively higher, participants reported lower SDI-self and lower SDI-self. Estrogen-to-progesterone (E:P) ratio yielded consistent results in that a higher E:P ratio on a given day was associated with greater SDI-self and SDI-other.

For SOI-desire, PdG was negatively associated while E1G showed a marginal negative association. This pattern contrasts with the positive E1G associations observed for self- and other-directed desire, but because the effect was only marginal, it should be treated as tentative. Neither hormone predicted daily fluctuations in SOI-attitudes, and E:P ratio predicted neither SOI-desire nor SOI-attitudes.

Table 4. Main Effects of Within-Person Estrogen (E1G) and Progesterone (PdG) on Daily Sexual Desire and Sociosexuality.

Outcome / Predictor	*b*	*SE*	*t(df)*	*p*
SDI-Self				

(*n* = 1,579; *k* = 66; ICC = .30)				
E1G	.039	.013	2.97 (1521)	.003**
PdG	-.031	.013	-2.43 (1515)	.015*
E:P	.032	.011	2.95(1514)	.003**
SDI-Other (*n* = 1,579; *k* = 66; ICC = .24)				
E1G	.033	.012	2.78 (1524)	.005**
PdG	-.030	.012	-2.55 (1517)	.011*
E:P	.029	.010	2.98 (1515)	.003**
SOI-Desire (*n* = 1,579; *k* = 66; ICC = .74)				
E1G	-.016	.009	-1.81 (1513)	.071†
PdG	-.018	.009	-2.06 (1512)	.040*
E:P	.007	.007	1.00 (1512)	.318
SOI-Attitudes (*n* = 1,579; *k* = 66; ICC = .96)				
E1G	.002	.005	0.37 (1511)	.714
PdG	-.008	.005	-1.52 (1511)	.129
E:P	.006	.004	1.33 (1512)	.184

Note. † $p < .10$. * $p < .05$. ** $p < .01$. *** $p < .001$. All models include random intercepts for participant ($k = 66$). Predictors are the within-person centered, sample-wide standardized, and log transformed. ICC = intraclass correlation coefficient from unconditional LME models. *b* = unstandardized regression coefficient; outcomes are sqrt-transformed, except for SOI-attitudes.

3.1.2 MLM - Moderation by Relationship status

Hormone effects on desire were moderated by relationship status (single/uncommitted vs. committed) for SDI-other, and at trend level for SDI-self (Table 5, Figure 1). For SDI-other, E1G positively interacted with relationship status. Simple slopes indicated that E1G positively predicted SDI-other among committed women but not among single/uncommitted women. Committed women also reported greater SDI-other overall than single/uncommitted women (Supplementary Table S10). PdG did not interact with relationship status for SDI-other; its negative association was similar in both groups. For SDI-self, both interactions were trend-level. Simple slopes showed that among committed women, E1G positively and PdG negatively predicted SDI-self. Neither hormone predicted SDI-self among single/uncommitted women.

Unlike SDI-other, SDI-self did not differ overall between committed and single/uncommitted women (Supplementary Table S10).

For SOI-desire, relationship status differentiated overall levels, with committed women reporting lower sociosexual desire than single/uncommitted women (Supplementary Table S10), whereas SOI-attitudes did not differ by relationship status. However, relationship status did not interact with hormone concentrations in predicting SOI-desire or SOI-attitudes (Table 5, Figure 2).

The E1G:PdG ratio showed a moderation pattern by relationship status similar to the individual hormone metabolites, though tested in a separate model. The ratio × relationship status interaction reached trend-level significance for SDI-self but not for SDI-other, SOI-desire, and SOI-attitudes (all *p*s ≥ .11). Simple slopes indicated that among committed women, a higher E1G:PdG ratio was associated with greater SDI-self, greater SDI-other, and greater SOI-attitudes. Among single/uncommitted women, the ratio did not predict any outcome (all *p*s > .37), and no ratio effects emerged for SOI-desire in either group. Relationship status main effects in the ratio models were virtually identical to those in the E1G and PdG models (Supplementary Table S10). These results broadly parallel the individual E1G and PdG findings, with hormonal predictors of SDI consistently stronger among committed women, suggesting the combined E:P ratio captures a similar underlying signal as the separate metabolites.

Table 5. Relationship status (Committed vs. Single/Uncommitted) as a Moderator
Panel A: Hormone × Relationship status interaction terms. Panel B: Conditional simple slopes.

Panel A: Interaction Coefficients

Outcome / Interaction Term	***b***	***SE***	***t(df)***	***p***
SDI-Self (n = 1,543; k = 65)				
E1G × Relationship status	.051	.028	1.84 (1481)	.066†

PdG × Relationship status	-.051	.027	-1.86 (1479)	.064†
E1G:PdG Ratio × Relationship status	.042	.023	1.87 (1478)	.062†
SDI-Other (n = 1,543; k = 65)				
E1G × Relationship status	.087	.025	3.48 (1486)	.001**
PdG × Relationship status	-.006	.024	-0.25 (1482)	.800
E1G:PdG Ratio × Relationship status	.025	.020	1.22 (1480)	.221
SOI-Desire (n = 1,543; k = 65)				
E1G × Relationship status	.023	.019	1.21 (1475)	.225
PdG × Relationship status	.013	.018	0.73 (1475)	.468
E1G:PdG Ratio × Relationship status	.006	.015	0.41 (1476)	.682
SOI-Attitudes (n = 1,543; k = 65)				
E1G × Relationship status	.009	.011	0.83 (1474)	.407
PdG × Relationship status	-.016	.011	-1.53 (1474)	.127
E1G:PdG Ratio × Relationship status	.014	.009	1.60 (1476)	.110

Panel B: Simple Slopes by Relationship status

Outcome	Relationship status	E1G slope b [95% CI]	PDG slope b [95% CI]	E1G:PdG Ratio slope b [95% CI]
SDI-Self	Single/Uncommitted	.016 [-.021, .052]	-.003 [-.045, .040]	.009 [-.026, .043]
	Committed	.067 [.026, .108]*	-.053 [-.086, -.020]*	.051 [.023, .079]***
SDI-Other	Single/Uncommitted	-.001 [-.033, .032]	-.027 [-.065, .011]	.014 [-.017, .045]
	Committed	.087 [.050, .124]***	-.033 [-.062, -.004]*	.039 [.014, .064]**
SOI-Desire	Single/Uncommitted	-.025 [-.049, .000]*	-.027 [-.055, .002]†	.004 [-.019, .027]
	Committed	-.002 [-.030, .026]	-.014 [-.036, .009]	.010 [-.009, .029]
SOI-Attitudes	Single/Uncommitted	-.003 [-.018, .011]	.002 [-.015, .019]	-.003 [-.016, .011]
	Committed	.006 [-.015, .027]	-.014 [-.035, .007]	.012 [.001, .023]*

Note. † $p < .10$. * $p < .05$. ** $p < .01$. *** $p < .001$. I = 65. Reference group = Single/Uncommitted. CIs are 95% confidence intervals from emtrends (emmeans package). Significant simple slopes in bold brackets. E1G:PdG Ratio = log-transformed ratio of estradiol (E1G) to progesterone (PdG) metabolites. E1G and PdG were entered together in the same model; the E1G:PdG ratio was tested in a separate model.

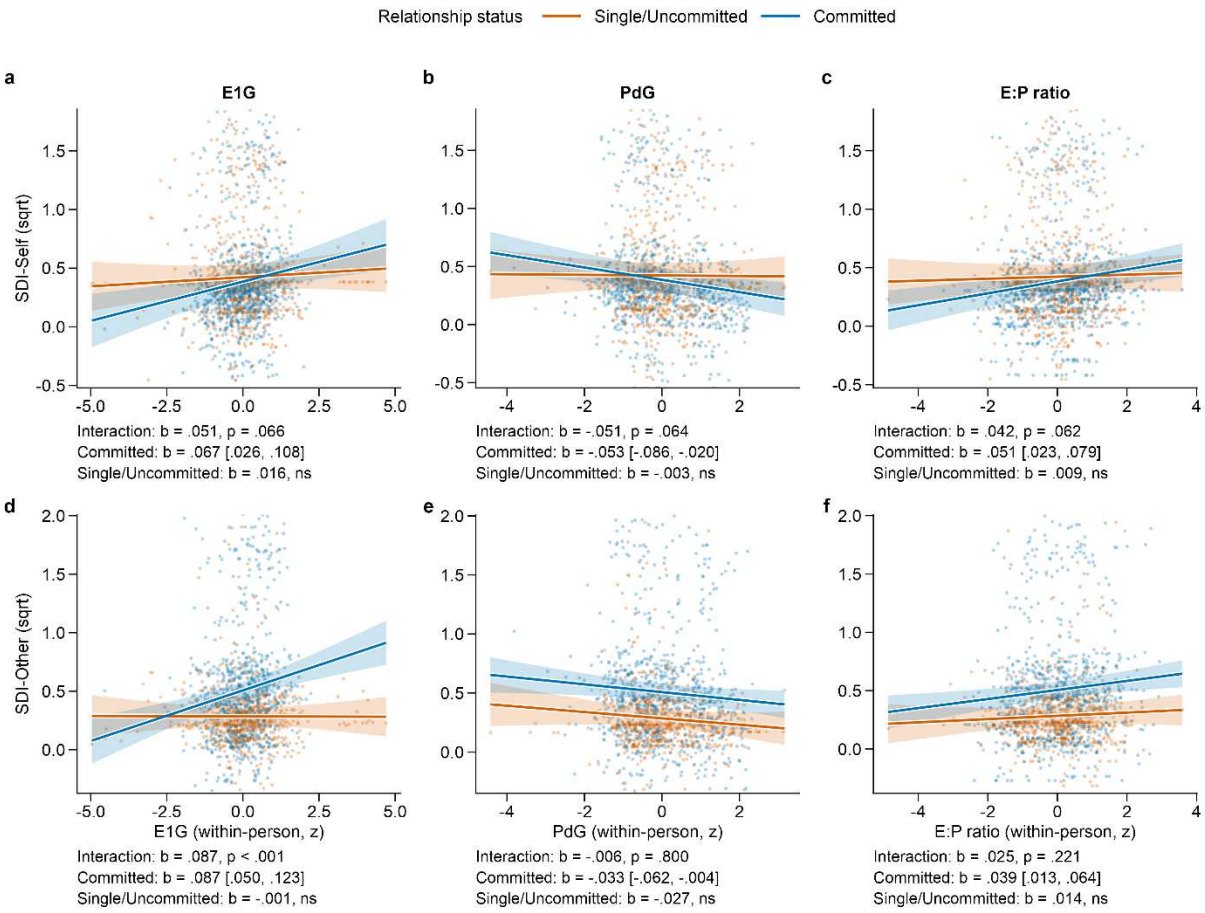


Figure 1. Simple Slope Plots by Relationship status on Sexual Desire Inventory using Multilevel Modeling. Predicted SDI-Self (**a–c**) and SDI-Other (**d–f**) scores as a function of within-person E1G (**a, d**), PdG (**b, e**) and E1G:PdG ratio (**c, f**) in committed and single/uncommitted women, from linear mixed-effects models. Shaded bands represent 95% CIs. Text below each panel gives the interaction estimate (slope difference, committed − single/uncommitted; *b*, two-tailed *p*) and simple slopes; ns: 95% CI includes zero.

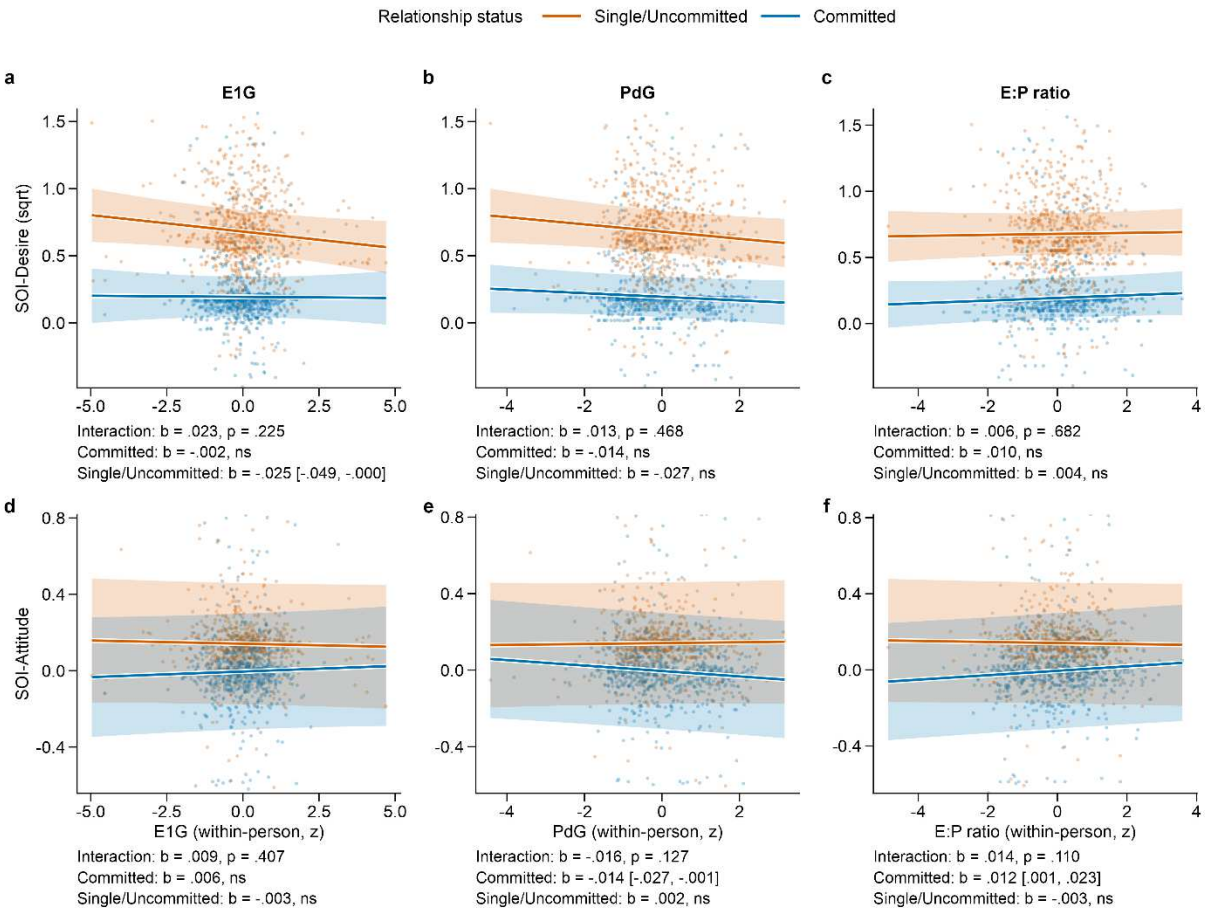


Figure 2. Simple Slope Plots by Relationship status on Sociosexual Orientation Inventory using Multilevel Modeling. Predicted SOI-R Desire (**a–c**) and SOI-R Attitude (**d–f**) scores as a function of within-person E1G (**a, d**), PdG (**b, e**) and E1G:PdG ratio (**c, f**) in committed and single/uncommitted women, from linear mixed-effects models. Shaded bands represent 95% CIs. Text below each panel gives the interaction estimate (slope difference, committed − single/uncommitted; *b*, two-tailed *p*) and simple slopes; ns: 95% CI includes zero.

3.1.3 MLM - Moderation by Partner Attractiveness

Partner attractiveness was examined as a moderator in a sample of $k = 65$ women ($n =$ 1,543 observations; Table 6, Figure 3, 4). Partner attractiveness positively interacted with E1G in predicting SDI-self, SOI-desire, and SOI-attitudes, but not SDI-other. For SDI-self and SOI-attitudes, the E1G effect was absent or near zero at low partner attractiveness but positive at mean and high attractiveness. For SOI-desire, E1G was negatively associated at low partner

attractiveness and near zero at high attractiveness. A PdG × Partner attractiveness interaction was found only for SOI-attitudes, where PdG shifted from a near-zero association at low attractiveness to a significant negative association at high attractiveness. For the remaining outcomes, PdG main effects persisted across partner attractiveness levels regardless of the non-significant interactions.

The E1G:PdG ratio × Partner attractiveness interaction was significant only for SOI-attitudes, and was non-significant for SDI-self, SDI-other, and SOI-desire (all *p*s > .23). Simple slopes indicated that the ratio positively predicted SDI-self at mean and +1 SD attractiveness, but not at -1 SD. A similar pattern held for SDI-other, with positive slopes at mean and +1 SD. For SOI-attitudes, the association with E1G:PdG reversed sign across partner attractiveness levels, from significantly negative at -1 SD to significantly positive at +1 SD, mirroring the crossover pattern already observed for PdG. No significant ratio slopes emerged for SOI-desire at any partner attractiveness level. Overall, the E1G:PdG ratio results largely parallel the individual hormone findings, with the ratio's association with sexual desire and attitudes becoming more strongly positive (or, for SOI-attitudes, shifting from negative to positive) as partner attractiveness increases.

In an exploratory analysis restricted to women in committed relationships, the group to which the dual sexuality prediction most directly applies, we repeated the partner attractiveness models in 34 of the 35 committed women (*n* = 809 observations; one woman did not report partner attractiveness; Supplementary Table S9, Figures S3, S4). E1G positively interacted with partner attractiveness in predicting SDI-self (*b* = .053, 95% CI [.011, .095]), SOI-desire (*b* = .033 [.009, .058]), and SOI-attitudes (*b* = .026 [.009, .044]). For SDI-self, E1G predicted higher desire at mean and high, but not low, partner attractiveness. For sociosexuality, higher E1G was

associated with more unrestricted desire and attitudes at higher partner attractiveness, whereas at low partner attractiveness, higher E1G was associated with lower sociosexual desire ($b = -.035$ [−.069, −.001]). PdG also interacted with partner attractiveness for SOI-attitudes ($b = -.021$ [−.035, −.006]), with the negative association between PdG and sociosexual attitudes strongest at higher partner attractiveness, and the E1G:PdG ratio showed the same pattern (SOI-desire: b = .017 [.00008, .033]; SOI-attitudes: b = .020 [.008, .032]). All E1G and PdG interactions survived Holm correction. When random hormone slopes were added, the E1G interactions and the ratio interaction for SOI-attitudes remained reliable, whereas the PdG interaction for SOI-attitudes (p = .061) and the ratio interaction for SOI-desire (p = .065) did not.

Table 6. Partner Attractiveness as a Moderator
Panel A: Fixed effects for interaction terms.

Outcome / Interaction Term	b	SE	*t*(df)	*p*
SDI-Self (n = 1,543; k = 65)				
E1G × Attractiveness	.041	.016	2.52 (1481)	.012*
PdG × Attractiveness	-.004	.014	-0.26 (1478)	.798
E1G:PdG × Attractiveness	.010	.012	0.85 (1478)	.395
SDI-Other (n = 1,543; k = 65)				
E1G × Attractiveness	.007	.015	0.51 (1484)	.614
PdG × Attractiveness	.000	.013	0.03 (1480)	.979
E1G:PdG × Attractiveness	.000	.011	0.03 (1478)	.975
SOI-Desire (n = 1,543; k = 65)				
E1G × Attractiveness	.023	.011	2.13 (1475)	.034*
PdG × Attractiveness	-.005	.010	-0.54 (1475)	.590
E1G:PdG × Attractiveness	.010	.008	1.20 (1476)	.232
SOI-Attitudes (n = 1,543; k = 65)				
E1G × Attractiveness	.017	.006	2.61 (1474)	.009**
PdG × Attractiveness	-.022	.006	-3.91 (1474)	< .001***
E1G:PdG × Attractiveness	.020	.005	4.05 (1476)	<.001***

Note. n = observations; k = participants. Outcomes are sqrt-transformed (self-directed desire, other-directed desire, SOI-desire) or sample-wide z-scored (SOI-attitudes). Hormones are within-person mean-centered and sample-wide standardized. Attractiveness combines partner or male friend ratings, standardized (M = 0, SD = 1). Random intercepts for participant. †p < .10. *p < .05. **p < .01. ***p < .001.

Panel B: Simple slopes of E1G, PdG, and the E1G:PdG ratio at three levels of partner attractiveness.

Outcome	Attractiveness Level	E1G slope b [95% CI]	PdG slope b [95% CI]	E1G:PdG Ratio slope b [95% CI]
SDI-Self	-1 SD	.001 [-.041, .042]	-.031 [-.071, .009]	.023 [-.010, .056]
	Mean	.041* [.015, .068]	-.035* [-.061, -.009]	.033* [.012, .055]
	+1 SD	.082* [.040, .124]	-.038* [-.075, -.002]	.044* [.012, .075]
SDI-Other	-1 SD	.026 [-.011, .063]	-.030 [-.065, .006]	.028 [-.002, .058]
	Mean	.033* [.009, .057]	-.029* [-.053, -.006]	.029* [.009, .048]
	+1 SD	.041* [.003, .078]	-.029 [-.062, .004]	.029* [.001, .057]
SOI-Desire	-1 SD	-.040* [-.068, -.012]	-.013 [-.040, .013]	-.003 [-.025, .020]
	Mean	-.017 [-.035, .001]	-.019* [-.036, -.001]	.007 [-.008, .022]
	+1 SD	.007 [-.022, .035]	-.024 [-.049, .001]	.017 [-.004, .038]
SOI-Attitudes	-1 SD	-.015 [-.031, .002]	.016 [-.000, .031]	-.015* [-.028, -.001]
	Mean	.002 [-.009, .012]	-.007 [-.017, .004]	.005 [-.004, .014]
	+1 SD	.018* [.002, .035]	-.029* [-.043, -.014]	.024* [.012, .037]

Note. * = 95% CI excludes zero. E1G, PdG, and E1G:PdG ratio slopes reflect within-person associations with outcomes at -1 SD, mean, and +1 SD of standardized attractiveness ratings. E1G:PdG Ratio = log-transformed ratio of estradiol (E1G) to progesterone (PdG) metabolites, tested in a model separate from E1G and PdG.

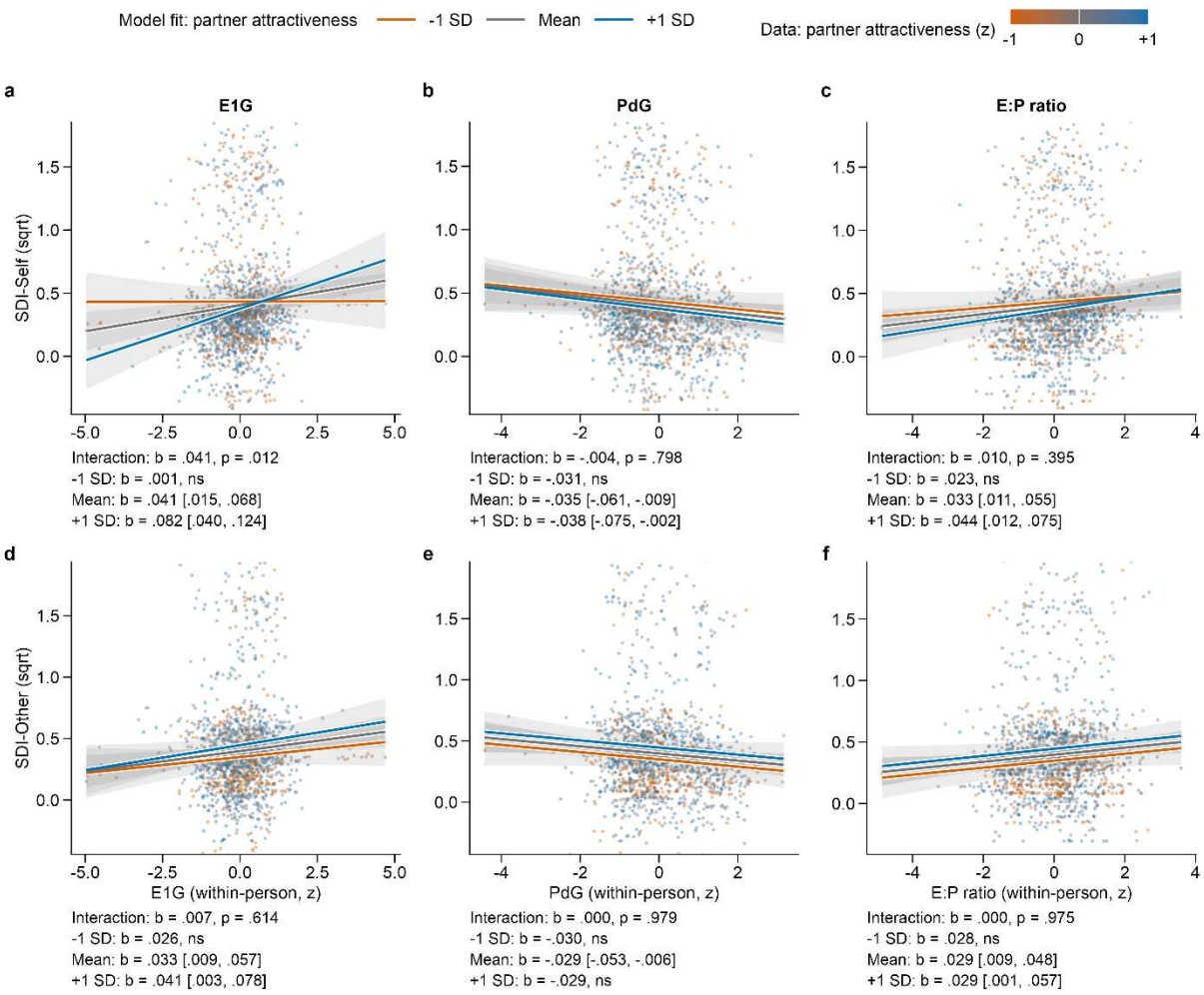


Figure 3. Simple Slope by Partner Attractiveness on Sexual Desire Inventory using Multilevel Modeling. Predicted SDI-Self (**a–c**) and SDI-Other (**d–f**) scores as a function of within-person E1G (**a, d**), PdG (**b, e**) and E1G:PdG ratio (**c, f**) at low (−1 SD), mean and high (+1 SD) partner attractiveness, from linear mixed-effects models. Shaded bands represent 95% CIs. Text below each panel gives the interaction estimate (*b*, two-tailed *p*) and simple slopes; ns: 95% CI includes zero.

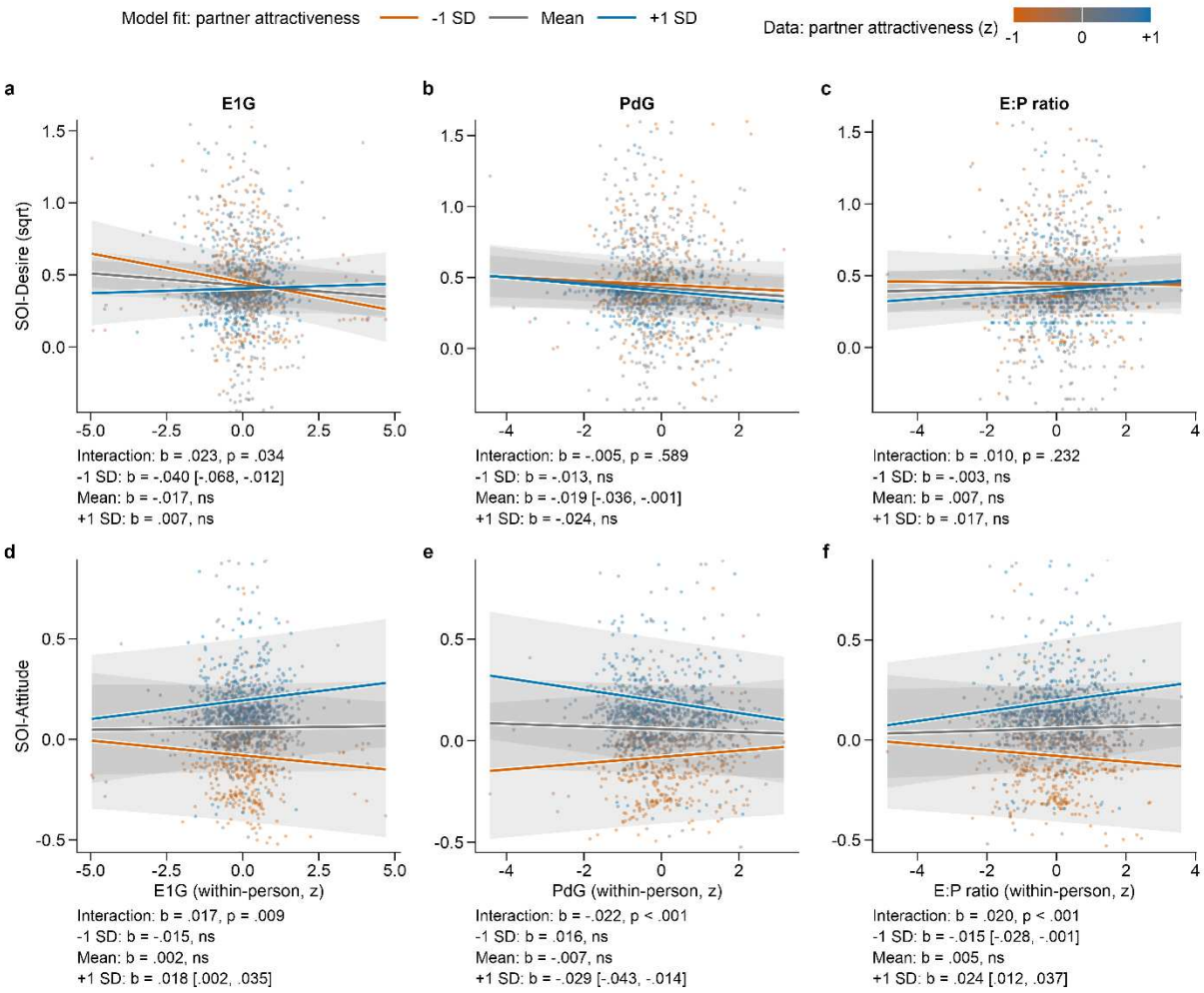


Figure 4. Simple Slope by Partner Attractiveness on Sociosexual Orientation Inventory using Multilevel Modeling. Predicted SOI-R Desire (**a–c**) and SOI-R Attitude (**d–f**) scores as a function of within-person E1G (**a, d**), PdG (**b, e**) and E1G:PdG ratio (**c, f**) at low (−1 SD), mean and high (+1 SD) partner attractiveness, from linear mixed-effects models. Shaded bands represent 95% CIs. Text below each panel gives the interaction estimate (*b*, two-tailed *p*) and simple slopes; ns: 95% CI includes zero.

3.2 5-day Rolling Area-Under-the-Curve Modeling

We estimated rolling 5-day area-under-the-curve (AUC) hormone metrics and tested their associations with sexual desire and sociosexuality in mixed-effects models (n = 1,473 daily observations; k = 66 women; Table 7). Cumulative estrogen exposure ($E1G_{AUC}$) was positively associated with SDI-self, marginally positively associated with SDI-other, and negatively

associated with SOI-desire. Cumulative progesterone (PdG_{AUC}) was negatively associated with SDI-self, and SDI-other, and marginally negatively associated with SOI-attitudes. Cumulative E:P ratio ($E:P_{AUC}$) was positively associated with SDI-self, and SDI-other, and non-significant for SOI-desire and SOI-attitudes. Full results on relationship status and attractiveness moderation are reported in Supplementary Material (Table S2, S3).

Table 7. AUC Main Effects on Sexuality Outcomes

Outcome	Hormone	*b*	*SE*	*t*	*p*
Self-directed desire	E1G	.028	.014	2.05	.040*
	PdG	−.038	.013	−2.87	.004**
	E:P ratio	.033	.011	2.85	.004**
Other-directed desire	E1G	.024	.012	1.95	.052†
	PdG	−.041	.012	−3.45	<.001***
	E:P ratio	.033	.010	3.18	.002**
SOI-desire	E1G	−.021	.009	−2.39	.017*
	PdG	−.014	.009	−1.59	.113
	E:P ratio	−.003	.007	−0.46	.646
SOI-attitudes	E1G	.002	.005	0.46	.648
	PdG	−.009	.005	−1.85	.065†
	E:P ratio	.007	.004	1.50	.135

Note. n = 1,473 daily observations; k = 66 women. Hormone predictors are rolling 5-day trapezoidal AUC values, within-person mean-centered and sample-wide standardized. Self-directed desire, other-directed desire, and SOI-desire are square-root transformed; SOI-attitudes is sample-wide z-scored. Each row reports the coefficient from a separate mixed-effects model with random intercepts for participant. E:P ratio coefficients come from separate models with only the ratio as the within-person predictor. † $p < .10$. * $p < .05$. ** $p < .01$. *** $p < .001$.

3.3 Continuous-Time Structural Equation Modeling

Table 8 presents the continuous-time DRIFT parameters for all four outcomes, and Table 9 and Figure 5 present the corresponding discrete-time implied cross-lagged effects at lags of 1–5 days. For SDI-self, E1G showed a positive hormone-to-outcome cross-effect, indicating that higher estradiol was followed by higher desire on subsequent days, and PdG showed a negative cross-effect, indicating that higher progesterone was followed by lower desire. Both effects grew in

magnitude across the 1–5-day window and had not plateaued by day 5. The same pattern, with a nearly identical temporal profile, was observed for SDI-other (Figure 5a–b). Fixing the desire auto-effect at faster values, which would imply effects that peak within a day and then fade, worsened model fit by more than 50 log-likelihood units for both SDI subscales (Supplementary Figure S8). For SOI-desire and SOI-attitudes, neither hormone showed reliable hormone-to-outcome cross-effects. Across all models, auto-effects were reliably negative, indicating mean-reverting dynamics. E1G → PdG cross-effects were negative in all models but reliable only in the SDI models, whereas PdG → E1G cross-effects were reliable only in the SOI models. In both SDI models, higher desire also predicted subsequently higher PdG, and for SDI-self, higher E1G. We interpret this as reflecting the ovulatory sequence, in which desire rises around ovulation shortly before the luteal rise in progesterone, rather than an effect of desire on hormones.

Table 8. Continuous-Time DRIFT Parameters from CT-SEM Models

Parameter	SDI-Self	SDI-Other	SOI-Desire	SOI-Attitudes
Auto-Effects				
E1G (a_1)	**-.369*** [-.436, -.305]	**-.365*** [-.439, -.303]	**-.332*** [-.402, -.268]	**-.337*** [-.420, -.278]
PdG (a_2)	**-.040*** [-.127, -.006]	**-.038*** [-.113, -.007]	**-.169*** [-.219, -.127]	**-.165*** [-.212, -.127]
Outcome (a_3)	**-.058*** [-.112, -.026]	**-.059*** [-.111, -.026]	**-.363*** [-.558, -.230]	**-.244*** [-.356, -.149]
Between-Hormone Cross-Effects				
PdG → E1G	-.040 [-.091, .014]	-.041 [-.094, .010]	**-.069*** [-.123, -.009]	**-.066*** [-.121, -.005]
E1G → PdG	**-.146*** [-.196, -.097]	**-.141*** [-.188, -.090]	-.025 [-.068, .018]	-.027 [-.071, .013]
Hormone → Outcome Cross-Effects (Focal)				
E1G → Outcome (b_1)	**.015*** [.009, .022]	**.013*** [.008, .018]	-.005 [-.033, .022]	.008 [-.000, .016]
PdG → Outcome (b_2)	**-.018*** [-.023, -.013]	**-.016*** [-.020, -.012]	-.003 [-.024, .019]	-.004 [-.011, .003]
Outcome → Hormone Cross-Effects				
Outcome → E1G (c_1)	**.772*** [.081, 1.511]	.759 [-.040, 1.636]	.035 [-.232, .298]	.354 [-.114, .841]
Outcome → PdG (c_2)	**2.825*** [2.116, 3.585]	**3.215*** [2.378, 4.028]	-.031 [-.212, .162]	.256 [-.077, .595]

Note. Values are posterior means [95% credible intervals] of the continuous-time DRIFT parameters. Bold values marked * have 95% credible intervals that exclude zero. Auto-effects (a_1–a_3) indicate how quickly each process returns to its own mean after a perturbation; more negative values indicate faster return. b_1 and b_2 are the focal hormone → outcome cross-effects; c_1 and c_2 are the reverse outcome → hormone cross-effects. Cross-effects are expressed in the units of the receiving variable per unit of the sending variable, so outcome → hormone effects are not comparable in magnitude to hormone → outcome effects. Each model was estimated from four starting values, and the solution with the highest log-posterior is reported. k = 66 women; n = 1,787 observations.

Table 9. Discrete-Time Implied Cross-Lagged Effects at Days 1–5

Path	Day 1	Day 2	Day 3	Day 4	Day 5
SDI-Self					
E1G → Self-Desire	.014	.024	.031	.036	.038
PdG → Self-Desire	-.018	-.033	-.047	-.057	-.064
SDI-Other					
E1G → Other-Desire	.012	.021	.027	.031	.032
PdG → Other-Desire	-.015	-.029	-.040	-.049	-.055
SOI-Desire					
E1G → SOI-Desire	-.003	-.005	-.005	-.005	-.004
PdG → SOI-Desire	-.002	-.003	-.003	-.003	-.002
SOI-Attitudes					
E1G → SOI-Attitudes	.006	.009	.010	.010	.010
PdG → SOI-Attitudes	-.003	-.006	-.008	-.009	-.009

Note. Values are posterior means of the discrete-time hormone → outcome effects implied by the CT-SEM DRIFT matrices (Table 8) at lags of 1–5 days, computed across all 1,000 posterior samples with ctStanDiscretePars. Coefficients represent the expected change in the outcome (in outcome units) per 1-SD increase in the hormone the given number of days earlier; positive values indicate a positive lagged association and negative values a negative lagged association. For both SDI subscales, effects increased in magnitude across the 1–5-day window. For SOI-desire and SOI-attitudes, effects were uniformly small, consistent with continuous-time cross-effects whose 95% credible intervals include zero.

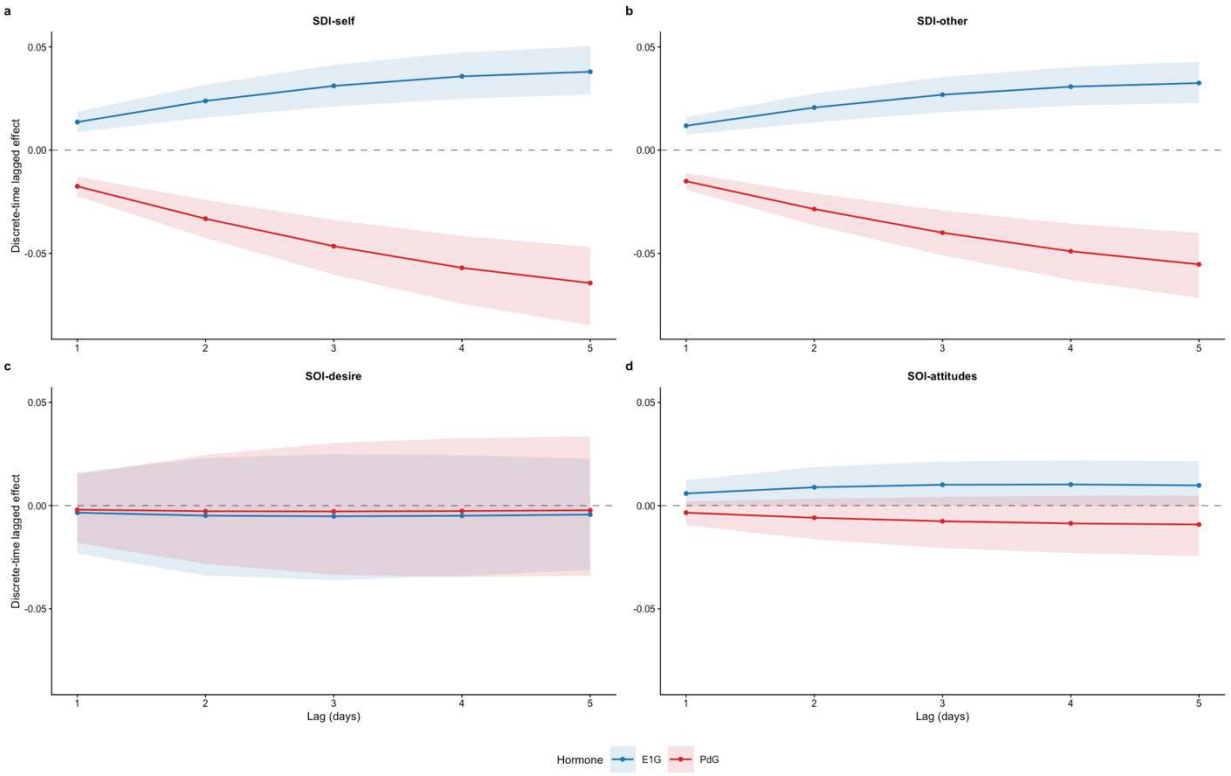


Figure 5. CT-SEM discrete-time hormone effects on sexuality across 1–5-day lags. Discrete-time effects of within-person E1G (blue) and PdG (red) on SDI-self (**a**), SDI-other (**b**), SOI-R desire (**c**) and SOI-R attitudes (**d**) at lags of 1–5 days, from continuous-time structural equation models. Points, posterior means; shaded band represent 95% credible intervals; dashed line represents zero effect. Y-axis scales differ across panels.

4. DISCUSSION

4.1 Ovarian hormones and general sexual desire

Across three complementary analytic approaches including multilevel modeling (MLM), rolling 5-day area-under-the-curve (AUC) models, and continuous-time structural equation modeling (CT-SEM), a highly consistent pattern emerged for the two Sexual Desire Inventory subscales (Spector et al., 1996; Table 10). Higher estrogen (E1G) and, in the two regression-based approaches, higher estrogen-to-progesterone ratio (E:P) predicted greater sexual desire, both self-directed (SDI-self) and other-directed (SDI-other), whereas higher progesterone (PdG) predicted lower desire on both subscales. Only one of these associations, between E1G and SDI-other in the AUC models, fell short of significance, and it trended in the same direction. Convergence across approaches that differ in their assumptions about the timing and accumulation of hormonal signals indicates that this association is not contingent on a particular modeling specification.

Table 10. Summary of Hormone Effects on Sexuality Outcomes Across Analytic Approaches

Outcome	Hormone	Main Effect			Single/ Uncommitted		Committed		Low Attract. (−1 SD)		High Attract. (+1 SD)	
		MLM	AUC	CT-SEM	MLM	AUC	MLM	AUC	MLM	AUC	MLM	AUC
SDI-Self	E1G	+**	+*	+*	ns	ns	+*	ns	ns	ns	+*	+*
	PdG	−*	−**	−*	ns	ns	−*	−*	ns	ns	−*	−*
	E:P	+**	+**	·	ns	ns	+***	+*	ns	ns	+*	+*
SDI-Other	E1G	+**	+†	+*	ns	ns	+***	+*	ns	ns	+*	+*
	PdG	−*	−***	−*	ns	−*	−*	−*	ns	ns	ns	−*
	E:P	+**	+**	·	ns	ns	+**	+*	+†	ns	+*	+*
SOI-Desire	E1G	−†	−*	ns	−*	−†	ns	ns	−*	−*	ns	ns
	PdG	−*	ns	ns	−†	ns	ns	ns	ns	ns	ns	ns
	E:P	ns	ns	·	ns	ns	ns	ns	ns	ns	ns	ns
SOI-Attitudes	E1G	ns	ns	ns	ns	ns	ns	ns	ns	ns	+*	ns
	PdG	ns	−†	ns	ns	ns	ns	−*	ns	ns	−*	−*
	E:P	ns	ns	·	ns	ns	+*	+*	−*	ns	+*	+*

Note. Cells summarize the direction and statistical significance of hormone effects on each sexuality outcome. + = positive effect; − = negative effect; ns = null effect (CI/p well above conventional thresholds); · = not applicable (CT-SEM models were

specified without moderators to preserve estimation stability; the E:P ratio was not modeled in CT-SEM). MLM = multilevel model with same-day within-person hormone values; AUC = multilevel model with rolling 5-day trapezoidal AUC values; CT-SEM = continuous-time SEM DRIFT cross-effect from hormone to outcome. Single/Uncommitted and Committed columns show simple slopes from the partner-status moderation models; Low/High Attractiveness columns show simple slopes at −1 SD / +1 SD of standardized partner or acquaintance attractiveness. E1G and PdG were entered together in the same model; the E:P ratio was tested in a separate model in both MLM and AUC. † p < .10. * p < .05. ** p < .01. *** p < .001

These main effects replicate and extend prior studies pairing repeated hormone measurement with reports of sexual desire (Jones et al., 2018; Marcinkowska et al., 2023; Roney & Simmons, 2013, 2016) and large-scale evidence of a broad periovulatory upregulation of sexual motivation (Arslan et al., 2021). They are consistent with the general sexuality and motivational priorities accounts, under which periovulatory ovarian hormonal change elevates sexual motivation broadly (Roney, 2018; Roney & Simmons, 2013, 2016).

The CT-SEM results also speak to the timing of these effects. For both SDI subscales, the implied effects of E1G and PdG on desire were modest at a 1-day lag and grew over subsequent days without plateauing within the 5-day window (Table 9; Fig. 5a–b), and models constraining desire to faster dynamics fit substantially worse (Supplementary Figure S8)**.** This cumulative profile reflects the different dynamics of the processes involved: E1G returned quickly toward its own baseline after a perturbation (auto-effect ≈ −.37), whereas desire returned slowly (≈ −.06; Table 8), so hormone-linked shifts in desire persisted and accumulated across days rather than tracking same-day concentrations. Sexual desire thus appears to integrate recent hormonal exposure, consistent with slower, genomic modes of steroid action (Lösel & Wehling, 2003) and with evidence that a woman's current hormonal state is better characterized by the trajectory of recent fluctuations than by single-day levels (Gloe et al., 2023). Designs that pair hormone and desire measurements on the same day, or sample at two or three sessions, would therefore capture only part of an effect that unfolds over several days.

Hormone–desire associations were further conditioned on relationship status and partner attractiveness. Simple-slope analyses indicated that the associations observed as main effects were confined almost entirely to women in committed relationships and to women who rated their partner or prospective partner as highly attractive (Table 10). Among single women, and among women rating a less attractive man, hormonal variation was largely unrelated to desire. Likewise, Roney & Simmons, (2016) found that hormonal effects on sexual motivation were larger for partnered women than for single women, and that the inhibitory within-cycle effect of progesterone on in-pair desire was stronger among women who rate their partners as more attractive.

An exploratory analysis restricted to the 34 women in committed relationships, the group to which the dual sexuality prediction most directly applies, tested whether partner attractiveness moderated hormone effects on sociosexuality; higher E1G predicted more unrestricted sociosexuality among women with more, not less, attractive partners (Supplementary Table S9; Supplementary Figure S3, S4). Every interaction whose confidence interval excluded zero ran opposite to the direction predicted by the dual sexuality framework, and the E1G interactions remained reliable when random hormone slopes were added. Given the smaller sample and the limited within-person variance in sociosexuality, these estimates should be interpreted with caution, but their direction is inconsistent with fertile-phase increases in extra-pair interest among women with less attractive partners.

This moderation pattern bears directly on the dual sexuality framework, which predicts that fertile-phase shifts in women's sexual interest should be largest among women whose primary partners are low in sexual attractiveness, and that these shifts should be directed toward extra-pair men of higher putative genetic quality (Dinh et al., 2022; Dobson et al., 2026; Haselton &

Gangestad, 2006; Larson et al., 2012; Pillsworth & Haselton, 2006; Thornhill & Gangestad, 2008). With respect to this extra-pair prediction, the present results show the reverse pattern: hormone-linked elevation in desire was concentrated among committed women and among women rating their partners as highly attractive and was largely absent among women rating a less attractive man. These findings are inconsistent with the hypothesis that periovulatory shifts in sexuality function to increase the probability of fertilization by extra-pair men of higher genetic quality than the long-term partner.

Roney (2022), suggests that women's sexual motivation is regulated by two broad inputs: (1) hormonal fluctuations across the menstrual cycle and (2) social factors related to mating opportunities and relationships dynamics. These inputs are conceptualized to operate independently, and thus Roney & Simmons (2016) interpret reduced influence of hormonal changes on sexual desire in single women as resulting from unpredictable external influences, such as the availability of desirable partners, which may obscure hormonal effects. In other words, in naturally-cycling women, sexual motivation is designed to increase in response to hormone levels associated with high conception risk, but these effects may be weakened by stochastic variation in extrinsic social factors. Our data are partly consistent with this view: committed women reported higher SDI-other on average than single/uncommitted women, although no such difference emerged for SDI-self. Both subscales, however, also showed hormone × relationship status interactions.

Given the clear interactions with relationship status and partner attractiveness observed in the present study, our data suggest an interpretation: These moderating effects are functional, serving to increase sexual motivation when women experience a confluence of conditions that would have been propitious for ancestral reproduction. We call this the "in-pair conception

hypothesis." Like the motivational priorities hypothesis, the in-pair conception hypothesis posits a strategic allocation of mating effort during the fertile window of the menstrual cycle. However, the shift in mating effort is, by design, greatest in women experiencing conditions that were advantageous for reproduction in our female ancestors, particularly being pair-bonded and having a high-quality mate or potential mate.

4.2 Ovarian hormones and sociosexual orientation

Associations with sociosexuality were smaller in magnitude and less consistent across approaches, but they were not unstructured (Table 10). Unrestricted sociosexual attitudes increased with E:P and decreased with PdG, specifically among committed women and women with attractive partners. Sociosexual desire exhibited the opposite sign, decreasing at higher E1G, predominantly among women rating a less attractive man and, less consistently, among uncommitted women.

These estimates require caution. Within-person variance was limited for sociosexual desire and negligible for sociosexual attitudes (Supplementary Table S1), constraining the signal recoverable by any daily-sampling design. This is consistent with the characterization of sociosexuality as a relatively stable individual-difference construct: the original SOI shows high two-month test–retest reliability (Simpson & Gangestad, 1991), and the SOI-R attitudes subscale is stable over one year (Penke & Asendorpf, 2008). Standard SOI-R items assess attitudes and desires without reference to a specific time window (Penke & Asendorpf, 2008), which may render them less sensitive to the day-to-day fluctuation that daily diary designs are best suited to detect. Although items were re-worded in the current study to anchor responses to the preceding 24 hours, the variance decomposition indicates that sociosexual orientation resists short-term hormonal

influence irrespective of item framing. Given the minimal within-person variance in these outcomes, the sociosexuality findings, including the moderation effects, should be regarded as tentative.

Nevertheless, to the extent that sociosexuality tracks hormonal fluctuation across the cycle, the present results are difficult to reconcile with the dual-sexuality framework. The SOI-R indexes interest in uncommitted sex rather than extra-pair interest specifically. Among partnered women, however, the two are effectively equivalent, because sex with a long-term partner is committed by definition. Neither observed pattern conforms to the prediction. Unrestricted sociosexual attitudes were elevated at a higher E:P ratio and lower PdG, but among committed women and women with attractive partners rather than among women whose partners were less attractive. Sociosexual desire moved in the opposite direction: among women rating a less attractive man, the group closest to the one the framework identifies, higher E1G was associated with lower, not higher, sociosexual desire, and a similar but less consistent association appeared among uncommitted women. No periovulatory shift toward sexuality in uncommitted relationship was detectable under the conditions in which the framework predicts it should be most pronounced. Sociosexuality instead displayed the same partner-attractiveness contingency observed for general sexual desire.

4.3 Converging implications, caveats, and future directions

Considered jointly, the two lines of evidence converge. Endocrine profiles of elevated conception probability predicted greater general sexual desire, an effect concentrated among committed women and women with attractive partners, whereas interest in uncommitted sex showed no corresponding increase among women whose partners were less attractive, the group in which the dual-sexuality framework predicts the largest fertile-phase shift toward extra-pair

men. The observation that all measured forms of sexual desire showed similar patterns suggest hormonal regulation of libido overall. The stronger hormonal tracking of general desire and weaker, context-dependent tracking of sociosexuality converges with evidence that estradiol and progesterone influence sexual desire broadly rather than desire specifically for uncommitted sexual relationships (Jones et al., 2018). Studies that have reported hormone–sociosexual desire associations assessed sociosexuality at two or three scheduled sessions rather than daily (Marcinkowska et al., 2021; Shirazi et al., 2019), which given the cumulative timing of hormonal effects noted above, complicates direct comparison. Evidence from large studies on partner-attractiveness moderation is itself mixed: one diary study found no moderation of cycle shifts by partner sexual attractiveness (Arslan et al., 2021), whereas others report moderation of women's extra-pair sexual interests (Dinh et al., 2022; Dobson et al., 2026). Those studies measured attraction to men other than the partner directly, whereas the present study assessed interest in uncommitted sex and desire for sex with another person, neither of which is specific to extra-pair targets.

Collectively, the findings more closely align with the motivational priorities account than the dual-sexuality framework, but they also suggest a more precisely calibrated motivational system. Ovarian hormones appear to upregulate sexual motivation most strongly within committed relationships with attractive partners (Roney, 2018; Roney & Simmons, 2013, 2016). Our findings are also perhaps compatible with the between-cycle account (Roney, 2009; Roney & Simmons, 2013), which the present single-cycle design cannot test: within-cycle variation is observable, but whether such variation was itself a target of selection is not. These findings are difficult to explain as a spandrel, or byproduct, of hormonal fluctuation (Havlíček et al., 2015). A byproduct account

predicts similar hormone–desire associations regardless of context, whereas the associations we observed varied systematically with relationship status and partner attractiveness.

A feature of our study design may also contribute to differences from earlier studies. Participation began at a random point in the cycle, and hormones and diaries were analyzed for the complete cycle that began at the next menses. When data collection starts at a fixed cycle point, such as menses, or follows a fixed order of cycle phases, time in the study is confounded with cycle phase. Because self-reports of internal states, such as mood and physical symptoms, tend to be elevated when first given and to decline over repeated assessment (Shrout et al., 2018), starting data collection at a fixed cycle point can mask or mimic cyclic shifts, depending on where in the cycle reporting begins. Here, the first days of reporting fell in a run-in period of variable length before hormone sampling began, and so were not tied to any cycle phase.

However, several limitations temper these conclusions. First, no measure captured sexual desire directed specifically toward the long-term partner: SDI-other indexes desire for sex with another person, not necessarily the partner, and the SOI-R indexes interest in uncommitted sex. The moderation by relationship status and partner attractiveness nonetheless suggests that the fertile-phase increase in sexual desire would most strongly influence proceptivity and receptivity directed toward the long-term partner. Second, attractiveness ratings referred to participants' own partners or, among single women, a self-nominated male friend. Relationship status and partner attractiveness were also modeled as separate moderators; the three-way interactions required to isolate partnered women with less attractive partners, the group central to the dual-sexuality prediction, were underpowered and are reported as exploratory (Tables S7–S8). It is possible that the moderating effects of being in a committed relationship and of having an attractive social partner (whether currently in a romantic relationship with him or merely being interested) are

additive rather than interactive. Third, self-perceived attractiveness, which has been reported to rise near ovulation (Haselton & Gangestad, 2006) and to covary with daily sexual desire (Gupta et al., 2024), was not assessed. Finally, the dual-sexuality framework concerns interest in extra-pair men of higher genetic quality than the current partner, and no within-cycle study to our knowledge, including the present one, has characterized the traits of such targets. The absence of an extra-pair shift here therefore constitutes evidence against the framework as operationalized rather than a demonstration that no such shift exists.

4.4 Conclusions

The current study examined sexual desire in relation to daily ovarian hormone fluctuations across a full menstrual cycle in 68 naturally cycling women, employing daily urinary hormone assessment, among the most methodologically rigorous approaches available for capturing within-cycle endocrine dynamics. Findings most consistently support ovarian steroid effects on general sexual desire: E1G positively and PdG negatively predicted self-directed and other-directed sexual desire, with the E:P ratio showing positive associations and reinforcing this pattern. Sociosexual outcomes showed more limited hormonal sensitivity, likely reflecting their trait-like stability. Moderation analyses on relationship status and partner attractiveness revealed relationships that were largely inconsistent with the dual-sexuality framework : Sociosexual attitudes exhibited evidence of progesterone-mediated cyclic shifts only in women with attractive male partners/romantic interests, whereas the dual-sexuality hypothesis predicts cyclic shifts in extra-pair sexual interest especially for women with less attractive mates (Dinh et al., 2022; Gangestad & Haselton, 2015). Likewise, E:P ratio showed a directional reversal in its association with on sociosexual attitudes across attractiveness levels, a pattern not captured by either hormone alone,

shifting from a negative association among women with less attractiveness partners to a positive association among those with more attractive partners.

These findings speak to longstanding questions in evolutionary biology regarding the nature of human estrus and women's extended sexuality, whether ovarian hormones primarily function to elevate general mating motivation across the cycle or to specifically redirect desire toward attractive extra-pair partners during the fertile window (Gangestad & Dinh, 2022; Roney & Simmons, 2013). The present evidence leans toward the former, while acknowledging that target-specific hormonal effects may emerge more clearly in designs that oversample partnered women, incorporate self-perceived attractiveness, and assess the perceived attractiveness of potential extra-pair individuals.

The methodological rigor of daily urinary hormonal assays across an entire cycle and converging evidence from three analytic approaches focusing on discrete, cumulative, and divergent hormonal effects provide an exceptionally clear picture of the contexts in which sexual desire is mostly strongly influenced by ovarian hormones: Being in a committed relationship and being attracted to one’s romantic partner or potential romantic partner. Because these conditions are likely to have been propitious for reproduction in our female ancestors, we hypothesize that their moderating effects function to calibrate sexual motivation – a hypothesis we call the in-pair conception hypothesis. Future work may build on the present design to test this hypothesis alongside others and advance a functional understanding of the endocrine regulation of human sexuality.

ACKNOWLEDGMENTS

We thank Emma Russell, Adrija Krishnamoorthy, Hannah Evans, Courtney K. Elmore, Sarah C. Bouley, Jayden O'Neel, Hannah C. Yurack, Rachel Buterbaugh, Reagen M. Dixon, Amber Penley, Emily E. Moran, Leah G. Rogers, Sabrina E. Smith, Stefanie Rose, Allyssa M. McDougal, Julie Colarusso, Cleo Gesenberg, Sabrina L. Cross, Ericka Pica, Leah Ji, Rae Mutu, LeMhai Baity, Nature Belluscio, and Sadie Barlett for their contributions in data curation.

REFERENCES

Allaway, H. C. M., Williams, N. I., Mallinson, R. J., Koehler, K., & De Souza, M. J. (2015). Reductions in urinary collection frequency for assessment of reproductive hormones provide physiologically representative exposure and mean concentrations when compared with daily collection. *American Journal of Human Biology*, *27*(3), 358–371. https://doi.org/10.1002/ajhb.22649

Arslan, R. C., Blake, K., Botzet, L. J., Bürkner, P.-C., DeBruine, L., Fiers, T., Grebe, N., Hahn, A., Jones, B. C., Marcinkowska, U. M., Mumford, S. L., Penke, L., Roney, J. R., Schisterman, E. F., & Stern, J. (2023). Not within spitting distance: Salivary immunoassays of estradiol have subpar validity for predicting cycle phase. *Psychoneuroendocrinology*, *149*, 105994. https://doi.org/10.1016/j.psyneuen.2022.105994

Arslan, R. C., Schilling, K. M., Gerlach, T. M., & Penke, L. (2021). Using 26,000 diary entries to show ovulatory changes in sexual desire and behavior. *Journal of Personality and Social Psychology*, *121*(2), 410–431. https://doi.org/10.1037/pspp0000208

Baird, D. D., McConnaughey, D. R., Weinberg, C. R., Musey, P. L., Collins, D. C., Kesner, J. S., Knecht, E. A., & Wilcox, A. J. (1995). Application of a Method for Estimating Day of

Ovulation Using Urinary Estrogen and Progesterone Metabolites. *Epidemiology*, *6*(5), 547.

Baird, D. D., Weinberg, C. R., Wilcox, A. J., McConnaughey, D. R., & Musey, P. I. (1991). Using the ratio of urinary oestrogen and progesterone metabolites to estimate day of ovulation. *Statistics in Medicine*, *10*(2), 255–266. https://doi.org/10.1002/sim.4780100209

Bates, D., Mächler, M., Bolker, B., & Walker, S. (2015). Fitting Linear Mixed-Effects Models Using lme4. *Journal of Statistical Software*, *67*, 1–48. https://doi.org/10.18637/jss.v067.i01

Blackwell, L. F., Brown, J. B., & Cooke, D. (1998). Definition of the potentially fertile period from urinary steroid excretion rates. Part II. A threshold value for pregnanediol glucuronide as a marker for the end of the potentially fertile period in the human menstrual cycle. *Steroids*, *63*(1), 5–13. https://doi.org/10.1016/s0039-128x(97)00117-7

Bolin, A., Whelehan, P., Vernon, M., & Antoine, K. (2021). *Human Sexuality: Biological, Psychological, and Cultural Perspectives*. Routledge.

Crewther, B. T., Hecht, M., & Cook, C. J. (2021). Diurnal Within-Person Coupling Between Testosterone and Cortisol in Healthy Men: Evidence of Positive and Bidirectional Time-Lagged Associations Using a Continuous-Time Model. *Adaptive Human Behavior and Physiology*, *7*(2), 89–104. https://doi.org/10.1007/s40750-021-00162-8

De Souza, M. J., Toombs, R. J., Scheid, J. L., O'Donnell, E., West, S. L., & Williams, N. I. (2010). High prevalence of subtle and severe menstrual disturbances in exercising women: Confirmation using daily hormone measures. *Human Reproduction*, *25*(2), 491–503. https://doi.org/10.1093/humrep/dep411

Delville, Y. (1991). Progesterone-facilitated sexual receptivity: A review of arguments supporting a nongenomic mechanism. *Neuroscience & Biobehavioral Reviews*, *15*(3), 407–414. https://doi.org/10.1016/S0149-7634(05)80033-8

Dinh, T., Emery Thompson, M., & Gangestad, S. W. (2022). Hormonal influences on women's extra-pair sexual interests: The moderating impact of partner attractiveness. *Evolution and Human Behavior*, *43*(5), 442–454. https://doi.org/10.1016/j.evolhumbehav.2022.08.001

Dixson, A. F. (1998). *Primate Sexuality: Comparative Studies of the Prosimians, Monkeys, Apes, and Human Beings*. Oxford University Press.

Dobson, R. T., Dinh, T., & Gangestad, S. W. (2026). Moderation of ovulatory cycle shifts in women's extra-pair sexual interests by partner sexual attractiveness: Two preregistered studies. *Evolution and Human Behavior*, *47*(6), 106965. https://doi.org/10.1016/j.evolhumbehav.2026.106965

Driver, C. C., Oud, J. H. L., & Voelkle, M. C. (2017). Continuous Time Structural Equation Modeling with R Package ctsem. *Journal of Statistical Software*, *77*, 1–35. https://doi.org/10.18637/jss.v077.i05

Fehring, R. J., Schneider, M., & Raviele, K. (2006). Variability in the phases of the menstrual cycle. *Journal of Obstetric, Gynecologic, and Neonatal Nursing: JOGNN*, *35*(3), 376–384. https://doi.org/10.1111/j.1552-6909.2006.00051.x

Furuichi, T. (2023). Prolonged Sexual Receptivity in Females and Its Impact on the Evolution of Bonobos. In T. Furuichi, G. Idani, D. Kimura, H. Ihobe, & C. Hashimoto (Eds.), *Bonobos and People at Wamba: 50 Years of Research* (pp. 545–564). Springer Nature. https://doi.org/10.1007/978-981-99-4788-1_39

Gangestad, S. W., & Dinh, T. (2022). Women's Estrus and Extended Sexuality: Reflections on Empirical Patterns and Fundamental Theoretical Issues. *Frontiers in Psychology*, *13*. https://doi.org/10.3389/fpsyg.2022.900737

Gangestad, S. W., Dinh, T., Lesko, L., & Haselton, M. G. (2022). Understanding Women's Estrus and Extended Sexuality: The Dual Sexuality Framework. In D. M. Buss (Ed.), *The Oxford Handbook of Human Mating* (p. 0). Oxford University Press. https://doi.org/10.1093/oxfordhb/9780197536438.013.9

Gangestad, S. W., & Haselton, M. G. (2015). Human estrus: Implications for relationship science. *Current Opinion in Psychology, Relationship Science*, *1*, 45–51. https://doi.org/10.1016/j.copsyc.2014.12.007

Gangestad, S. W., Haselton, M. G., Welling, L. L. M., Gildersleeve, K., Pillsworth, E. G., Burriss, R. P., Larson, C. M., & Puts, D. A. (2016). How valid are assessments of conception probability in ovulatory cycle research? Evaluations, recommendations, and theoretical implications. *Evolution and Human Behavior*, *37*(2), 85–96. https://doi.org/10.1016/j.evolhumbehav.2015.09.001

Gloe, L. M., Russman Block, S., Klump, K. L., Beltz, A. M., & Moser, J. S. (2023). Determining menstrual cycle phase: An empirical examination of methodologies and recommendations for improvement in behavioral and brain sciences. *Hormones and Behavior*, *155*, 105421. https://doi.org/10.1016/j.yhbeh.2023.105421

Green, P., & MacLeod, C. J. (2016). SIMR: An R package for power analysis of generalized linear mixed models by simulation. *Methods in Ecology and Evolution*, *7*(4), 493–498. https://doi.org/10.1111/2041-210X.12504

Gupta, G., Simmons, Z. L., & Roney, J. R. (2024). Hormonal and cycle phase predictors of within-women shifts in self-perceived attractiveness: Tests of alternative functional models. *Hormones and Behavior*, *164*, 105602. https://doi.org/10.1016/j.yhbeh.2024.105602

Haselton, M. G., & Gangestad, S. W. (2006). Conditional expression of women's desires and men's mate guarding across the ovulatory cycle. *Hormones and Behavior*, *49*(4), 509–518. https://doi.org/10.1016/j.yhbeh.2005.10.006

Havliček, J., Cobey, K. D., Barrett, L., Klapilová, K., & Roberts, S. C. (2015). The spandrels of Santa Barbara? A new perspective on the peri-ovulation paradigm. *Behavioral Ecology*, *26*(5), 1249–1260. https://doi.org/10.1093/beheco/arv064

Jones, B. C., Hahn, A. C., Fisher, C. I., Wang, H., Kandrik, M., & DeBruine, L. M. (2018). General sexual desire, but not desire for uncommitted sexual relationships, tracks changes in women's hormonal status. *Psychoneuroendocrinology*, *88*, 153–157. https://doi.org/10.1016/j.psyneuen.2017.12.015

Klump, K. L., Keel, P. K., Racine, S. E., Burt, S. A., Neale, M., Sisk, C. L., Boker, S., & Hu, J. Y. (2013). The interactive effects of estrogen and progesterone on changes in emotional eating across the menstrual cycle. *Journal of Abnormal Psychology*, *122*(1), 131–137. https://doi.org/10.1037/a0029524

Larson, C. M., Pillsworth, E. G., & Haselton, M. G. (2012). Ovulatory Shifts in Women's Attractions to Primary Partners and Other Men: Further Evidence of the Importance of Primary Partner Sexual Attractiveness. *PLOS ONE*, *7*(9), e44456. https://doi.org/10.1371/journal.pone.0044456

Lenth, R. V., & Piaskowski, J. (2017). *emmeans: Estimated Marginal Means, aka Least-Squares Means* (p. 2.0.4) [Data set]. https://doi.org/10.32614/CRAN.package.emmeans

Lösel, R., & Wehling, M. (2003). Nongenomic actions of steroid hormones. *Nature Reviews Molecular Cell Biology*, *4*(1), 46–55. https://doi.org/10.1038/nrm1009

Marcinkowska, U. M. (2020). Importance of Daily Sex Hormone Measurements Within the Menstrual Cycle for Fertility Estimates in Cyclical Shifts Studies. *Evolutionary Psychology*, *18*(1), 1474704919897913. https://doi.org/10.1177/1474704919897913

Marcinkowska, U. M., Mijas, M., Koziara, K., Grebe, N. M., & Jasienska, G. (2021). Variation in sociosexuality across natural menstrual cycles: Associations with ovarian hormones and cycle phase. *Evolution and Human Behavior*, *42*(1), 35–42. https://doi.org/10.1016/j.evolhumbehav.2020.06.008

Marcinkowska, U. M., Shirazi, T., Mijas, M., & Roney, J. R. (2023). Hormonal Underpinnings of the Variation in Sexual Desire, Arousal and Activity Throughout the Menstrual Cycle – A Multifaceted Approach. *The Journal of Sex Research*, *60*(9), 1297–1303. https://doi.org/10.1080/00224499.2022.2110558

Marlowe, F. W., & Berbesque, J. C. (2012). The human operational sex ratio: Effects of marriage, concealed ovulation, and menopause on mate competition. *Journal of Human Evolution*, *63*(6), 834–842. https://doi.org/10.1016/j.jhevol.2012.09.004

Mikhail, M. E., Culbert, K. M., Keel, P. K., Burt, S. A., Sisk, C. L., Johnson, A., Boker, S., Neale, M. C., & Klump, K. L. (2025). Within-Person Changes in Daily Ovarian Hormone Levels Influence Genetic Effects on Emotional Eating in Women. *The International Journal of Eating Disorders*, *58*(12), 2352–2365. https://doi.org/10.1002/eat.24545

Mikhail, M. E., Keel, P. K., Burt, S. A., Sisk, C. L., Neale, M., Boker, S., & Klump, K. L. (2021). Trait Negative Affect Interacts With Ovarian Hormones to Predict Risk for Emotional Eating. *Clinical Psychological Science*, *9*(1), 114–128. https://doi.org/10.1177/2167702620951535

Miller, R. C., Brindle, E., Holman, D. J., Shofer, J., Klein, N. A., Soules, M. R., & O'Connor, K. A. (2004). Comparison of Specific Gravity and Creatinine for Normalizing Urinary Reproductive Hormone Concentrations. *Clinical Chemistry*, *50*(5), 924–932. https://doi.org/10.1373/clinchem.2004.032292

Munro, C. J., Stabenfeldt, G. H., Cragun, J. R., Addiego, L. A., Overstreet, J. W., & Lasley, B. L. (1991). Relationship of serum estradiol and progesterone concentrations to the excretion profiles of their major urinary metabolites as measured by enzyme immunoassay and radioimmunoassay. *Clinical Chemistry*, *37*(6), 838–844. https://doi.org/10.1093/clinchem/37.6.838

O'Connor, K. A., Brindle, E., Miller, R. C., Shofer, J. B., Ferrell, R. J., Klein, N. A., Soules, M. R., Holman, D. J., Mansfield, P. K., & Wood, J. W. (2006). Ovulation detection methods for urinary hormones: Precision, daily and intermittent sampling and a combined hierarchical method. *Human Reproduction*, *21*(6), 1442–1452. https://doi.org/10.1093/humrep/dei497

Penke, L., & Asendorpf, J. B. (2008). Beyond global sociosexual orientations: A more differentiated look at sociosexuality and its effects on courtship and romantic relationships. *Journal of Personality and Social Psychology*, *95*(5), 1113–1135. https://doi.org/10.1037/0022-3514.95.5.1113

Pillsworth, E. G., & Haselton, M. G. (2006). Male sexual attractiveness predicts differential ovulatory shifts in female extra-pair attraction and male mate retention. *Evolution and Human Behavior*, *27*(4), 247–258. https://doi.org/10.1016/j.evolhumbehav.2005.10.002

Roney, J. R. (2009). The role of sex hormones in the initiation of human mating relationships. In *Endocrinology of social relationships* (pp. 246–269). Harvard University Press.

Roney, J. R. (2018). Functional roles of gonadal hormones in human pair bonding and sexuality. In *Routledge International Handbook of Social Neuroendocrinology*. Routledge.

Roney, J. R. (2022). Hormones and Human Mating. In D. M. Buss (Ed.), *The Oxford Handbook of Human Mating* (p. 0). Oxford University Press. https://doi.org/10.1093/oxfordhb/9780197536438.013.37

Roney, J. R., & Simmons, Z. L. (2013). Hormonal predictors of sexual motivation in natural menstrual cycles. *Hormones and Behavior*, *63*(4), 636–645. https://doi.org/10.1016/j.yhbeh.2013.02.013

Roney, J. R., & Simmons, Z. L. (2016). Within-cycle fluctuations in progesterone negatively predict changes in both in-pair and extra-pair desire among partnered women. *Hormones and Behavior*, *81*, 45–52. https://doi.org/10.1016/j.yhbeh.2016.03.008

Schaik, C. P. V., Noordwijk, M. A. V., & Nunn, C. L. (1999). Sex and social evolution in primates. *Comparative Primate Socioecology*, 204–240. https://doi.org/10.1017/cbo9780511542466.011

Schleifenbaum, L., Stern, J., Driebe, J. C., Wieczorek, L. L., Gerlach, T. M., Arslan, R. C., & Penke, L. (2024). Ovulatory cycle shifts in human motivational prioritisation of sex and food. *Hormones and Behavior*, *162*, 105542. https://doi.org/10.1016/j.yhbeh.2024.105542

Shirazi, T. N., Self, H., Dawood, K., Rosenfield, K. A., Penke, L., Carré, J. M., Ortiz, T., & Puts, D. A. (2019). Hormonal predictors of women's sexual motivation. *Evolution and Human Behavior*, *40*(3), 336–344. https://doi.org/10.1016/j.evolhumbehav.2019.02.002

Shrout, P. E., Stadler, G., Lane, S. P., McClure, M. J., Jackson, G. L., Clavél, F. D., Iida, M., Gleason, M. E. J., Xu, J. H., & Bolger, N. (2018). Initial elevation bias in subjective reports. *Proceedings of the National Academy of Sciences of the United States of America*, *115*(1), E15–E23. https://doi.org/10.1073/pnas.1712277115

Simpson, J. A., & Gangestad, S. W. (1991). Individual differences in sociosexuality: Evidence for convergent and discriminant validity. *Journal of Personality and Social Psychology*, *60*(6), 870–883. https://doi.org/10.1037/0022-3514.60.6.870

Spector, I. P., Carey, M. P., & Steinberg, L. (1996). The sexual desire inventory: Development, factor structure, and evidence of reliability. *Journal of Sex & Marital Therapy*, *22*(3), 175–190. https://doi.org/10.1080/00926239608414655

Stern, J., Kordsmeyer, T. L., & Penke, L. (2021). A longitudinal evaluation of ovulatory cycle shifts in women's mate attraction and preferences. *Hormones and Behavior*, *128*, 104916. https://doi.org/10.1016/j.yhbeh.2020.104916

Stern, J., & Penke, L. (2022). Ovulatory Cycle Effects and Hormonal Influences on Women's Mating Psychology. In D. M. Buss (Ed.), *The Oxford Handbook of Human Mating* (p. 0). Oxford University Press. https://doi.org/10.1093/oxfordhb/9780197536438.013.13

Strassmann, B. I. (1981). Sexual selection, paternal care, and concealed ovulation in humans. *Ethology and Sociobiology*, *2*(1), 31–40. https://doi.org/10.1016/0162-3095(81)90020-0

Taziaux, M., Keller, M., Bakker, J., & Balthazart, J. (2007). Sexual behavior activity tracks rapid changes in brain estrogen concentrations. *The Journal of Neuroscience: The Official*

Journal of the Society for Neuroscience, *27*(24), 6563–6572. https://doi.org/10.1523/JNEUROSCI.1797-07.2007

Thomas, A. G., Armstrong, S. L., Stewart-Williams, S., & Jones, B. C. (2021). Current Fertility Status Does Not Predict Sociosexual Attitudes and Desires in Normally Ovulating Women. *Evolutionary Psychology*, *19*(1), 1474704920976318. https://doi.org/10.1177/1474704920976318

Thornhill, R., & Gangestad, S. W. (2008). *The Evolutionary Biology of Human Female Sexuality*. Oxford University Press.

Usala, S. J., Alliende, M. E., & Trindade, A. A. (2022). Algorithms with Area under the Curve for Daily Urinary Estrone-3-Glucuronide and Pregnanediol-3-Glucuronide to Signal the Transition to the Luteal Phase. *Medicina*, *58*(1), 119. https://doi.org/10.3390/medicina58010119

van Stein, K. R., Strauß, B., & Brenk-Franz, K. (2019). Ovulatory Shifts in Sexual Desire But Not Mate Preferences: An LH-Test-Confirmed, Longitudinal Study. *Evolutionary Psychology*, *17*(2), 1474704919848116. https://doi.org/10.1177/1474704919848116

Voelkle, M. C., Gische, C., Driver, C. C., & Lindenberger, U. (2018). The Role of Time in the Quest for Understanding Psychological Mechanisms. *Multivariate Behavioral Research*, *53*(6), 782–805. https://doi.org/10.1080/00273171.2018.1496813

Williams, N. I., Mallinson, R. J., & De Souza, M. J. (2019). Rationale and study design of an intervention of increased energy intake in women with exercise-associated menstrual disturbances to improve menstrual function and bone health: The REFUEL study. *Contemporary Clinical Trials Communications*, *14*, 100325. https://doi.org/10.1016/j.conctc.2019.100325

SUPPLEMENTARY MATERIALS

Multilevel reliability of the Sexuality Outcomes

Multilevel reliability was examined using generalizability theory with linear mixed-effects estimation (psych package; Revelle, 2024; Table S1). For the self-directed sexual desire items (k = 4), variance was primarily within-person (56%), with modest between-person differences (ICC = .17). Reliability was good for both within-person fluctuations (ω_within = .89) and between-person differences (ω_between = .88). The other-directed sexual desire items (k = 6) showed a similar pattern, with 54% within-person variance (ICC = .12), ω_within = .90, and ω_between = .84. These results support the use of both composites in multilevel analyses. The SOI-desire composite (k = 3) showed a predominantly between-person variance structure (ICC = .58), consistent with its nature as a stable dispositional trait. Between-person reliability was excellent (ω_between = .98), supporting its use as a person-level moderator variable. Within-person reliability was low (ω_within = .47), expected given minimal within-person variance (10%), and the composite was therefore used only in between-person analyses. The SOI-attitudes composite (k = 3) showed near-perfect between-person stability (ICC = .72, ω_between ≈ 1.00), with virtually no within-person variability (id(time) variance ≈ 0, ω_within ≈ .00).

Table S1. Multilevel reliability test on sexuality outcomes

Scale	Between	Within	Residual	ICC
Self	17%	56%	27%	.17
Other	12%	54%	35%	.12
SOI-d	58%	10%	32%	.58
SOI-a	72%	0%	28%	.72

Three outcomes were square-root transformed prior to analysis (self-directed desire, other-directed desire, and SOI-desire) due to severe positive skew and floor effects (skew range: 2.51–3.62; proportion at floor: 27–53%). SOI-attitudes was approximately normally distributed (skew = 0.53) and was analyzed without transformation.

Missing observations

Missing observations for both hormone predictors and outcome variables were handled exclusively through available-data analysis; no imputation was performed for either. For outcome variables, `na.action = na.exclude` in *lme4* retains all available person-days, with restricted maximum likelihood (REML) estimation producing unbiased fixed-effect estimates under the missing-at-random assumption (Enders, 2022). For hormone predictors, imputation was deliberately avoided despite the associated reduction in statistical power, as standard imputation

procedures would require imposing parametric assumptions about the biological trajectory of urinary metabolite, assumptions that we were unwilling to substitute for observed endocrine data given the physiologically dynamic nature of E1G and PdG across the cycle (Munro et al., 1991).

AUC - Moderation by Relationship status

PdG_{AUC} marginally interacted with relationship status to predict SDI-self; among committed women, PdG_{AUC} was negatively associated with SDI-self, whereas the association was null among single women. A similar pattern emerged for SDI-other despite a non-significant interaction term: PdG_{AUC} reliably suppressed SDI-other in both groups, while $E1G_{AUC}$ was positively associated with SDI-other only among committed women and not among single women. Independent of hormone effects, committed women reported significantly higher SDI-other ($M_{committed}$ = .521 vs. .283; Δ = .238, t(62.7) = 4.40, p < .001) and lower SOI-desire ($M_{committed}$ = .184 vs. .675; Δ = −.491, t(63) = −4.56, p < .001) than single women. A negative PdG_{AUC} × relationship status interaction emerged for SOI-attitudes (n = 1,439; k = 65). Simple slopes indicated that PdG_{AUC} was negatively associated with SOI-attitudes among committed women but not among single women.

The cumulative E:P ratio (5-day AUC) × relationship status interaction reached trend-level significance for self-directed desire (*b* = .043, *SE* = .024, *t* = 1.79, *p* = .074) and for SOI-attitudes (*b* = .017, *SE* = .009, *t* = 1.83, *p* = .068) but was non-significant for other-directed desire and SOI-desire (both *p*s > .40). Conditional slopes indicated that among committed women, a higher cumulative E:P ratio was significantly associated with greater self-directed desire (*b* = .051, 95% CI [.022, .081]), greater other-directed desire (*b* = .040, 95% CI [.013, .067]), and greater SOI-attitudes (*b* = .014, 95% CI [.002, .025]). Among single/uncommitted women, the cumulative ratio did not significantly predict any outcome (all 95% CIs included zero). No significant slopes emerged for SOI-desire in either relationship status group. As with the individual AUC hormones (E1G_AUC, PdG_AUC), cumulative E:P ratio exposure was more strongly and consistently associated with sexual desire and attitudes among committed women, with associations essentially flat among single/uncommitted women.

Table S2. AUC Relationship status Moderation: Interaction Terms and Conditional Slopes
Panel A: Interaction terms

Outcome	Term	*b*	*SE*	*t*	*p*
Self-directed desire	$E1G_{AUC}$ × relationship status	.018	.028	0.64	.526
	PdG_{AUC} × relationship status	-.056	.029	-1.94	.053†
	$E:P_{AUC}$ × relationship status	.043	.024	1.79	.074†
Other-directed desire	$E1G_{AUC}$ × relationship status	.026	.026	1.03	.304
	PdG_{AUC} × relationship status	.005	.026	0.19	.848
	$E:P_{AUC}$ × relationship status	.018	.022	0.83	.404
	Main effect: Committed vs. Single	0.238	.054	4.40	<.001***
SOI-desire	$E1G_{AUC}$ × relationship status	.009	.018	0.50	.617
	PdG_{AUC} × relationship status	.023	.019	1.21	.226
	$E:P_{AUC}$ × relationship status	.006	.016	0.36	.721
	Main effect: Committed vs. Single	-0.491	.108	-4.56	<.001***
SOI-attitudes	$E1G_{AUC}$ × relationship status	.002	.011	0.16	.872
	PdG_{AUC} × relationship status	-.028	.011	-2.48	.013*

Outcome	Term	*b*	*SE*	*t*	*p*
	E:P_{AUC} × relationship status	.017	.009	1.83	.068†

Note. n = 1,439; k = 65. Reference group = Single/Uncommitted. Coefficients are unstandardized regression estimates from mixed-effects models with random intercepts for participant. E1G_AUC and PdG_AUC were entered together in the same model; the E:P_AUC ratio was tested in a separate model. Main effects represent between-person mean differences from emmeans pairwise contrasts. For other-directed desire, committed women reported higher values (M = .521 vs .283); for SOI-desire, committed women reported lower values (M = .184 vs .675). † p < .10. * p < .05. ** p < .01. *** p < .001.

Panel B: Conditional slopes of E1G$_{AUC}$, PdG$_{AUC}$, and the E:P$_{AUC}$ ratio by relationship status.

Outcome	Relationship status	E1G$_{AUC}$ slope b [95% CI]	PdG$_{AUC}$ slope b [95% CI]	E:P$_{AUC}$ slope b [95% CI]
Self-directed desire	Single/Uncommitted	.015 [-.024, .055]	-.003 [-.049, .044]	.009 [-.027, .045]
	Committed	.033 [-.006, .073]	-.059* [-.092, -.026]	.051* [.022, .081]
Other-directed desire	Single/Uncommitted	.013 [-.022, .049]	-.045* [-.087, -.003]	.022 [-.011, .055]
	Committed	.040* [.004, .075]	-.040* [-.069, -.010]	.040* [.013, .067]
SOI-desire	Single/Uncommitted	-.024 [-.050, .002]	-.030 [-.060, .000]	-.007 [-.031, .017]
	Committed	-.015 [-.040, .011]	-.007 [-.029, .014]	-.001 [-.021, .018]
SOI-attitudes	Single/Uncommitted	-.001 [-.016, .014]	.009 [-.009, .027]	-.003 [-.017, .011]
	Committed	.001 [-.014, .016]	-.019* [-.032, -.006]	.014* [.002, .025]

Note. Conditional slopes are unstandardized regression coefficients from emtrends (emmeans package). 95% confidence intervals shown in brackets; * = CI excludes zero. n = 1,439; k = 65. The PdG_AUC × relationship status interaction was significant only for SOI-attitudes (p = .013); for self-directed desire, the interaction was marginal (p = .053), and for the E:P_AUC ratio, interactions were marginal for self-directed desire (p = .074) and SOI-attitudes (p = .068); conditional slopes are reported for descriptive comparison. E:P_AUC ratio = log-transformed ratio of estradiol (E1G) to progesterone (PdG) rolling 5-day AUC values.

AUC - Moderation by Partner Attractiveness

E1G$_{AUC}$ interacted with attractiveness to predict SDI-self. Simple slopes revealed that E1G$_{AUC}$ was positively associated with SDI-self only at higher attractiveness, but not at average or lower attractiveness. PdG$_{AUC}$ significantly interacted with attractiveness to predict SOI-attitudes: the negative association between PdG$_{AUC}$ and SOI-attitudes was significant at average and at higher attractiveness, but not at lower attractiveness. A marginal E1G$_{AUC}$ × attractiveness interaction also emerged for SOI-desire: higher E1G$_{AUC}$ was associated with lower SOI-desire at below-average but not above-average attractiveness levels.

The cumulative E:P ratio (5-day AUC) × attractiveness interaction was significant for self-directed desire and for SOI-attitudes but was non-significant for other-directed desire and SOI-desire (both *p*s > .24). Conditional slopes indicated that the cumulative E:P ratio was a significant positive predictor of self-directed desire at mean and +1 SD attractiveness, but not at -1 SD, mirroring the pattern seen for E1G$_{AUC}$. A similar pattern held for other-directed desire, with significant positive slopes at mean and +1 SD. For SOI-attitudes, the ratio was only a significant positive predictor at high attractiveness, with slopes near zero at the mean and at low attractiveness, again paralleling the E1G$_{AUC}$ pattern for that outcome. No significant ratio slopes emerged for SOI-desire at any attractiveness level. Overall, the cumulative E:P ratio's association with desire and attitudes grew more strongly positive as partner/acquaintance attractiveness increased, closely tracking the E1G$_{AUC}$ main-effect pattern rather than the PdG$_{AUC}$ pattern.

Table S3. **AUC Attractiveness Moderation: Interaction Terms and Conditional Slopes**
Panel A: Interaction terms

Outcome	Term	*b*	*SE*	*t*	*p*
Self-directed desire	$E1G_{AUC}$ × Attractiveness	.040	.016	2.52	.012*
	PdG_{AUC} × Attractiveness	-.009	.015	-0.63	.526
	$E:P_{AUC}$ × Attractiveness	.026	.013	2.04	.042*
Other-directed desire	$E1G_{AUC}$ × Attractiveness	.017	.015	1.19	.233
	PdG_{AUC} × Attractiveness	-.003	.013	-0.23	.822
	$E:P_{AUC}$ × Attractiveness	.010	.012	0.86	.392
SOI-desire	$E1G_{AUC}$ × Attractiveness	.021	.010	1.96	.051†
	PdG_{AUC} × Attractiveness	-.001	.010	-0.07	.945
	$E:P_{AUC}$ × Attractiveness	.010	.009	1.15	.249
SOI-attitudes	$E1G_{AUC}$ × Attractiveness	.009	.006	1.44	.150
	PdG_{AUC} × Attractiveness	-.020	.006	-3.44	<.001***
	$E:P_{AUC}$ × Attractiveness	.015	.005	3.05	.002**

Note. n = 1,439; k = 65. Attractiveness combines partner ratings (for committed/uncommitted women) or close male friend ratings (for single women), z-standardized. Coefficients are from mixed-effects models with random intercepts for participant. E1G_AUC and PdG_AUC were entered together in the same model; the E:P_AUC ratio was tested in a separate model. † p < .10. * p < .05. ** p < .01. *** p < .001.

Panel B: Conditional slopes of $E1G_{AUC}$, PdG_{AUC}, and the $E:P_{AUC}$ ratio at three levels of partner/acquaintance attractiveness.

Outcome	Att Level	$E1G_{AUC}$ slope b [95% CI]	PdG_{AUC} slope b [95% CI]	$E:P_{AUC}$ slope b [95% CI]
Self-directed desire	-1 SD	-.015 [-.059, .029]	-.030 [-.071, .012]	.006 [-.030, .041]
	Mean	.026 [-.002, .053]	-.039* [-.066, -.012]	.032* [.009, .055]
	+1 SD	.066* [.026, .106]	-.048* [-.086, -.011]	.059* [.026, .092]
Other-directed desire	-1 SD	.006 [-.034, .045]	-.038 [-.075, .000]	.022 [-.010, .055]
	Mean	.023 [-.002, .048]	-.041* [-.065, -.016]	.032* [.011, .053]
	+1 SD	.041* [.005, .077]	-.044* [-.078, -.009]	.042* [.013, .072]
SOI-desire	-1 SD	-.044* [-.072, -.015]	-.014 [-.041, .014]	-.014 [-.038, .009]
	Mean	-.023* [-.041, -.005]	-.014 [-.032, .003]	-.004 [-.019, .011]
	+1 SD	-.003 [-.029, .023]	-.015 [-.039, .010]	.006 [-.016, .027]
SOI-attitudes	-1 SD	-.007 [-.024, .009]	.012 [-.004, .028]	-.010 [-.023, .004]
	Mean	.001 [-.009, .012]	-.008 [-.018, .002]	.006 [-.003, .015]
	+1 SD	.010 [-.005, .026]	-.028* [-.042, -.013]	.021* [.008, .034]

Note. Conditional hormone slopes are unstandardized regression coefficients from emtrends (emmeans package), evaluated at -1 SD, mean, and +1 SD of z-standardized partner/acquaintance attractiveness. 95% confidence intervals shown in brackets; * = CI excludes zero. n = 1,439; k = 65. E:P_AUC ratio = log-transformed ratio of estradiol (E1G) to progesterone (PdG) rolling 5-day AUC values, tested in a model separate from $E1G_{AUC}$ and PdG_{AUC}.

A-priori power analysis

Power analysis was performed prior to data collection, based on the planned study design of 60 participants completing 25 daily observations (1,500 person-days).

Power was estimated via Monte Carlo simulation in R using the simr package (Green & MacLeod, 2016), which extends generalized linear mixed models fit with lme4 (Bates et al., 2015) to simulation-based power analysis. The simulated design comprised 60 participants completing 25 daily observations each (1,500 person-days), with a random intercept for participant. Variance components were set at σ (between-participant) = 0.55 and σ (residual, within-person) = 0.95.

Three sets of power analyses were conducted:

- Main effects of within-person E1G and PdG on the outcome variable.
- The hormone × Partner Attractiveness interaction, with partner attractiveness modeled as a continuous, standardized (SD = 1) between-person moderator.
- The hormone × Relationship status interaction, with relationship status modeled as an effect-coded, binary between-person moderator (single/uncommitted = −0.5, committed = 0.5; approximately 60% of the simulated sample partnered).

For each analysis, power was estimated across a range of plausible standardized effect sizes (β), based on 1,000 simulated datasets per effect size (seed = 1,234 for reproducibility). An approximate Cohen's f^2 is reported alongside each β, computed as $f^2 = R^2(\text{partial}) / (1 - R^2(\text{partial}))$.

Main Effects of E1G and PdG

Table S4 and Figure S1 present power to detect the within-person hormone main effect across the simulated range of effect sizes. Power reached the conventional 80% threshold at $\beta \approx .07$ and approached ceiling ($\geq$ 98%) by $\beta = .10$, indicating that the planned design affords strong sensitivity to detect within-person hormone main effects, including effects classified as small by conventional standards ($f^2 < .02$).

Table S4. Power to detect the within-person hormone main effect across standardized effect sizes.

β	f^2	Power
.05	.0021	.50
.07	.0041	.80
.10	.0084	.98
.13	.0142	1.00
.15	.0190	1.00
.20	.0343	1.00

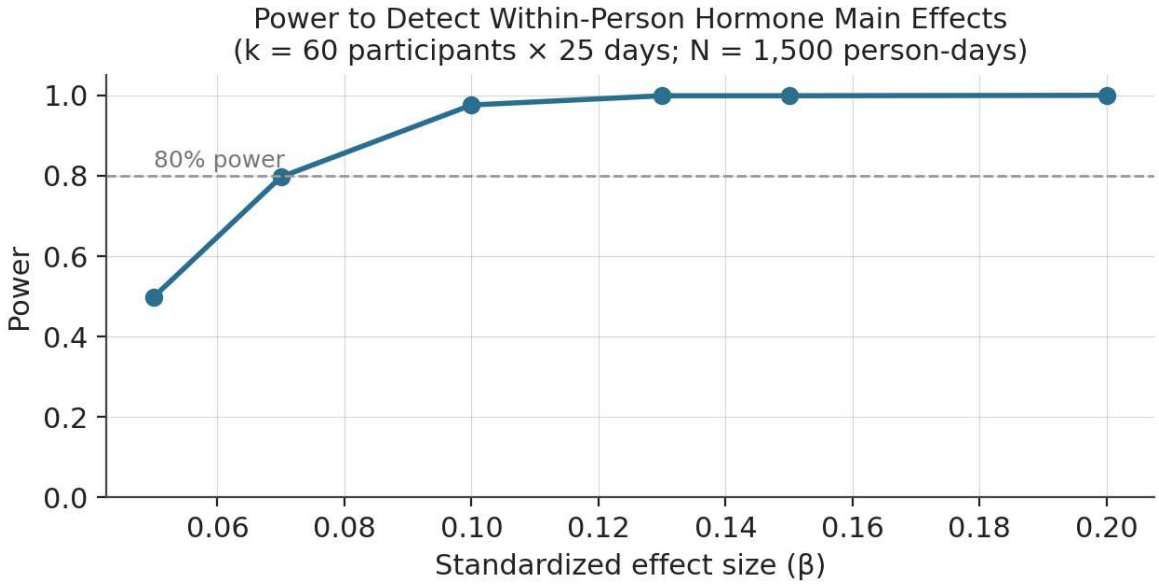


Figure S1. *Power to detect the within-person hormone main effect across standardized effect sizes.*

Hormone × Partner Attractiveness Interaction

Table S5 presents power for the hormone × Partner Attractiveness interaction. This interaction showed comparably strong power to the main-effects analysis, crossing the 80% threshold around β = .08 and reaching near-ceiling power by β = .10–.15. Because partner attractiveness was modeled as a continuous, standardized (SD = 1) moderator, the cross-level interaction retained most of the sensitivity of the main-effect analysis.

Table S5. Power to detect the within-person hormone x partner attractiveness across standardized effect sizes.

β	f^2	Power
.02	.0003	.12
.04	.0013	.33
.06	.0030	.60
.08	.0053	.85
.10	.0084	.95
.15	.0190	1.00

Hormone × Relationship status Interaction

Table S6 and Figure S2 present power for the Hormone × Relationship status interactions. Power for this interaction was consistently lower than for the attractiveness interaction at matched effect sizes: even the largest simulated effect (β = .15) yielded power of only 75–79%, below the 80% convention.

Table S6. Power to detect the within-person hormone x relationship status across standardized effect sizes.

β	f^2	Power
.02	.0001	.08
.04	.0003	.12
.06	.0006	.19
.08	.0011	.30
.10	.0018	.42
.15	.0040	.75

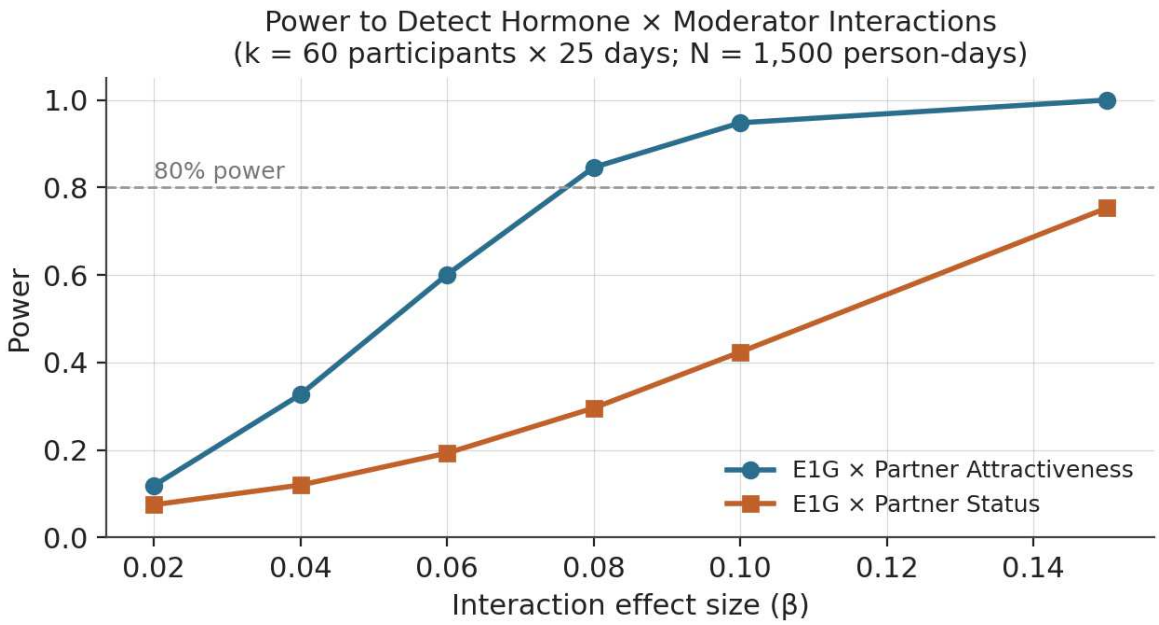


Figure S2. Power to detect hormone × moderator interactions, comparing the continuous partner-attractiveness moderator with the binary partner-status moderator.

This reduced sensitivity follows from the binary, effect-coded parameterization of relationship status (values of ±0.5), whose variance is mathematically capped at 0.25 — one quarter that of a standardized continuous moderator (variance = 1.0) — irrespective of the sample's status composition. The assumed 60% partnered split in this simulation yields a moderator variance of .24, negligibly different from the theoretical maximum of .25 at a perfectly balanced 50/50 split. Because interaction power scales with the product of both predictors' variances, this reduced sensitivity reflects a structural property of testing moderation by a two-level categorical variable, rather than a limitation specific to this sample's status composition.

The planned design (60 participants, 25 daily observations) affords strong power to detect within-person hormone main effects and hormone × partner-attractiveness moderation, down to fairly modest true effect sizes (80% power at $\beta \approx .07–.08$). Power to detect hormone × partner-status moderation is comparatively limited: a true effect approaching or exceeding $\beta = .15$ would be required for reliable detection under the planned design.

The realized dataset (66 participants; 1,847 total daily observations) exceeds the planned design, so actual power achieved is expected to be modestly higher than the estimates reported here. Nonetheless, given the structural limitation, findings concerning hormone × partner-status moderation should be interpreted with appropriate caution and may be best characterized as an exploratory or secondary analysis. Increasing power for this specific test in future work would require a larger participant sample rather than a more balanced partner-status split, since rebalancing the split has only a negligible effect on the moderator's variance.

Bates, D., Mächler, M., Bolker, B., & Walker, S. (2015). Fitting linear mixed-effects models using lme4. Journal of Statistical Software, 67(1), 1–48. https://doi.org/10.18637/jss.v067.i01

Green, P., & MacLeod, C. J. (2016). SIMR: An R package for power analysis of generalized linear mixed models by simulation. Methods in Ecology and Evolution, 7(4), 493–498. https://doi.org/10.1111/2041-210X.12504

Exploratory three-way interaction power analysis

We ran a simulation-based sensitivity power analysis (Lakens, 2022) for the exploratory models *outcome* ~ E1G × Partner Attractiveness × Relationship status + PdG × Partner Attractiveness × Relationship status. Data were simulated to match the realized design (66 participants × 28 days). E1G and PdG were within-person standardized, partner attractiveness was a standardized person-level variable, and relationship status was effect-coded (single = −0.5, committed = +0.5; about 60% committed). The random-intercept *SD* was set to 0.55 and the residual *SD* to 0.95; both were assumed values. Models included uncorrelated random slopes for E1G and PdG (*SD* = 0.10), as recommended for cross-level interactions (Heisig & Schaeffer, 2019). They were fit with lme4 (Bates et al., 2015) and tested with Satterthwaite *t*-tests in lmerTest (Kuznetsova et al., 2017). We varied the three-way coefficient from β = .05 to .30 and ran 1,000 simulations per value (α = .05, two-tailed).

Power reached 80% only at $\beta \approx .16$ (E1G) and $\beta \approx .17$ (PdG). At $\beta = .10$, power was .43 and .46 (Table S7). Because of this limited power, we treat the three-way interactions as exploratory. Non-significant results are not interpreted as evidence of no moderation. Significant estimates are reported with 95% CIs, because effects that reach significance at this level of power are likely to be overestimated (Gelman & Carlin, 2014).

Table S7. Power to detect the three-way interactions.

β	.05	.10	.15	.20	.25	.30
E1G × Att × Status	.15	.43	.75	.94	.99	1.00
PdG × Att × Status	.14	.46	.75	.92	.99	1.00

Note. β is the difference in the hormone × attractiveness slope between committed and single women.

References

Bates, D., Mächler, M., Bolker, B., & Walker, S. (2015). Fitting linear mixed-effects models using lme4. *Journal of Statistical Software, 67*(1), 1–48.

Gelman, A., & Carlin, J. (2014). Beyond power calculations: Assessing Type S (sign) and Type M (magnitude) errors. *Perspectives on Psychological Science, 9*(6), 641–651.

Heisig, J. P., & Schaeffer, M. (2019). Why you should always include a random slope for the lower-level variable involved in a cross-level interaction. *European Sociological Review, 35*(2), 258–279.

Kuznetsova, A., Brockhoff, P. B., & Christensen, R. H. B. (2017). lmerTest package: Tests in linear mixed effects models. *Journal of Statistical Software, 82*(13), 1–26.

Lakens, D. (2022). Sample size justification. *Collabra: Psychology, 8*(1), 33267.

Exploratory three-way interaction analysis

Three-way interactions testing whether relationship status moderated hormone × Att effects were not significant after Holm correction (smallest p_Holm = .091) and were non-significant in all models with random hormone slopes (all $p \geq .077$). Exploratory decomposition suggested that hormone × Att interactions, particularly for E1G, were concentrated among committed women,

but because the formal tests of moderation were not supported, we do not interpret this pattern further.

Table S8. Hormone x Attractiveness x Relationship status three-way interaction

Outcome	Model	Term	Fixed slopes: b [95% CI]	p	p (Holm)	Random slopes: b [95% CI]	df	p
SDI-Self	A	E1G × Att × Status	0.045 [–0.022, 0.111]	.189	.378	0.054 [–0.020, 0.129]	68.7	.156
SDI-Self	A	PdG × Att × Status	0.011 [–0.047, 0.069]	.698	.698	0.010 [–0.052, 0.071]	30.3	.756
SDI-Self	B	E:P × Att × Status	–0.001 [–0.050, 0.048]	.969	—	0.000 [–0.052, 0.052]	21.9	.997
SDI-Other	A	E1G × Att × Status	0.039 [–0.021, 0.099]	.198	.396	0.051 [–0.037, 0.140]	68.5	.260
SDI-Other	A	PdG × Att × Status	–0.032 [–0.084, 0.020]	.232	.396	–0.026 [–0.082, 0.030]	39.0	.372
SDI-Other	B	E:P × Att × Status	0.028 [–0.016, 0.073]	.214	—	0.026 [–0.023, 0.075]	49.4	.306
SOI-Desire	A	E1G × Att × Status	0.034 [–0.011, 0.079]	.139	.279	0.037 [–0.023, 0.097]	93.6	.235
SOI-Desire	A	PdG × Att × Status	–0.017 [–0.057, 0.022]	.381	.381	–0.021 [–0.067, 0.025]	38.4	.376
SOI-Desire	B	E:P × Att × Status	0.021 [–0.013, 0.054]	.221	—	0.024 [–0.021, 0.068]	55.2	.302
SOI-Attitudes	A	E1G × Att × Status	0.027 [0.001, 0.053]	.046	.091	0.028 [–0.002, 0.058]	59.3	.077
SOI-Attitudes	A	PdG × Att × Status	–0.009 [–0.032, 0.014]	.462	.462	–0.008 [–0.040, 0.023]	65.0	.597
SOI-Attitudes	B	E:P × Att × Status	0.012 [–0.007, 0.032]	.222	—	0.013 [–0.013, 0.039]	56.1	.329

Note. Estimates are unstandardized coefficients from multilevel models of daily diary data (n = 1,543 days, k = 65 women). Model A entered E1G and PdG together; Model B entered the E:P ratio. Fixed-slope models had a random intercept per participant (Satterthwaite df = 1,470–1,477). Random-slope models added participant-level random slopes for the hormone terms; none was singular. Holm correction was applied to the two Model A terms within each outcome. Model B has a single three-way term per outcome, so no correction applies (—). Status is coded 0 = single or uncommitted, 1 = committed.

Exploratory analysis on partner attractiveness among committed women

Table S9. Partner Attractiveness as a Moderator Among Women in Committed Relationships

Panel A: Fixed effects for interaction terms.

Outcome / Interaction Term	*b* [95% CI]	SE	*t*(df)	*p*	*p* (Holm)	Random slopes *b* [95% CI]	*p*
SDI-Self (n = 809; k = 34)							
E1G × Attractiveness	.053 [.011, .095]	.021	2.49 (772)	.013*	.026	.057 [.006, .108]	.034
PdG × Attractiveness	.009 [-.026, .043]	.017	0.50 (774)	.619	.619	.007 [-.029, .043]	.695
E1G:PdG × Attractiveness	.004 [-.025, .033]	.015	0.27 (774)	.791	—	.007 [-.027, .041]	.698
SDI-Other (n = 809; k = 34)							
E1G × Attractiveness	.014 [-.033, .061]	.024	0.58 (773)	.562	> .999	.026 [-.047, .099]	.488
PdG × Attractiveness	-.013 [-.051, .025]	.019	-0.67 (777)	.501	> .999	-.011 [-.049, .026]	.556
E1G:PdG × Attractiveness	.009 [-.023, .042]	.016	0.56 (775)	.573	—	.009 [-.023, .042]	.573
SOI-Desire (n = 809; k = 34)							
E1G × Attractiveness	.033 [.009, .058]	.012	2.72 (771)	.007**	.013	.034 [.004, .064]	.032
PdG × Attractiveness	-.013 [-.033, .006]	.010	-1.32 (772)	.188	.188	-.013 [-.036, .010]	.293
E1G:PdG × Attractiveness	.017 [.00008, .033]	.008	1.97 (773)	.049*	—	.017 [-.0002, .034]	.065
SOI-Attitudes (n = 809; k = 34)							
E1G × Attractiveness	.026 [.009, .044]	.009	2.99 (771)	.003**	.006	.027 [.010, .045]	.002
PdG × Attractiveness	-.021 [-.035, -.006]	.007	-2.85 (771)	.005**	.006	-.019 [-.037, .0001]	.061
E1G:PdG × Attractiveness	.020 [.008, .032]	.006	3.35 (773)	< .001***	—	.020 [.003, .036]	.024

Panel B: Simple slopes of E1G, PdG, and the E1G:PdG ratio at three levels of partner attractiveness.

Outcome	Attractiveness Level	E1G slope *b* [95% CI]	PdG slope *b* [95% CI]	E1G:PdG Ratio slope *b* [95% CI]
SDI-Self	-1 SD	.012 [-.047, .071]	-.065* [-.114, -.017]	.047* [.006, .088]
	Mean	.065* [.024, .107]	-.057* [-.090, -.024]	.051* [.023, .079]
	+1 SD	.119* [.060, .178]	-.048* [-.095, -.001]	.055* [.014, .095]
SDI-Other	-1 SD	.073* [.008, .139]	-.020 [-.074, .034]	.030 [-.016, .075]
	Mean	.087* [.041, .133]	-.033 [-.070, .004]	.039* [.007, .070]
	+1 SD	.101* [.035, .167]	-.046 [-.098, .006]	.048* [.003, .093]
SOI-Desire	-1 SD	-.035* [-.069, -.001]	-.002 [-.029, .026]	-.007 [-.030, .017]
	Mean	-.001 [-.025, .022]	-.015 [-.034, .004]	.010 [-.006, .026]
	+1 SD	.032 [-.002, .066]	-.028* [-.055, -.001]	.027* [.004, .050]
SOI-Attitudes	-1 SD	-.020 [-.044, .005]	.006 [-.014, .026]	-.009 [-.025, .008]
	Mean	.007 [-.010, .024]	-.014* [-.028, -.001]	.012* [.000003, .023]
	+1 SD	.033* [.009, .058]	-.035* [-.054, -.016]	.032* [.015, .049]

Note. Analyses restricted to women in committed relationships, each of whom rated her own partner's attractiveness (n = daily observations; k = women). Outcomes are sqrt-transformed (SDI-self, SDI-other, SOI-desire) or sample-wide z-scored (SOI-attitudes). Hormones are within-person mean-centered and sample-wide standardized. Partner attractiveness was standardized among committed women (M = 0, SD = 1). E1G and PdG were entered in the same model; the E1G:PdG ratio was tested in a separate model. Fixed-slope estimates come from models with random intercepts for participant; 95% CIs are Wald intervals. Holm correction was applied to the two terms of the E1G/PdG model within each outcome (— = not applicable). Random-slope models added uncorrelated participant-level random slopes for the hormone terms; fits were singular for SDI-Other (both models) and SOI-

Attitudes (E1G/PdG model). Interval bounds smaller than .001 in absolute value are shown to one significant digit. *p < .05. **p < .01. ***p < .001. 95% CI excludes zero. Simple slopes are within-person associations of E1G, PdG, and the E1G:PdG ratio with each outcome at −1 SD, the mean, and +1 SD of partner attractiveness among committed women, from the fixed-slope models in Panel A. E1G:PdG Ratio = log-transformed ratio of estradiol (E1G) to progesterone (PdG) metabolites, tested in a model separate from E1G and PdG.

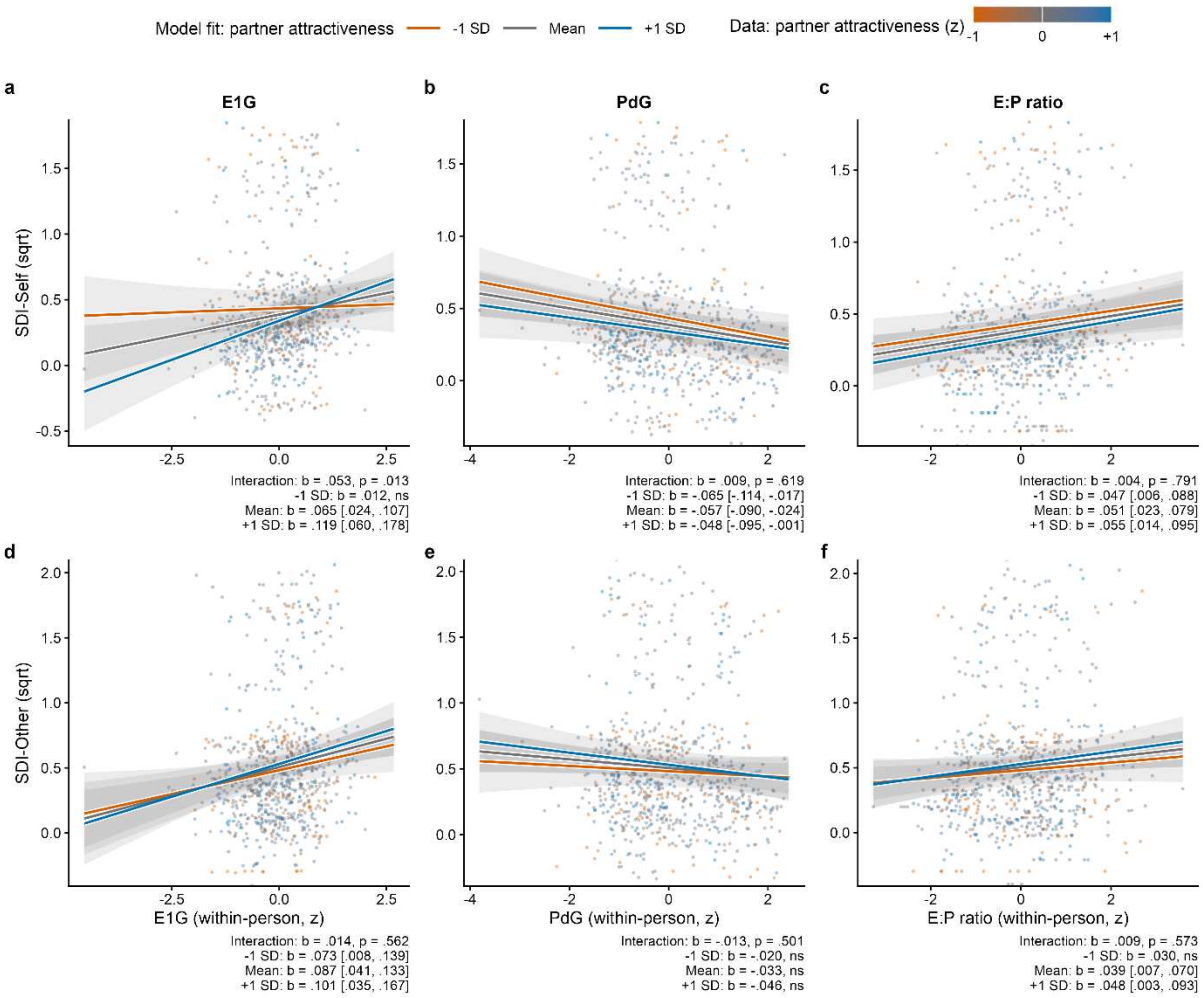


Figure S3. Hormone × partner attractiveness interactions for sexual desire among women in committed relationships (k = 34; n = 809).

*Notes.*Predicted SDI-Self (**a–c**) and SDI-Other (**d–f**) scores as a function of within-person E1G, PdG and E1G:PdG ratio (columns), at −1 SD, mean and +1 SD of partner attractiveness (standardized among committed women). Lines and bands show model predictions with 95% CIs. Points show daily observations adjusted for each woman's baseline, colored by partner attractiveness. Text below each panel gives the interaction (b, p) and simple slopes with 95% CIs (ns: CI includes zero).

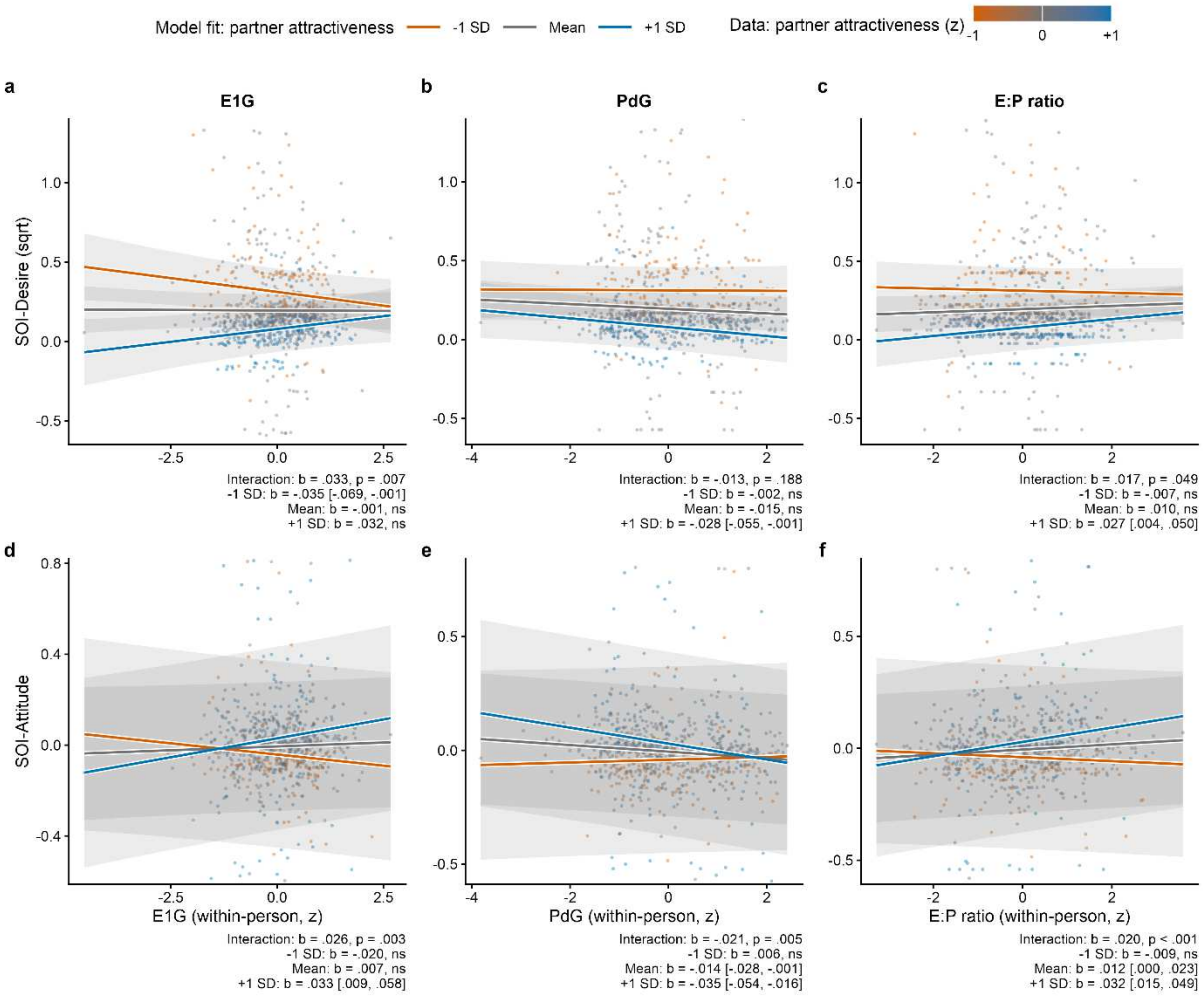


Figure S4. Hormone × partner attractiveness interactions for sociosexuality among women in committed relationships (k = 34; n = 809).

Notes. Predicted SOI-R Desire (**a–c**) and SOI-R Attitude (**d–f**) scores as a function of within-person E1G, PdG and E1G:PdG ratio (columns), at −1 SD, mean and +1 SD of partner attractiveness (standardized among committed women). Lines and bands show model predictions with 95% CIs. Points show daily observations adjusted for each woman's baseline, coloured by partner attractiveness. Text below each panel gives the interaction (b, p) and simple slopes with 95% CIs (ns: CI includes zero).

Main effects of relationship status

Table S10. Main Effects of Relationship Status (Committed vs. Single/Uncommitted) on Sexual Desire and Sociosexuality

Panel A: Fixed effects of relationship status.

Outcome / Model	*b*	SE	*t*(df)	*p*
SDI-Self (n = 1,543; k = 65)				
E1G and PdG model	-.038	.075	-0.50 (63.5)	.619
E1G:PdG ratio model	-.041	.075	-0.54 (63.6)	.591
SDI-Other (n = 1,543; k = 65)				
E1G and PdG model	.222	.052	4.28 (64.1)	< .001***
E1G:PdG ratio model	.222	.052	4.26 (64.1)	< .001***
SOI-Desire (n = 1,543; k = 65)				
E1G and PdG model	-.486	.109	-4.46 (62.7)	< .001***
E1G:PdG ratio model	-.484	.109	-4.44 (62.7)	< .001***
SOI-Attitudes (n = 1,543; k = 65)				
E1G and PdG model	-.146	.220	-0.66 (63.0)	.510
E1G:PdG ratio model	-.146	.220	-0.67 (63.0)	.508

Panel B: Estimated marginal means by relationship status (E1G and PdG model).

Outcome	Single/Uncommitted EMM [95% CI]	Committed EMM [95% CI]
SDI-Self	.423 [.314, .532]	.385 [.282, .489]
SDI-Other	.284 [.209, .359]	.508 [.437, .580]
SOI-Desire	.679 [.521, .836]	.194 [.043, .344]
SOI-Attitudes	.141 [-.177, .459]	-.005 [-.308, .299]

Note. Estimates are the fixed effect of relationship status (0 = single/uncommitted [reference], 1 = committed) from the multilevel models summarized in Table 5 (n = 1,543 daily observations; k = 65 women). Because hormones were within-person mean-centered, the coefficient is the difference between committed and single/uncommitted women at each woman's own average hormone level. The E1G and PdG model entered both hormones and their interactions with relationship status; the E1G:PdG ratio model entered the log-transformed ratio and its interaction with relationship status. All models included random intercepts for participant; *t*-tests use Satterthwaite degrees of freedom. Panel B shows estimated marginal means (EMM) from the E1G and PdG model (emmeans; Kenward–Roger degrees of freedom) on the analysis scale: sqrt-transformed for SDI-self, SDI-other, and SOI-desire, and sample-wide z-scored for SOI-attitudes. ***p < .001.

Data pattern

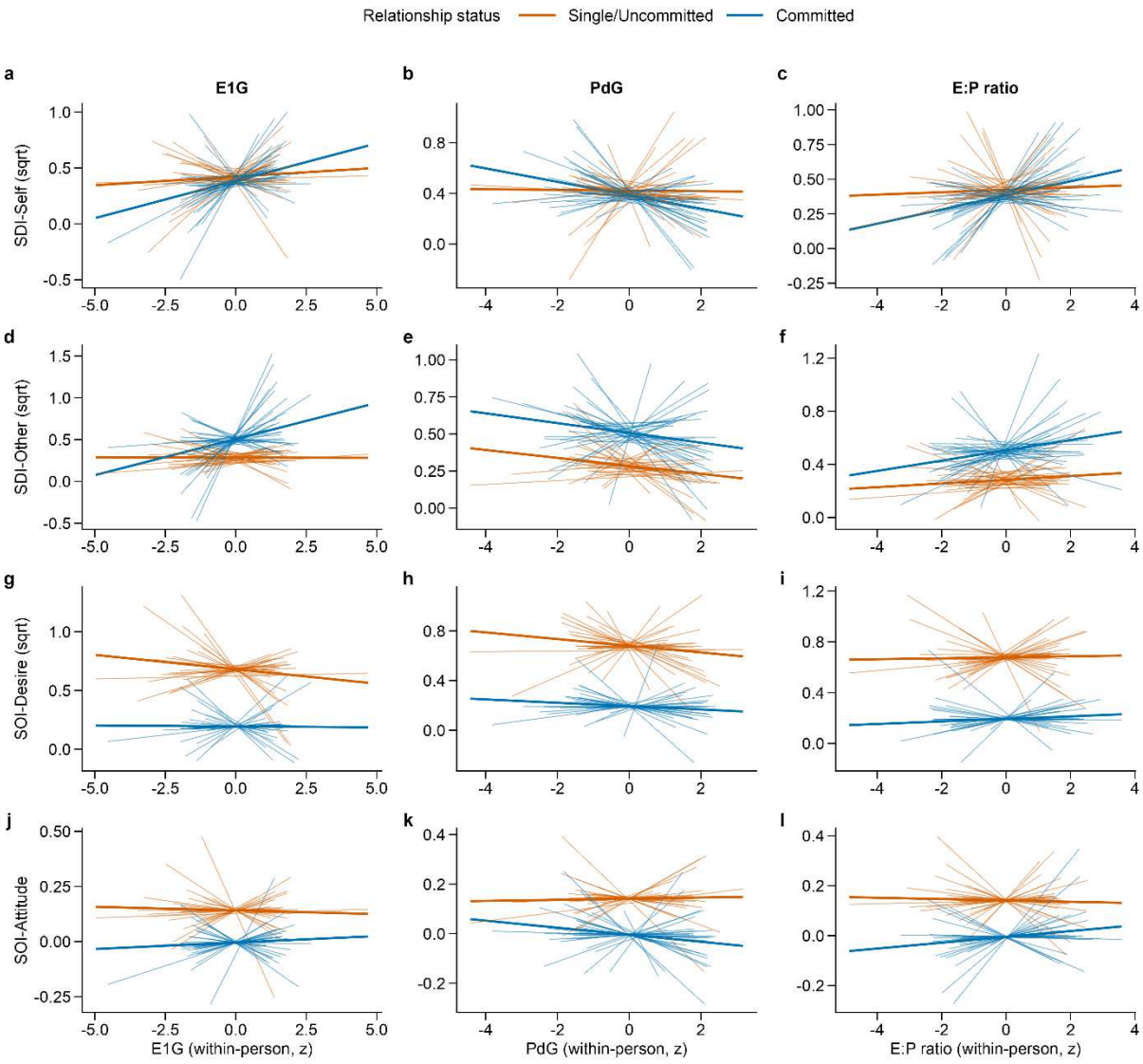


Fig. S5 Individual variation in within-woman hormone slopes for sexual desire and sociosexuality, by relationship status

Notes. Each panel plots one outcome (rows: SDI-Self, a–c; SDI-Other, d–f; SOI-Desire, g–i; SOI-Attitude, j–l) against one within-woman standardized hormone measure (columns: E1G, PdG and E:P ratio). Thin lines show each woman's own least-squares slope across her observed hormone range. The slopes are fitted to partial residuals: each woman's baseline is removed and, for E1G and PdG, the other hormone is held at its mean. Only women with at least 5 days of data are shown. Thick lines show the linear mixed-model estimates for single/uncommitted (solid) and committed (dashed) women. The spread of thin lines around the thick lines shows how much individual women vary around the group-level estimates. E1G, estrone-3-glucuronide; PdG, pregnanediol-3-glucuronide; E:P ratio, E1G:PdG ratio; SDI, Sexual Desire Inventory; SOI, Sociosexual Orientation Inventory

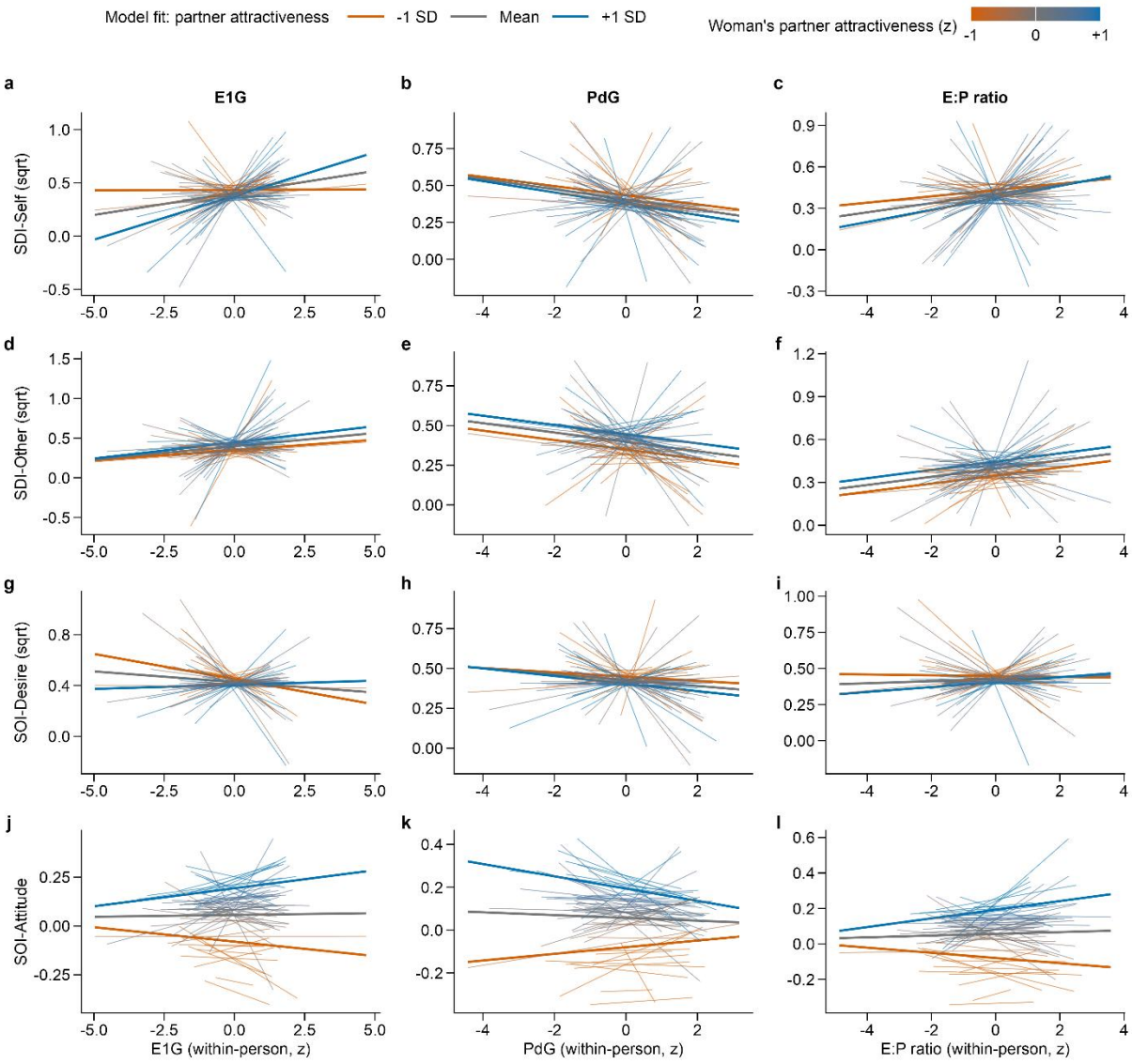


Fig. S6 Individual variation in within-woman hormone slopes for sexual desire and sociosexuality, by partner attractiveness

Notes. Panels and abbreviations are as in Fig. S1. Thin lines show each woman's own least-squares slope, shaded by her partner's attractiveness rating (z; the shading scale saturates at ±1 SD). Thick lines show the linear mixed-model estimates at partner attractiveness 1 SD below the mean (dashed), at the mean (dotted) and 1 SD above the mean (solid).

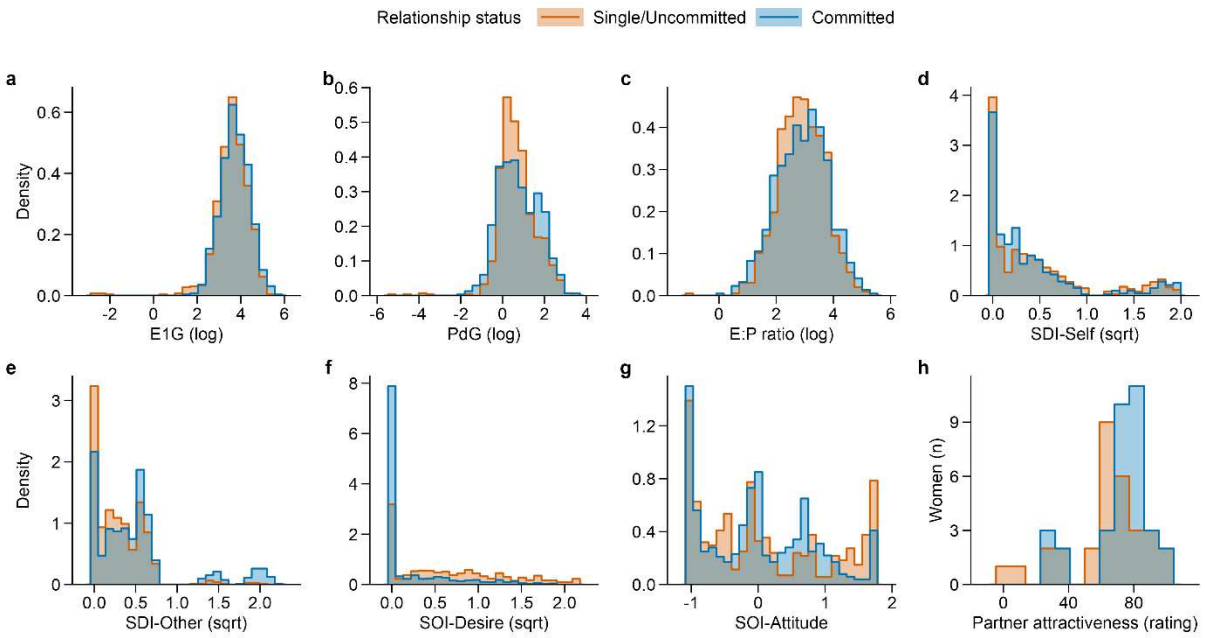


Fig. S7 Distributions of hormone, sexuality and partner attractiveness measures by relationship status

Notes. Overlaid histograms for single/uncommitted (solid outline) and committed (dashed outline) women cover three sets of measures. Panels a–c show daily hormone measures (log-transformed E1G, PdG and E:P ratio), and panels d–g show daily outcome scores (SDI-Self, SDI-Other and SOI-Desire, square-root transformed, and SOI-Attitude). Panel h shows partner attractiveness ratings, one mean rating per woman. Bar heights are densities in a–g, so groups of different sizes can be compared, and numbers of women in h.

CT-SEM Model fit

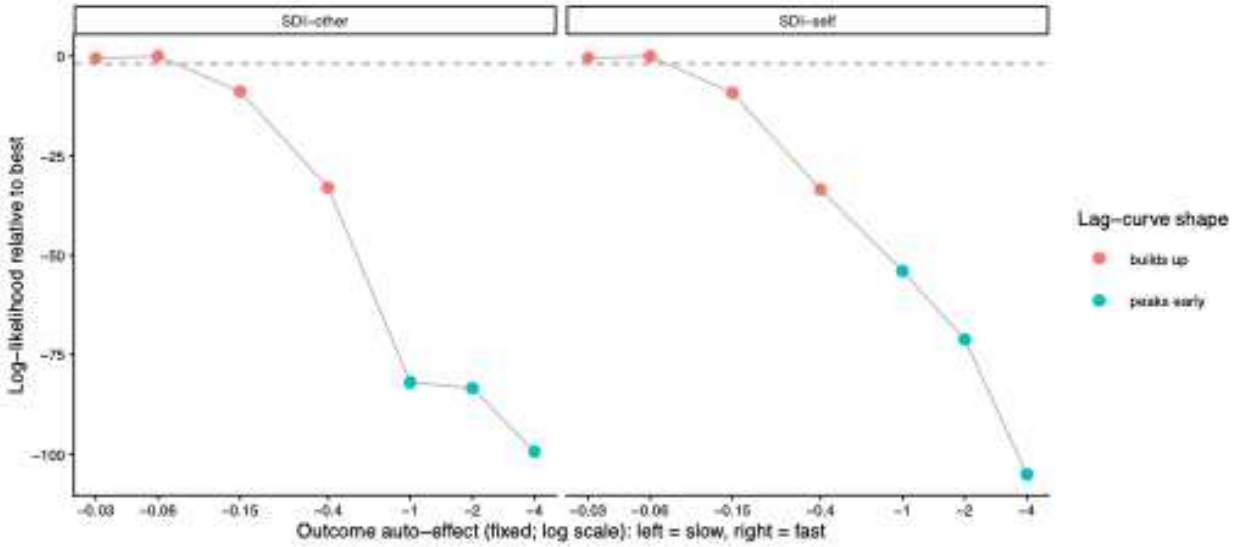


Figure S8. Model fit of the SDI CT-SEM models across fixed values of the desire auto-effect.

Notes. Log-likelihood relative to the best-fitting value for SDI-other (**a**) and SDI-self (**b**), with the outcome auto-effect fixed at seven values from slow (−0.03) to fast (−4; log scale). Point colour shows the shape of the implied lag curve: effects that build up across days (red) or peak early and fade (blue). The dashed line marks 1.92 units below the best fit, the conventional 95% profile-likelihood threshold. Fast dynamics fit substantially worse for both subscales.