Motivation Science

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Motives and Gonadal Steroid Hormones Across the Menstrual Cycle: A Longitudinal Replication Study

Emilia Pekarek, Jessica Hinzmann, Kyra Göbel, and Oliver C. Schultheiss
Department of Psychology, Friedrich-Alexander University

We aimed at replicating findings reported by Schultheiss et al. (2003) on the associations between gonadal steroid hormones and implicit motives across the menstrual cycle. We tested whether the implicit needs for affiliation (*n* Affiliation) and power (*n* Power) covary with salivary estradiol, testosterone, and progesterone. Our longitudinal study ($N = 131$, 49 men, 50 normally cycling women, 32 women taking hormonal contraception) with three assessments, corresponding to the follicular, periovulatory, and luteal phases of the cycle, included the Picture-Story Exercise (*n* Power, *n* Affiliation), saliva collection, and radioimmunoassays (estradiol, testosterone, and progesterone). Multilevel analyses revealed that even though most of the expected hormonal characteristics were observable in our sample, none of the previously reported motive–hormone associations were fully replicated, except for testosterone positively covarying with *n* Power in men. Contrary to our hypotheses, the association between progesterone and *n* Affiliation in men was positive. We observed a difference in *n* Power in women depending on relationship status, but it was not associated with estradiol. This is the first longitudinal study attempting to replicate findings reported by Schultheiss et al. (2003). Our results are based on a larger sample, sensitive and valid assays, and we were not able to replicate most of the previously reported associations.

Keywords: motivation, gonadal steroid hormones, power motive, affiliation motive, menstrual cycle

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More than 20 years ago, Schultheiss et al. (2003) reported that implicit motives—nonconsciously operating preferences for specific classes of incentives—fluctuate across the menstrual cycle, corresponding to fluctuating levels of gonadal steroid hormones. According to their results, the implicit need for affiliation (*n* Affiliation)—a capacity for deriving pleasure from forming and maintaining close relationships with others (Schultheiss & Köllner, 2021; Weinberger et al., 2010)—is associated with progesterone, and the implicit need for power (*n* Power)—a capacity for deriving pleasure from having emotional, mental or physical impact on others (McClelland, 1987; Schultheiss & Köllner, 2021)—is associated with testosterone and estradiol (17ß-estradiol). Because these results have implications for motivation science and behavioral endocrinology but have not yet been replicated in the context of a longitudinal design, we will revisit their findings and aim to replicate them in a larger sample and using a more appropriate and sophisticated analytical strategy (multilevel modeling analysis).

Implicit Motives

Implicit motives are defined as recurrent concerns for goal states based on a natural incentive (McClelland, 1987). They energize, orient, and select behavior (McClelland, 1987). Implicit motives cannot be equated with the motivational needs individuals attribute to themselves on questionnaires (Köllner & Schultheiss, 2014; Schultheiss et al., 2009), and thus can only be measured by

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Emilia Pekarek https://orcid.org/0009-0006-1108-6112
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Correspondence concerning this article should be addressed to Emilia Pekarek, Department of Psychology, Friedrich-Alexander University, Nägelsbachstrasse 49b, 91052 Erlangen, Germany. Email: emilia.pekarek@fau.de

analyzing the content of imaginative stories written or spoken by research participants in response to specific picture cues, a method called Picture-Story Exercise (PSE; McClelland et al., 1989). Motives are measured by counting the frequency of motive-relevant themes in written PSE stories. These themes have repeatedly shown their sensitivity to motivational arousal (e.g., Rawolle et al., 2017; Schultheiss et al., 2004) and are therefore valid in a causal sense (Borsboom et al., 2004). One of the most widely used coding systems is the *Manual of Scoring Motive Imagery in Running Text* by Winter (1994), which allows the simultaneous coding of both affiliation and power imagery (Pang, 2010; Schultheiss & Pang, 2007).

n Affiliation and *n* Power have previously been linked to various cognitive, behavioral, and emotional outcomes (Köllner et al., 2019; Schultheiss, 2013; Schultheiss & Köllner, 2021). More specifically, research has demonstrated the associations between *n* Power and *n* Affiliation and the gonadal steroid hormones testosterone, estradiol, and progesterone (for an overview, see Schultheiss, 2013).

Gonadal Steroids and Motives

The hypothalamus represents a key neurobiological nexus between motivation and hormone release (e.g., Hahn et al., 2019; Hall et al., 2010; Kruk et al., 1998). It is functionally connected to other motivational–brain areas (Schultheiss & Wirth, 2018), like amygdala, striatum, hippocampus, and orbitofrontal cortex, which all are involved in central aspects of motivation, such as emotional responses, instrumental learning and behavior via the processing of rewards, and the experience of subjective feelings (Schultheiss & Wirth, 2018). The hypothalamus is also a key regulator of endocrine responses (Nelson & Kriegsfeld, 2017). Together with the pituitary, it governs several hormonal systems, including the hypothalamic–pituitary–gonadal (HPG) axis, which directs the release of the gonadal steroids testosterone, estradiol, and progesterone (Kaprara & Huhtaniemi, 2018). Hypothalamic effects on the HPG are also indirectly mediated by its regulation of the stress axes (Sapolsky, 1987; Viau, 2002). Thus, circulating gonadal steroid hormones reflect both the direct activity of the HPG axis as well as indirect effects of hormonal systems not directly involved in reproduction.

Reviewing evidence from correlational and experimental studies on implicit motives, hormones and hormonal changes, Schultheiss (2013) argued that the hypothalamus is critically involved in implicit motivational processes, with this brain structure being a key mediator of motive effects on hormone release and behavior, and circulating hormones in turn affecting motivational brain functions and thus current motive levels. Accordingly, motive–hormone associations are not a coincidence but should be expected, given the integrating role of the hypothalamus in both motivational and endocrine regulation and the typically bidirectional relationship between hormones and behavior (Schultheiss & Mehta, 2019). In keeping with this notion, Schultheiss (2013) reported correlation coefficients, aggregated across several studies, indicating positive associations between *n* Power and testosterone in men and estradiol in women.

Although testosterone is also made in the adrenal cortex and ovaries, it is produced in far greater amounts in the testicles, leading to a much higher concentration of this hormone in men than in women (Clifton et al., 2016). This in turn is crucial for the growth of sexual characteristics, for sexual reproduction, and for social behavior (Clifton et al., 2016; Dabbs, 1990; Eisenegger et al., 2011; Mazur & Booth, 1998; Tsai & Sapolsky, 1996). Reviewing evidence from experimental studies, Schultheiss (2013) concluded that this motive–hormone relationship is stronger in the presence of specific incentives than in their absence. This is based on results showing specific salivary testosterone responses elicited by power-related (dis-) incentives such as winning or losing a contest depending on variations in *n* Power (e.g., Schultheiss & Rohde, 2002; Schultheiss et al., 2004; Vongas & Al Hajj, in press).

Estradiol is mainly produced in the ovaries and influences the growth of sexual characteristics and is involved in the initiation and regulation of the reproductive cycle (Barbieri, 2014; Hampson, 2020). Apart from its role in sexual reproduction, estradiol is associated with a variety of cognitive and central nervous processes (Becker, 2002; Becker & Chartoff, 2019). Similar to results for testosterone and *n* Power in men, estradiol responses are associated with *n* Power in women after winning or losing a dominance contest (Oxford et al., 2017; Stanton & Schultheiss, 2007). The estradiol–*n* Power relationship is also moderated by relationship status (absent in partnered, present in single women) and the use of hormonal contraception (HC), with contraceptives attenuating the association (Schultheiss et al., 2003; Stanton & Edelstein, 2009; Stanton & Schultheiss, 2007). These results suggest that both endocrine (HC) as well as social (relationship status) factors contribute to the relationship between *n* Power and estradiol (Schultheiss, 2013). It is not clear yet why relationship status plays such a role in this context, but Stanton and Edelstein (2009) assumed that it can be explained from an evolutionary perspective. In high-estradiol single women, higher levels of *n* Power could improve access to potential mates, while, in partnered women, this association is not needed and thus not fostered because access to a mate is a given (Stanton & Edelstein, 2009).

Progesterone is mainly produced by the corpus luteum during the luteal phase of the cycle, and, in smaller quantities, by the adrenal cortex and the testicles (Schmalenberger et al., 2021). Changes in progesterone concentrations are associated with processes of sexual reproduction, ranging from fertilization to the support of a fetus during pregnancy (Hampson, 2020; Toffoletto et al., 2014). Research also suggests that progesterone is linked to emotional and (neuro-)cognitive processing (Bernal & Paolieri, 2022; Toffoletto et al., 2014; Wirth, 2011) and that higher progesterone is associated with more social closeness (Brown et al., 2009; Duffy et al., 2017), a behavioral correlate of *n* Affiliation. In both men and women, affiliation-relevant arousal via experimentally varied movie clips has been linked to a salivary progesterone response as well as an increase in *n* Affiliation (Schultheiss et al., 2004; Wirth & Schultheiss, 2006). Elevated *n* Affiliation has been reported for women taking oral contraceptives (OC), which contain synthetic progestins, as well as in normally cycling (NC) women during the typical progesterone peak during the luteal cycle phase (Schultheiss et al., 2003; Schultheiss & Zimni, 2015). These results suggest a bidirectional link between *n* Affiliation and progesterone: A release of progesterone in response to motive-specific arousal as well as a priming effect of fluctuating progesterone on *n* Affiliation. The role of gender in the context of the latter association (positive in women, negative in men; Schultheiss et al., 2003) still needs further examination.

Overall, our review of motive–hormone associations reported in previous studies both suggests that links between motivation and gonadal steroids exist and are particularly evident in the presence of strong social incentives but also that more research is needed to replicate correlational findings in nonexperimental settings and to explore potential effects of natal sex and HC use. Our goal in this article is therefore to exploit natural variations in gonadal steroid

levels to study their within-subject covariation with *n* Power and *n* Affiliation in women and men.

Menstrual Cycle in a Longitudinal Design

A key factor for the replication of Schultheiss et al. (2003) is the longitudinal design, which captures fluctuating hormone concentrations over the course of a menstrual cycle and allows intra- and inter-individual comparisons. In fertile NC women, a menstrual cycle is counted from the first day of menstrual bleeding and begins with the follicular phase (Hampson, 2020; Schmalenberger et al., 2021). During this time, both estradiol and progesterone are at low concentrations (Barbieri, 2014; Jabbour et al., 2006). In the following days, estradiol increases, culminating in a peak around Days 11–14, followed by a decrease after the maturation of the ovarian follicle and subsequent ovulation (Barbieri, 2014; Gangestad et al., 2016). With the formation of the corpus luteum, the luteal cycle phase begins, and both progesterone and estradiol rise to a sustained peak and decline again before the onset of the next menstruation (Barbieri, 2014; Jabbour et al., 2006). Thus, the follicular, periovulatory, and luteal phases of the menstrual cycle provide a naturally occurring quasi-experimental design when studying NC women. In contrast to NC women, women who use HC (oral or other) have low and flat estradiol and progesterone levels throughout the cycle because the continuous presence of synthetic hormones inhibits its natural endogenous hormone release (Blumenthal & Edelman, 2008; Hampson, 2020), leading to low salivary gonadal steroid levels (Schultheiss et al., 2018).

Typical cycle length and the curves of fluctuating estradiol and progesterone show variations among the general population (Barbieri, 2014; Bull et al., 2019; Gandara et al., 2007), and therefore, research should address the whole cycle when examining steroid-associated changes in implicit motives.

Since the study by Schultheiss et al. (2003), there have been numerous new results and advances in menstrual cycle research, including the now widely accepted criticism of the forward counting method used in the original study for determining cycle phases (Gangestad et al., 2016; Gloe et al., 2023). The now recommended inclusion of biomarkers like salivary hormones has increased (Gangestad et al., 2016), and there has also been methodological progress in this hormone measurement since 2003, reflected in the critical evaluation of some of the salivary assay methods (Arslan et al., 2023; Schultheiss et al., 2018) or new recommendations on saliva sampling (Becker et al., 2023). Salivary measurements are a noninvasive method for assessing cycle fluctuations in hormones (reviewed in Allen et al., 2016) and thus provide, when used in a longitudinal context, a comprehensive picture of hormonal changes throughout the cycle (Celec et al., 2009; Dlugash et al., 2025).

Thus far and to the best of our knowledge, the study by Schultheiss et al. (2003) is the only previous study examining the whole menstrual cycle and measuring implicit motives with the PSE in a within-subject longitudinal design, which underscores the relevance of a replication with to some extend more refined methodology.

Current Study

Closely following Schultheiss et al.'s (2003) earlier study, we conducted a longitudinal study using a similar protocol regarding implicit motive (PSE) and salivary hormone assessment (radioimmunoassay) at three phases of the cycle (follicular, periovulatory, and luteal) with a larger sample of NC women, HC women, and men. We also assessed relationship status (single vs. partnered) as a potential moderator variable. In contrast to the study by Schultheiss et al. (2003), we employed multilevel modeling analyses in order to take into account simultaneously the variance associated with measurements at two levels of the analysis.

Hypotheses

Our preregistered hypotheses (https://osf.io/dvmt4/) were derived from the results of Schultheiss et al. (2003). As a nonpreregistered adjustment to our hypotheses and planned analyses, we included not only women taking OC but also women using other forms of HC (e.g., injections and intrauterine devices). We used the preregistered hypotheses as orientation in terms of content, as their original formulation does not exactly match the multilevel analyses we decided to employ after data collection as the most suitable analytical approach. We thus analyzed the preregistered associations but with necessary adaptations for multilevel modeling (for detailed information, see Supplement F in the online supplemental materials).

The first set of hypotheses serves the purpose of evaluating the reliability of the subsequent analyses with motives and salivary hormones.

Regarding estradiol, we hypothesized that in NC women there is an increase in estradiol between the follicular and the periovulatory phase, and a second, shallower peak in the luteal phase (Hypothesis 1a). We did not expect to observe these cycle-based changes in HC women (Hypothesis 1b) or men (Hypothesis 1c). For progesterone, we hypothesized that in NC women, relative to the follicular and periovulatory phase, there would be an increase in salivary concentrations in the luteal phase (Hypothesis 1d), which we did not expect to observe in HC women (Hypothesis 1e) or men (Hypothesis 1f). We did not predict systematic changes in testosterone across the three assessments/cycle phases in NC women, HC women, or men (Hypotheses 1g, 1h, and 1i, respectively).

Regarding between-group differences for salivary testosterone, we hypothesized that men would have the highest concentrations, followed by NC women and HC women (Hypothesis 1j). For estradiol, we assumed that NC women would show the highest concentrations of all groups, especially during the periovulatory phase, followed by men and HC women (Hypothesis 1k). For progesterone, we hypothesized that NC women would again have the highest concentrations, especially during the luteal phase, followed by men and HC women (Hypothesis 1l).

Based on studies showing that estradiol is associated with *n* Power (Oxford et al., 2017; Stanton & Edelstein, 2009; Stanton & Schultheiss, 2007), we expected that in single NC women, *n* Power changes would be positively associated with estradiol changes. For this reason, we also expected to observe elevated *n* Power levels in the periovulatory and luteal phases. Finally, we expected this association to be negative for partnered NC women (Hypothesis 2a).

Based on studies showing that progesterone is associated with *n* Affiliation (Oxford et al., 2017; Wirth & Schultheiss, 2006), we expected that in NC women, *n* Affiliation changes would be positively associated with progesterone changes and that therefore *n* Affiliation levels would also be elevated in the high-progesterone luteal phase (Hypothesis 2b).

Based on studies showing that testosterone is repeatedly associated with *n* Power (reviewed by Oxford et al., 2017; Schultheiss,

2013), we hypothesized that in men more testosterone would be associated with more overall *n* Power (Hypothesis 3a).

Similarly, and based on studies showing that estradiol is associated with *n* Power (Oxford et al., 2017; Stanton & Edelstein, 2009; Stanton & Schultheiss, 2007), we expected that in single women higher estradiol would be associated with more overall *n* Power, but that this association would be absent in partnered women (Hypothesis 3b).

Finally, and based on studies showing that progesterone is with *n* Affiliation (Oxford et al., 2017; Wirth & Schultheiss, 2006), we expected salivary progesterone to be positively associated with *n* Affiliation in women and negatively in men (Hypothesis 3c).

Method

Sample

A power analysis based on typical motive–criterion associations observed in previous research (see Spangler, 1992) suggested that we recruit and test 237 participants to detect effect sizes of $r = .22$ with 80% power at $p < .01$. But because of the advent of the COVID-19 pandemic and the resulting restrictions in our laboratory, we were only able to recruit 150 individuals via online advertisement and flyers, of which only 134 enrolled in the study. Participants had to be between 18 and 45 years of age, not currently pregnant, fluent in German, as well as not previously enrolled in other studies employing the PSE by our lab, and, in the case of psychology students, have not previously participated in seminars about implicit motives. Due to the requirements of our statistical analyses, we only included participants who completed at least two assessments (Nezlek, 2012).

After a dropout of three participants, the final sample with data of at least two assessments consisted of $N = 131$ participants ($M_{age} = 23.46$, $SD = 4.32$; range = 18.0–43.0), of which 49 reported to be male ($M_{age} = 24.22$, $SD = 4.17$), 50 to be NC women ($M_{age} = 23.20$, $SD = 4.99$), and 32 to be HC women ($M_{age} = 22.69$, $SD = 3.22$). Of the HC women, 25 used OC (23 used estrogen–progestogen combination pills, two used progestogen-only pills) and seven used intrauterine devices with an estrogen–progestin combination. Seventy-three participants reported to be living in a relationship and 58 reported to be single.

Eighteen participants had to be excluded from specific analyses, either because of missing PSE data (<30 words for each picture stimulus, $n = 1$) or because of grossly divergent duplicate measurements of hormone concentrations. We excluded (a) one man, two NC women, and six HC women from all analyses involving estradiol; (b) one NC woman and two HC women from all analyses involving testosterone; and (c) two men and two HC women from all analyses involving progesterone.

Design

As depicted in Figure 1, we conducted three assessments (T1, T2, and T3) in a longitudinal study design. For NC and HC women, the first assessment could take place in any of the three cycle phases, with one assessment each representing the follicular phase (3–4 days after menses onset), the periovulatory phase (13–15 days after menses onset), and the luteal phase (20–24 days after menses onset), based on a typical cycle duration of approximately 27–29 days (Bull et al., 2019; Hampson, 2020). The assessment schedule could be expanded or contracted proportionately, depending on self-reported cycle lengths. Assessments of men were scheduled accordingly based on a pseudocycle duration of 28 days. All participants received the same PSE picture sets in a random order. Hormone data as well as PSE data were the dependent variables, and the expected hormonal changes in NC women were used as predictors. The design implemented in our study corresponds to the one used by Schultheiss et al. (2003).

Procedure

Assessments were scheduled 7–10 days apart, resulting in a total duration of 21–30 days completion time for the study, depending on individual cycle length. We assessed demographic data at T1. In all sessions (T1, T2, T3), we administered a PSE set and collected a saliva sample. After giving informed consent, participants completed computer-administered tasks (Inquisit 5, Version 5.0.14.0, Millisecond, Seattle, Washington, United States) in separate laboratory cabins. They started with a saliva sample collection, followed by a PSE set, and then other tasks unrelated to the present research. Participants received a total reimbursement of €50.

Materials

Demographic Data and Factors Influencing Hormones

We assessed demographic data and factors influencing hormones through self-report. Participants responded to items regarding relevant demographics (e.g., age, gender, and relationship status) and factors influencing hormone concentrations (e.g., medication, chronic or hormonal diseases, and consumption of nicotine and alcohol). For women, the questionnaire also included items regarding their menstrual cycle (e.g., typical cycle duration, date of onset of the last menstrual bleeding, and duration of menstruation) and their contraceptive method (e.g., brand of HC). To minimize inaccurate recall of cycle data (Wegienka & Baird, 2005), female participants were informed in advance and encouraged to bring notes with them to the testing session.

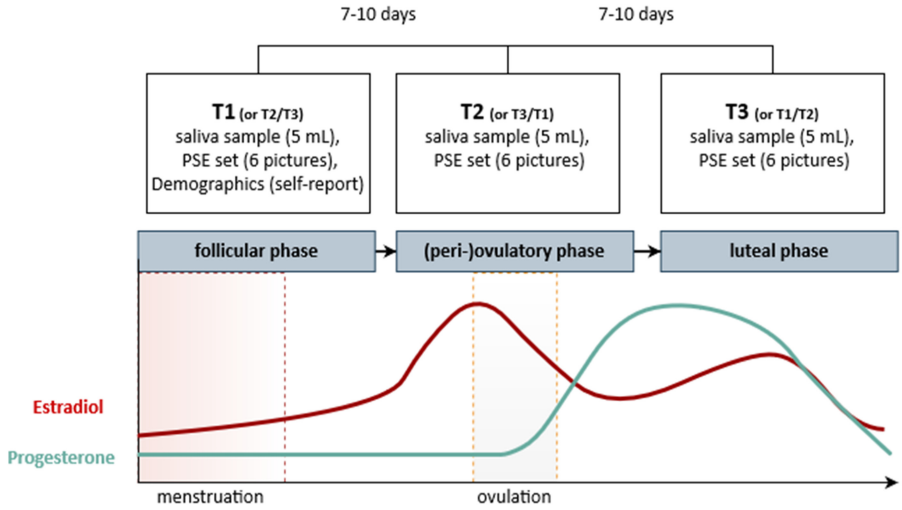
Implicit Motives

Deviating from Schultheiss et al. (2003), the PSE was computer administered, with standardized instructions (Pang, 2010; Smith, 1992). Participants were given 10 s each to look at a picture cue and then had 4 min to type an imaginative story in an empty text field on their screen. Like Schultheiss et al. (2003), we assessed participants' motives with three parallel PSE picture sets (A, B, C) consisting of six pictures each (i.e., one more than the original study). Because this study was part of a project studying sexual motivation, most of the picture cues differed from those used by Schultheiss et al. (2003), but all have been used in previous studies and were suitable for the assessment of *n* Power and *n* Affiliation (Hinzmann et al., 2023; Schönbrodt et al., 2021; Schultheiss et al., 2021, 2023). The pictures were selected and arranged specifically for the study based on results concerning their cue strength, well-balanced cue ambiguity (Pang, 2010; Ramsay & Pang, 2013), and their social setting.

All pictures used in the study are described in Table 1. To prevent a possible confounding effect between picture set and assessment session, the sequences in which the sets were administered to participants across sessions varied randomly. This resulted in six different sequences (i.e., ABC, ACB, BAC, BCA, CAB, CBA). Each picture cue was used only once.

Figure 1

Overview of Exemplary Assessment Schedule and Schematic Illustration of Cycle-Based Hormone Changes



Note. Schematic overview of exemplary assessment schedule corresponding to the follicular, periovulatory, and luteal cycle phases. The first assessment (T1) could be scheduled in any cycle phase; the following two assessments (T2 and T3) were scheduled in subsequent cycle phases. Below the illustration of the study procedure is a schematic illustration of the typical cycle-based hormonal changes (estradiol, progesterone) in normally cycling women, based on Hampson (2020). Assessments of men and women using hormonal contraception followed the same schematic. PSE = Picture-Story Exercise. See the online article for the color version of this figure.

The stories were scored for power and affiliation motive imagery according to *the Manual for Scoring Motive Imagery in Running Text* by Winter (1994) by trained coders who had previously attained 85% agreement with expert-coded material provided in the manual. As recommended by Schönbrodt et al. (2021), every consecutive sentence could be coded for the same type of imagery. Subcategories for coding *n* Affiliation and *n* Power are presented in Table 2 (Winter, 1994). Before coding, we stripped stories of all participant-specific information to ensure coders' blindness to participants' group and cycle phase (Pang, 2010).

Salivary Hormones

At the beginning of each session, participants collected a saliva sample (5 ml) into a sterile polypropylene vial. To ensure sufficient sample quality, participants were not allowed to consume food or drinks, or chew gum 20 min prior to and during the assessment (Celec et al., 2009; Granger et al., 2007; Van Anders, 2010). Participants used a piece of paraffin wax foil as a stimulant (Dlugash & Schultheiss, 2021). Vials were closed and frozen at −20 °C immediately after saliva collection. To break down mucopolysaccharides,

Table 1

Names and Descriptions of Picture Cues of the Three Sets (A, B, and C)

Set		
A	B	C
(Un)dressing[a] (a man unzipping the dress of a woman)	Button shirt[a] (a man unbuttoning a woman's shirt)	Massage[a] (a man massaging a woman's back)
Woman blindfolding man[b] (a woman blindfolding a man)	Man on couch[a] (a woman standing with widespread legs in front of a sitting man)	Woman in charge[a] (a man standing with widespread legs in front of a sitting woman)
Pillow fight[a] (laughing couple having a pillow fight)	Couple in bathroom[a] (smiling couple brushing their teeth together in a bathroom)	Flirt[a] (couple smiling at each other while eating dinner in a restaurant)
Orator[b] (a man giving a speech in front of a crowd)	Woman in golden gown[b] (a woman in a golden dress entering a room with a man holding her coat in the background)	School teacher[b] (a teacher in front of a class)
Tango dancers[a] (couple performing a tango on a stage)	Billiards[a] (couple playing billiard together)	Trapeze artists[b] (couple performing a trapeze stunt)
Girlfriends in café with male approaching[b] (two women in a café with a man approaching)	Nightclub scene[c] (a woman and a man sitting in a restaurant with a guitarist playing next to them)	Couple sitting opposite a woman[b] (two women and a man drinking wine together)

Note. Overview of picture cues used in the study in form of three paralleled sets (A, B, and C). Pictures are accessible on project page and can be found as the additional online materials (https://osf.io/dvmt4/?view_only=ccc9b4f0dfb14a10baaf66ddbe519753). Descriptions are given in parenthesis.
[a] Hinzmann et al. (2023). [b] Schultheiss et al. (2003). [c] Schultheiss and Pang (2007).

Table 2
Categories for Coding Motive Imagery (Winter, 1994) With Examples From the Present Study

Motive	Subcategory	Criteria for coding	Examples
Affiliation	Aff1	Positive, friendly, or intimate feelings toward others	"They have known each other forever; he had always been her best friend."
	Aff2	Negative feeling about separation	"She missed him terribly."
	Aff3	Affiliative, companionate activities	"They liked playing billiard together."
	Aff4	Friendly nurturant acts	"I enjoy the soothing massage [of my partner] and slowly the tension falls away."
Power	Pow1	Strong, forceful actions which inherently have an impact on other people	"She blackmailed me, saying that if I did not follow her, she would reveal everything to my wife."
	Pow2	Control or regulation	"Against my wishes, I had to present myself in public according to my mother's taste."
	Pow3	Attempts to convince, persuade, influence, argue, make a point, and so on.	"It had taken a while to get his trust, but finally I had succeeded."
	Pow4	Giving help, support, or advice that is not explicitly solicited	"Eva had always had a premonition, but actually had it confirmed for the first time when her boss asked her if she wanted to go out for a nightcap after work."
	Pow5	Impressing others, concern about fame, prestige, and reputation	"She wore the tight fitting leather dress that showed off her breasts perfectly."
	Pow6	Strong emotional reactions in one person to intentional actions of another person	"He dreamed of a crowd of students who listened to him spellbound and were inspired by him."

Note. Overview of the criteria for coding power and affiliation imagery in running text (Winter, 1994), including numbered subcategories as well as illustrative examples for each subcategory from the present study. Aff = affiliation; Pow = power.

samples were thawed 3 times at room temperature and refrozen at −20 °C. Afterward, to free the samples of other residuals and allow precipitation of proteins, samples were centrifuged for 20 min at 4 °C and 2,000 rounds per minute. The watery supernatant was transferred into a new test tube and then refrozen at −20 °C before being assayed. Information regarding the kits used for our radioimmunoassay procedures can be found in Supplement A in the online supplemental materials. Assay procedures followed previously established guidelines for hormone measurements in social neuroendocrinology (Schultheiss et al., 2018). Standards and quality controls were measured in triplicate, and samples were measured in duplicate. For estradiol, one assay included all samples, whereas two assays were conducted for testosterone and three for progesterone. All calibration curves were above the accepted minimum of $R^2 = .970$ (Chard, 1982; see Table 3). Analytical sensitivity was assessed with the lower limit of detection ($B_0 - 3 \times SD$). Recovery was calculated for the low, middle, and high range of calibration curve. Assay reliability was evaluated by calculating intraassay coefficients of variation of sample duplicates and by including independent reference samples with known steroid concentrations.

Statistical Methods

Data processing and statistical analyses were conducted with SYSTAT (Version: 13.0; Systat Software GmbH; Düsseldorf), R software (https://r-project.org) with the package lme4 (Bates et al., 2015), and Jeffreys's Amazing Statistics Program (Version 0.18.0; University of Amsterdam). In women, assessment sessions were assigned to the respective cycle phases based on self-report using the provided information of the demographic questionnaire. In an approach described as pseudo backward counting (Gonzales & Ferrer, 2016), we aggregated typical cycle length and day of onset of last menstrual bleeding (backward counting), previous results on cycle phase lengths (Bull et al., 2019), and we instructed women how to schedule their appointments prospectively according to their cycle (forward counting). Additionally, we compared our cycle

Table 3
Quality Control Parameters of the Performed Hormone Assays

Quality control parameters	Testosterone	Estradiol	Progesterone
Linearity (R^2)	.990	.971	.978
LLOD (pg/ml)	0.28	0.86	0.45
Recovery			
Low concentrations	117.60% (10.00 pg/ml; 6.00 pg/ml)	187.04% (2.42 pg/ml)	70.16% (5.50 pg/ml)
Medium concentrations	151.91% (20.00 pg/ml; 12.00 pg/ml)	126.03% (4.84 pg/ml)	117.54% (27.50 pg/ml)
High concentrations	129.27% (67.00 pg/ml; 24.00 pg/ml)	127.43% (7.30 pg/ml)	99.11% (105.00 pg/ml)
Intraassay CV	8.45%	19.90%	10.77%

Note. Quality control parameters of assays performed on the current study's saliva samples (testosterone, estradiol, and progesterone). Recovery (%) is presented for low, medium, and high concentration range of the calibration curve. Intraassay reliability is presented as the averaged CVs (%) of sample duplicates. LLOD = lower limit of detection; CV = coefficients of variation.

phase determination with hormone levels. In men, we assigned assessment sessions to pseudocycle phases to counteract measurement point-specific effects on PSE data. Preparing the data, we identified outliers in motive scores and hormone concentrations via histograms and Shapiro–Wilk tests. Additionally, because all saliva samples were measured in duplicate to derive a mean, we were able to evaluate within-subject concentrations and their coefficient of variation to identify measurement errors and outliers. For all analyses, we used the maximum *N* available for the variables involved.

As participants completed three assessments and our data are hierarchically structured, motive and hormone data (Level 1) are nested within participants (Level 2) and thus must be analyzed from a multilevel perspective. Level 1 variables were person-mean centered to consider within-person, cycle-based fluctuations, and Level 2 variables were entered uncentered because they are categorical (e.g., relationship status and gender). Models were estimated via log-likelihood (difference) tests. By calculating intraclass coefficients, we checked for between-level variance (see Supplemental B in the online supplemental materials). Nesting motive and hormone data across the cycle within participants enabled us to take into account simultaneously the variance associated with the sampling of measurements at two levels of analyses.

Descriptive statistics are given as mean and standard deviation. Even though it was not explicitly mentioned in the preregistration, an α level of .05 (two-sided) was employed in all analyses, except Hypothesis 2 and 3a. For Hypotheses 3b and 3c, which focus on interaction effects, we further differentiate the reported two-sided analyses with supplemental one-sided analyses (see Supplemental H in the online supplemental materials). Analysis scripts and data files are uploaded on the Open Science Framework project page and can be found as the additional online materials (https://osf.io/dvmt4/).

Results

Our sample of 131 participants completed a total of 390 assessments. Table 4 shows means, standard deviations, and correlations (Pearson) of each group and cycle-level variables aggregated at the person-level and basic demographic data. This means that for each cycle-level variable, person-mean centered values across assessment sessions were calculated and correlated. Table 5 shows means, standard deviations, and correlations of all cycle-level variables of each group. Due to high correlations between word count and motives (*n* Power, *n* Affiliation; $ps < .01$), we will control for this effect by including word count in any analyses involving motives.

Hypothesis Testing

Figure 2 shows a descriptive overview of hormone levels and motive scores per cycle phase and separated by group.

Hypothesis Set 1: Cycle- and Gender-Related Hormone Differences

Hypothesis set 1 addressed within-group and between-group hormonal differences during the menstrual cycle. Table 6 gives an overview of dummy and contrast variables as well as resulting effects. To test cycle-based, within-group changes in salivary hormones (estradiol, progesterone) across cycle phases, we tested Level 1 contrasts coded specifically for the expected course of salivary hormones in each cycle phase as predictors, using subsets of data representing each group (see Table 6). This approach has been used before to model progression with ordinally scaled variables (change variables) as growth models (Bliese & Ployhart, 2002; Niessen & Jimmieson, 2016).

Hypothesis 1a predicted that for NC women ($n = 48$), estradiol would increase in the periovulatory phase and show a second, shallower peak in the luteal phase, which we tested with contrasts coded 0 = *follicular*, 2 = *periovulatory*, and 1 = *luteal*. The resulting fixed slope model showed differences of statistical significance ($p = .018$), supporting the hypothesis. Hypothesis 1b and 1c predicted that no such cycle-based changes are observable in HC women ($n = 26$) and men ($n = 48$). Thus, the same procedure was applied to HC women, resulting in a fixed-slope model ($p = .381$) and again to men, resulting in a random slope model ($p = .708$), both models support the hypotheses. Supporting Hypothesis 1d, that for NC women ($n = 50$), progesterone would increase in the luteal phase, the contrast variable (0 = *follicular*, 0 = *periovulatory*, 1 = *luteal*) reached statistical significance in our random slope model ($p = .002$). Hypothesis 1e predicted that no such cycle-based changes in progesterone are observable in HC women ($n = 30$), which was supported by the fixed-slope model ($p = .257$). Hypothesis 1f predicted that no cycle-based changes in progesterone are observable in men ($n = 47$), which was contradicted by the random slope model ($p = .036$). In men, there was a within-group progesterone decrease. Another subset of Hypothesis 1 predicted no testosterone changes for NC women (Hypothesis 1g), HC women (Hypothesis 1h), and men (Hypothesis 1i). As we did not test any within-subject testosterone changes, multilevel modeling analyses with a contrast variable are not suitable. Instead, we ran repeated-measures analyses of variance on each subset of the sample with the square-root-transformed means of each cycle phase. Neither for men, $F(2, 94) = 0.32$, $p = .725$; $n = 48$, nor for NC women, $F(2, 92) = 2.70$, $p = .073$; $n = 49$, or HC women, $F(2, 56) = 1.32$, $p = .275$; $n = 30$, did testosterone show statistically significant changes across cycle phases. This fully supports Hypotheses 1g–1i.

To examine between-group differences in salivary hormones, we tested the effect of a dummy-coded Level 2 predictor representing group, in each case compared to the other two groups (see Table 6). For estradiol and progesterone, the hypotheses included specific cycle-phase based effects for NC women, which we tested in a second step with a dummy-coded Level 1 predictor representing the targeted cycle phase in an interaction with the dummy representing the targeted group.

Supporting Hypothesis 1j, our dummy model (1 = *men*, 0 = *NC/HC women*) showed that men had higher testosterone compared to HC and NC women in a random slope model ($p = .000$; $n = 127$). NC women, compared to men and HC women, had higher estradiol (1 = *NC women*, 0 = *men/HC women*; $n = 122$), but this association did not reach statistical significance in a fixed slope model ($p = .171$) or after adding cross-level interactions with Level 1 dummies representing cycle phases—neither the periovulatory ($p = .452$) nor the luteal phase ($p = .150$) reached statistical significance. Overall, our findings did not support the hypothesized (1k) between-group estradiol differences.

NC women had the highest progesterone levels compared to men and HC women, as shown in a random slope model (1 = *NC women*, 0 = *men/HC women*; $p = .000$). After adding the interaction of a dummy representing the luteal phase (0 = *follicular*, 0 = *periovulatory*, 1 = *luteal*) × Group, this difference was marked during the luteal phase of the cycle ($p = .000$), fully supporting Hypothesis 1l ($n = 127$; see Table 6; for a visual representation see Figure 2).

Table 4
Means, Standard Deviations, and Correlations of Cycle-Level Variables Aggregated on the Person Level (Level 2) and Basic Demographic Data

Variable (aggregated on person level, $N = 131$)	*M*	*SD*	1	2	3	4	5	6	7	8
1. Testosterone	21.57	41.20	—							
2. Estradiol	1.21	1.12	.29** [.12, .44]	—						
3. Progesterone	36.02	31.20	−.14 [−.30, .03]	.01 [−.17, .18]	—					
4. *n* Power	8.67	3.10	−.15 [−.32, .02]	.05 [−.12, .22]	−.02 [−.19, .15]	—				
5. *n* Affiliation	11.24	3.21	−.11 [−.27, .06]	.07 [−.10, .24]	−.13 [−.30, .04]	.18* [.01, .34]	—			
6. Word count	598.98	177.63	−.04 [−.21, .13]	.10 [−.07, .27]	−.01 [−.18, .16]	.73** [.64, .80]	.43** [.28, .56]	—		
7. Gender	0.37	0.48	.43** [.27, .56]	−.01 [−.18, .16]	−.25** [−.40, −.08]	−.23** [−.39, −.06]	−.18* [−.34, −.01]	−.23** [−.38, −.06]	—	
8. Age	23.46	4.32	.17* [.00, .33]	−.06 [−.23, .12]	−.01 [−.16, .18]	−.25** [−.41, −.08]	−.04 [−.21, .13]	−.07 [−.24, .10]	.14 [−.03, .30]	—
9. Relationship status	0.56	0.50	.01 [−.17, .18]	−.08 [−.25, .09]	−.06 [−.23, .11]	.09 [−.08, .26]	.03 [−.14, .20]	.03 [−.15, .20]	−.10 [−.27, .07]	.18* [.01, .34]

Note. Overview of means, standard deviations, and correlations of all cycle-level variables of the entire sample, aggregated on the person level. Gender (0 = *female*, 1 = *male*), age, and relationship status (0 = *single*, 1 = *partnered*) are Level 2 variables and not aggregated. Estradiol, testosterone, and progesterone are given in pg/ml. Values in square brackets indicate the 95% confidence interval for each correlation.
* $p < .05$. ** $p < .01$.

Hypothesis Set 2: Motive–Hormone Associations in NC Women

Hypothesis 2a predicted that (a) in single NC women, *n* Power changes are positively associated with estradiol changes, with elevated *n* Power in the periovulatory and luteal phases and (b) negatively associated in partnered NC women. We built a random-slope model with word count, estradiol (both person-mean centered, Level 1) as well as relationship status (0 = *single*, 1 = *partnered*; uncentered, Level 2), dummy-coded cycle phases (periovulatory: 0 = *follicular*, 1 = *periovulatory,* 0 = *luteal*; luteal: 0 = *follicular*, 0 = *periovulatory*, 1 = *luteal*; uncentered, Level 2) as well as cross-level interactions between all variables to predict *n* Power in NC women ($n = 48$). As shown in Table 7, neither estradiol nor its interaction with relationship status significantly predicted *n* Power, while the periovulatory cycle phase did ($p = .048$), indicating reduced *n* Power in this cycle phase while controlling for estradiol. Our results thus contradict Hypothesis 2a.

Hypothesis 2b predicted that *n* Affiliation changes are positively associated with progesterone changes, with elevated *n* Affiliation in the luteal phase. To test this hypothesis, we built a random slope model with word count, progesterone (both person-mean centered, Level 1), and dummy-coded luteal cycle phase (0 = *follicular*, 0 = *periovulatory*, 1 = *luteal*) as well as cross-level interactions between all variables to predict *n* Affiliation in NC women ($n = 47$). As shown in Table 7, none of the hypothesized predictors were significant, apart from a positive effect of word count ($p = .013$). Thus, neither progesterone nor the luteal phase predict elevated *n* Affiliation in NC women (see Table 7).

We also analyzed the main effects (without additional predictors) of both estradiol on *n* Power ($p = .313$) and progesterone on *n* Affiliation ($p = .474$) in NC women, which still lead to the same results as presented here (see Supplemental G in the online supplemental materials).

Hypothesis Set 3: Motive–Hormone Associations in the Whole Sample

In Hypothesis 3a, we assumed that testosterone is positively associated with *n* Power in men. We built a random slope model with predictors testosterone and word count (person-mean centered, Level 1) including the male subsample ($n = 47$). After controlling for word count, we observed a positive association between testosterone and *n* Power ($p = .032$; see Table 8). Thus, our findings support Hypothesis 3a.

To test whether estradiol and *n* Power are positively associated in all women ($n = 74$), particularly in singles (Hypothesis 3b), we built a random slope model with estradiol and word count (person-mean centered, Level 1), relationship status (0 = *single*, 1 = *partnered*; uncentered, Level 2) as well as all predictors in cross-level interactions to predict *n* Power. As shown in Table 8, after controlling for word count ($p = .017$), none of the hypothesized predictors reached the threshold of significance, rejecting our Hypothesis 3b. We performed a sample split to analyze the main effect of estradiol on *n* Power in single ($p = .305$) and in partnered ($p = .313$) NC women separately while controlling for word count and our results show that even though the directions of the coefficients conformed with the hypothesis, they are far from significant (see Supplement H in the online supplemental materials).

Table 5
Means, Standard Deviations, and Correlations of All Cycle-Level (Level 1) Variables of Each Group

Variable	*M*	*SD*	1	2	3	4	5
				Men			
1. Testosterone	35.48	12.78	—				
2. Estradiol	1.15	1.42	.22* [.05, .38]	—			
3. Progesterone	25.25	14.55	−.13 [−.29, .04]	.03 [−.15, .20]	—		
4. *n* Power	8.27	3.29	−.04 [−.21, .13]	.04 [−.13, .21]	.01 [−.16, .18]	—	
5. *n* Affiliation	10.77	4.30	−.08 [−.25, .09]	.02 [−.16, .19]	.11 [−.06, .28]	−.14 [−.31, .03]	—
6. Word count	567.78	148.95	−.17* [−.33, −.00]	.04 [−.14, .21]	.04 [−.13, .21]	.50** [.36, .62]	.42** [.27, .56]
				NC women			
1. Testosterone	9.74	9.74	—				
2. Estradiol	1.33	1.25	.16 [−.01, .32]	—			
3. Progesterone	52.44	70.82	−.08 [−.25, .08]	−.05 [−.21, .12]	—		
4. *n* Power	9.27	4.25	.06 [−.11, .22]	.11 [−.06, .27]	.04 [−.13, .20]	—	
5. *n* Affiliation	11.35	4.48	.04 [−.12, .21]	.08 [−.09, .24]	−.20* [−.35, −.03]	.04 [−.13, .21]	—
6. Word count	622.93	219.84	.10 [−.07, .26]	.17 [−.00, .32]	−.02 [−.19, .14]	.65** [.54, .74]	.32** [.17, .46]
				HC women			
1. Testosterone	5.53	3.29	—				
2. Estradiol	0.87	0.81	.26* [.02, .48]	—			
3. Progesterone	26.43	14.91	−.22 [−.44, .02]	.03 [−.22, .27]	—		
4. *n* Power	9.40	3.95	.00 [−.24, .25]	−.12 [−.36, .12]	.19 [−.05, .42]	—	
5. *n* Affiliation	12.62	4.13	.10 [−.15, .33]	.04 [−.21, .28]	.23 [−.02, .45]	−.14 [−.37, .10]	—
6. Word count	670.62	171.08	.02 [−.23, .26]	.07 [−.18, .31]	0.35** [.12, .55]	.53** [.33, .69]	.43** [.20, .61]

Note. Overview of means, standard deviations, and correlations of all cycle-level variables of each group: Men, NC women, and women taking HC. Estradiol, testosterone, and progesterone are given in pg/ml. Values in square brackets indicate the 95% confidence interval for each correlation. NC = normally cycling; HC = hormonal contraception.
* $p < .05$. ** $p < .01$.

To test whether progesterone is positively associated with *n* Affiliation in women and negatively in men (Hypothesis 3c), we built a random-slope model with the predictors progesterone and word count (person-mean centered, Level 1), gender (0 = *female*, 1 = *male*; uncentered, Level 2) as well as corresponding cross-level interactions to predict *n* Affiliation in the whole sample ($n = 126$). None of the predictors reached the threshold of statistical significance, except for word count ($p = .000$). The Progesterone × Gender interaction came close to significance ($p = .053$), but the direction of the effect was contrary to the hypothesis. In men, progesterone was positively associated with *n* Affiliation and in women negatively. Therefore, our findings did not support Hypothesis 3c (see Table 8). To differentiate this result, we performed a sample split to analyze the effect of progesterone on *n* Affiliation in subsamples separated by gender. In men, progesterone positively predicted *n* Affiliation ($p = .019$) but not in women ($p = .468$) while controlling for word count (see Supplement H in the online supplemental materials).

Exploratory Analyses

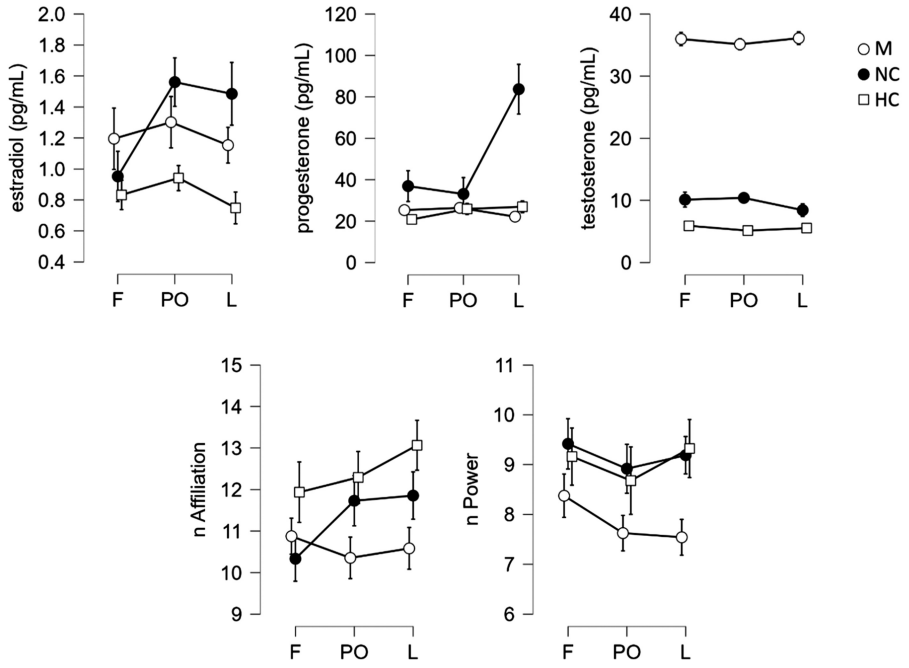
We ran a second set of analyses to examine a numeric variable indicating time of day of the saliva sample collection (coded 0–24) as a predictor for hormone concentrations (person-mean centered, Level 1; see Supplement D in the online supplemental materials). Only in the case of estradiol was time of day a significant predictor ($\gamma = -0.10$, $SE = 0.04$), $t(67) = -2.49$, $p = .013$, in a random-slope model. An examination of the motive–estradiol relationships with the addition of the time of day showed that this did not change the results (see Supplement I in the online supplemental materials). For progesterone and testosterone, time of day did negatively influence hormone concentrations but not with statistical significance.

Discussion

The aim of this study was to replicate findings by Schultheiss et al. (2003) regarding associations between salivary steroid hormones and implicit motives across the menstrual cycle in a longitudinal

Figure 2

Descriptive Overview of Salivary Hormones and Motives Across Cycle Phases of All Groups



Note. Overview of raw salivary hormone concentrations (estradiol, testosterone, and progesterone in pg/ml) and *n* Power and *n* Affiliation scores, separated by group and cycle phases presented with standard error bars. In men, we assigned assessment sessions to pseudocycle phases to counteract measurement point-specific effects on motive data. F = follicular phase; PO = periovulatory phase; L = luteal phase; M = men; NC = normally cycling women; HC = women using hormonal contraception.

study. Because the data were hierarchically structured and measurements nested within participants, we were able to consider simultaneously the variance associated with measurements at two levels of analysis via multilevel modeling.

Gonadal Steroid Hormones

Our results regarding salivary hormones across the cycle were mostly in accordance with our hypotheses. With regard to estradiol, the within-group changes in NC women corresponded to the expected cycle-based peaks in the periovulatory and luteal phases. These changes were not observable in men or HC women. When we compared the three groups regarding estradiol, our results did not show the expected differences. Although estradiol in NC women was higher than in HC women or men, this difference did not reach statistical significance. Taking cycle phase into consideration did not change this result.

We were able to identify the typical increase of progesterone in NC women during the luteal phase, which did not occur in HC women. For men, we observed a slight decline in progesterone across assessment phases, an effect that we consider as a chance finding.

As expected, none of the three groups showed testosterone changes across the cycle. Further, as expected testosterone in men was almost fourfold higher than in NC women and more than sixfold higher than in HC women.

Overall, we were able to observe most of the expected cycle- and gender-based hormonal patterns and changes with our research design and hormone assay methods. This provided us with a firm conceptual and empirical basis for testing our hypotheses regarding motives and hormones.

Hormones and Motives

We examined previously reported associations between estradiol and *n* Power in NC women as well as in women generally, both depending on relationship status. We were unable to replicate previous results (Schultheiss et al., 2003; Stanton & Edelstein, 2009; Stanton & Schultheiss, 2007). First, we found a nonsignificant difference in *n* Power between partnered and single NC women. However, it was not related to estradiol levels. For the periovulatory phase, we observed a negative *n* Power–estradiol association for NC women. However, the requisite *n* Power × Cycle Phase Effect was only marginally significant. Second, when we looked at all women in the sample, a similar pattern emerged. Although there were (nonsignificant) *n* Power differences depending on relationship status, a negative association in partnered and positive association in single women, estradiol was by no means a relevant predictor in our models. There are previous results showing positive associations between baseline estradiol and *n* Power in single women and NC women (Stanton & Schultheiss, 2007) or in NC women using a contest setting (Oxford et al., 2017). Stanton and Schultheiss (2007) showed that the association between *n* Power and estradiol was stronger for samples with a lower measurement error. Therefore, there are indications that we could expect an

Table 6
Multilevel Models of Within- and Between-Group Differences in Salivary Hormones

H	Hormone	Sample	Modelled predictor: Contrasts	Modelled predictor: Dummies	Results
1a	E	NC	F = 0, PO = 2, L = 1		$\gamma = 0.29$, $SE = 0.12$, $t(93) = 2.41$, $p = .018$
1b		HC	F = 0, PO = 2, L = 1		$\gamma = 0.06$, $SE = 0.07$, $t(50) = 0.87$, $p = .381$
1c		M	F = 0, PO = 2, L = 1		$\gamma = 0.05$, $SE = 0.14$, $t(47) = 0.38$, $p = .708$
1d	P	NC	F = 0, PO = 0, L = 1		$\gamma = 48.69$, $SE = 14.72$, $t(47) = 3.31$, $p = .002$
1e		HC	F = 0, PO = 0, L = 1		$\gamma = 3.91$, $SE = 3.08$, $t(58) = 1.27$, $p = .257$
1f		M	F = 0, PO = 0, L = 1		$\gamma = -3.69$, $SE = 1.73$, $t(72) = -2.14$, $p = .036$
1j	T	All		M = 1 (NC, HC = 0)	$\gamma = 27.74$, $SE = 1.89$, $t(66) = 14.67$, $p = .000$
1k	E	All		NC = 1 (M, HC = 0)	$\gamma = 0.24$, SE = 0.17, $t(120) = 1.38$, $p = .171$
		All	F = 0, PO = 1, L = 0	NC = 1 (M, HC = 0)	$\gamma = 0.18$, $SE = 0.24$, $t(240) = 0.75$, $p = .452$
		All	F = 0, PO = 0, L = 1	NC = 1 (M, HC = 0)	$\gamma = 0.35$, $SE = 0.24$, $t(241) = 1.44$, $p = .150$
1l	P	All		NC = 1 (M, HC = 0)	$\gamma = 26.73$, $SE = 6.53$, $t(70) = 4.10$, $p = .000$
	P	All	F = 0, PO = 0, L = 1	NC = 1 (M, HC = 0)	$\gamma = 49.17$, $SE = 8.34$, $t(327) = 5.89$, $p = .000$

Note. Overview of the results of multilevel modeling analyses regarding the first hypothesis set, with the targeted hormones E, P, or T, and specific subsets of the sample of M, NC women, or women taking HC. The modeled predictors indicate the tested cycle-based changes via contrast variables, representing the F, PO, and L phase and dummy variables representing the targeted group in between-group comparisons. Estradiol, testosterone, and progesterone are given in pg/ml. H = hypothesis; E = estradiol; NC = normally cycling women; F = follicular; PO = periovulatory; L = luteal; HC = hormonal contraception; M = men; P = progesterone; T = testosterone.

association between baseline estradiol and *n* Power in NC women and women generally; however, we were unable to replicate them (Schultheiss, 2013).

We hypothesized that in NC women, and women generally, *n* Affiliation and progesterone would be positively associated and negatively in men. Our findings for *n* Affiliation did not support this hypothesis. Although we were able to observe the typical luteal peak in progesterone in NC women, *n* Affiliation did not covary with this increase. This result contradicts observations by Schultheiss et al. (2003). Progesterone has been associated with social behavior and processes related to the interpretation of social cues (Brown et al., 2009; Maner & Miller, 2014), and in the luteal phase, the body prepares for a possible pregnancy (Buffet et al., 1998). But apart from Schultheiss et al. (2003), there are no studies showing a cycle-based change of *n* Affiliation longitudinally, so more studies are needed to clarify this issue. We analyzed the whole sample to examine progesterone associations with *n* Affiliation depending on gender. When looking at the mean scores, our results show that there is a difference between women and men regarding *n* Affiliation, as previously reported (Schönbrodt et al., 2021), that is, women show comparably more *n* Affiliation, but is only subtle. In our multilevel model, only the Progesterone × Gender interaction came close to statistical significance, and further analyses revealed that men with higher progesterone show more *n* Affiliation and that there is no association between these variables in women, contradicting our hypothesis (see Supplement H in the online supplemental materials). Previous studies, apart from Schultheiss et al. (2003), show associations between progesterone and *n* Affiliation depending on gender (e.g., in affiliation arousal studies), with positive correlations in women (Wirth & Schultheiss, 2006), while others failed to find sex differences (Schultheiss et al., 2004). Other results regarding this association are inconclusive because affiliation arousal was not experimentally varied (Schultheiss & Zimni, 2015). Thus, more research on endocrine factors involved in the expression of *n* Affiliation is needed (Schultheiss, 2013; Schultheiss & Köllner, 2021). Another important factor might be the validity of *n* Affiliation coding according to Winter (1994) employed in this study. The coding criteria are based on research that failed to yield replicable findings, was based on small samples, and did not show strong associations between motivational arousal state and *n* Affiliation (see Schultheiss, in press, for a discussion). Therefore, our *n* Affiliation measure may not have been sufficiently sensitive and valid for testing the hypothesis of an association between *n* Affiliation and progesterone.

Replicating findings obtained for between-individual variations in testosterone and *n* Power by Schultheiss et al. (2003), we were able to detect that in men, intraindividual variations in testosterone positively covary with intraindividual variations in *n* Power. This is in line with a range of studies which have linked high *n* Power to testosterone, for example, through organizational hormone effects, and some observational studies that have demonstrated a positive, but weak correlation between *n* Power and salivary testosterone (reviewed by Köllner et al., 2019; Schultheiss, 2013; Schultheiss & Köllner, 2021). However, previous observational studies have been cross-sectional, correlating baseline testosterone with *n* Power. With our longitudinal evidence, we can demonstrate that within a given male individual, testosterone covaries positively with *n* Power, independently of the absolute level of each component. Of course, because of the correlational design of our study, we cannot make strong inferences based on this finding about the direction of causality, although in line with our arguments above, we suspect that *n* Power, in seeking and interacting with power incentives in everyday life, may influence testosterone levels. A replication should be pursued in studies with larger samples.

For now, based on our results, we can conclude that although hormonal changes during the menstrual cycle have a variety of implications for socioemotional, cognitive, and behavioral processes in NC women (Becker & Chartoff, 2019; Bernal & Paolieri, 2022; Maner & Miller, 2014), the assumption of a direct functional relationship of steroid hormones with implicit motives received only scant support. We regard our results as an indication that hormones are perhaps better described as dependent variables that are responsive to motive-specific environmental conditions, in the context of incentive stimulus effects on motive and hormone levels (Schultheiss et al., 2005; Stanton & Schultheiss, 2007; Wirth & Schultheiss, 2006).

Table 7
Overview of Multilevel Regression Model Results of Hypothesis 2

		Dependent variable model											
		n Power						*n* Affiliation					
H	Coefficients	*b*	β	*SE*	*t*	*df*	*p*	*b*	β	*SE*	*t*	*df*	*p*
a	(Constant)	10.27 [8.57, 11.97]	.00 [.00, .00]	0.86	12.00	100	.000						
	Word count	0.02 [0.00, 0.04]	.38 [−.06, .83]	0.01	1.70	56	.099						
	Estradiol[a]	0.28 [−0.97, 1.52]	.08 [−.30, .47]	0.63	0.44	100	.332[b]						
	Relationship	−1.01 [−3.44, 1.42]	−.18 [−.61, .25]	1.22	−0.82	92	.412						
	PO Phase	−1.71 [−3.40,−0.03]	−.25 [−.50, .00]	0.85	−2.01	85	.048						
	L phase	−0.15 [−1.79, 1.50]	−.02 [−.26, .22]	0.83	−0.18	75	.860						
	Estradiol × Relationship	−0.30 [−1.63, 1.02]	−.04 [−.22, .14]	0.67	−0.45	82	.651						
	Estradiol × Word Count	−0.00 [−0.01, 0.01]	−.03 [−.25, .18]	0.01	−0.32	101	.750						
	Estradiol × PO Phase	−0.12 [−1.77, 1.53]	−.02 [−.28, .24]	0.83	−0.14	104	.887						
	Estradiol × L Phase	−0.08 [−1.75, 1.58]	−.02 [−.25, .18]	0.84	−0.10	106	.922						
	Word Count × Relationship	−0.01 [−0.03, 0.01]	−.10 [−.42, .22]	0.01	−0.62	25	.540						
	Word Count × PO Phase	0.01 [−0.02, 0.03]	.09 [−.22, .39]	0.01	0.57	123	.570						
	Word Count × L Phase	−0.02 [−0.04, 0.01]	−.18 [−.43, .08]	0.01	−1.35	117	.180						
	Relationship × PO Phase	1.42 [−1.01, 3.85]	.16 [−.11, .43]	1.23	1.16	81	.249						
	Relationship × L Phase	−1.35 [−3.70, 1.01]	−.15 [−.40, .11]	1.19	−1.13	74	.261						
b	(Constant)							11.14 [10.18, 12.09]	.00 [.00, .00]	0.48	23.01	76	.000
	Word count							0.02 [0.00, 0.03]	.33 [.08, .59]	0.00	2.64	30	.013
	Progesterone[a]							0.00 [−0.01, 0.03]	.08 [−.20, .36]	0.01	0.59	133	.280[b]
	L phase							0.64 [−0.74, 2.01]	.08 [−.09, .24]	0.70	0.92	79	.361
	Progesterone × Word Count							0.00 [0.00, 0.00]	.01 [−.19, .21]	0.00	0.13	119	.894
	Progesterone × L Phase							−0.01 [−0.04, 0.02]	−.14 [−.44, .16]	0.01	−0.93	109	.355
	Word Count × L Phase							0.01 [−0.01, 0.04]	.10 [−.12, .32]	0.01	0.92	123	.362

Note. Overview of results of Hypothesis 2a (upper left side) and 2b (lower right side). Word count, estradiol, and progesterone are person-mean centered. Hormones are given in pg/ml. Relationship status is coded as 0 = *single* and 1 = *partnered*. Cycle phases are dummy-coded with the luteal phase coded as 0 = *follicular phase*, 0 = *periovulatory phase*, 1 = *luteal phase* and the periovulatory phase coded as 0 = *follicular phase*, 1 = *periovulatory phase*, 0 = *luteal phase*. Values in square brackets indicate the 95% confidence interval for each the estimate, standard errors referring to unstandardized estimates. H = hypothesis; PO = periovulatory; L = luteal.

[a] An analysis of the main effect of the hormone on respective motive scores did not change the results. [b] One-sided testing because of direction of hypothesis.

Table 8
Overview of Multilevel Regression Model Results of Hypothesis 3

		Dependent variable model											
		n Power						*n* Affiliation					
H	Coefficients	*b*	β	*SE*	*t*	*df*	*p*	*b*	β	*SE*	*t*	*df*	*p*
3a (men)	(Constant)	7.89 [7.10, 8.69]	.00 [.00, .00]	0.40	19.59	46	.000						
	Word count	0.01 [0.00, 0.02]	.20 [.04, .36]	0.00	2.44	92	.017						
	Testosterone	0.09 [0.00, 0.19]	.18 [−.01, .37]	0.05	0.92	35	.032[a]						
3b (women)	(Constant)	9.32 [8.12, 10.51]	.00 [.00, .00]	0.61	15.35	74	.000						
	Word count	0.02 [0.00, 0.03]	.34 [.06, .62]	0.00	2.40	37	.017						
	Estradiol[b]	0.08 [−0.48, 0.64]	.02 [−.13, .16]	0.28	0.27	138	.791						
	Relationship status	−0.15 [−1.70, 1.39]	−.03 [−.31, .25]	0.78	−0.20	73	.844						
	Estradiol × Word Count	0.00 [−0.01, 0.02]	.07 [−.09, .23]	0.00	0.87	182	.387						
	Estradiol × Relationship Status	−0.45 [−1.54, 0.65]	−.06 [−.20, .08]	0.55	−0.80	132	.422						
	Word Count × Relationship Status	−0.00 [−0.02, 0.01]	−.12 [−.40, .16]	0.00	−0.84	38	.403						
3c (all)	(Constant)							11.65 [10.93, 12.37]	.00 [.00, .00]	0.37	31.83	115	.000
	Word count							0.02 [0.01, 0.03]	.36 [.22, .50]	0.00	5.00	44	.000
	Progesterone[b]							0.00 [−0.01, 0.01]	.00 [−.09, .10]	0.00	0.06	246	.951
	Gender							−0.97 [−2.16, 0.21]	−.20 [−.44, .04]	0.60	−1.61	114	.108
	Progesterone × Word Count							0.00 [0.00, 0.00]	.05 [−.06, .17]	0.00	0.89	328	.374
	Progesterone × Gender							0.07 [0.00, 0.14]	.09 [.00, .18]	0.04	1.94	243	.053
	Word Count × Gender							0.00 [−0.02, 0.01]	−.08 [−.21, .05]	0.01	−1.21	62	.229

Note. Continuous Level 1 variables (word count, estradiol, testosterone, and progesterone) are centered around person mean; categorical Level 2 variables were entered uncentered. Relationship status is coded as 0 = *single* and 1 = *partnered*, Gender is coded as 0 = *female* and 1 = *male*. Hormones are given in pg/ml. Values in square brackets indicate the 95% confidence interval for each the estimate, standard errors referring to unstandardized estimates. H = hypothesis.
[a] One-sided testing because of direction of hypothesis. [b] An analysis of the main effect of the hormone on respective motive scores did not change the results.

Strengths, Limitations, and Future Research

This study has several methodological strengths. To assess motives, we used the PSE, a causally valid measure featuring little overlap with people's explicit views of their motivational needs or personal goals (Köllner & Schultheiss, 2014). Differing from the original study, we were able to consider within-sample variations of saliva sample duplicates and thus make an informed decision about subject exclusion (Schultheiss et al., 2003). In addition, multilevel analyses provided a more detailed and accurate examination of the data and allowed us to focus on within-subject covariation between motives and hormones. Besides, our sample was larger than that of the original study, which assessed 18 people per group (Schultheiss et al., 2003).

But there are also several limitations to this study. Although we had a larger sample than the original study, our recruitment was far below the targeted 237 participants, which lowered the effective power of our study. Due to the difficult conditions for conducting the study in 2021, when the laboratory could not be fully used because of COVID-19 regulations, we only recruited 150 people and had sufficient data for even fewer. We assume that this might be one of the reasons why our multilevel models oftentimes did not reach or closely missed significance thresholds in some cases.

Our results on salivary estradiol might have limited reliability since we assayed very low concentrations (Arslan et al., 2023). This is especially important for the subset of HC women. Our salivary assessment only measures endogenously produced steroids (Schultheiss et al., 2018) and does not include the synthetic hormone levels resulting from the contraceptive method (Hampson, 2020).

Furthermore, there were fewer HC women than men or NC women and thus analyses involving HC women provided only few observations to build a multilevel regression model on.

Furthermore, as shown in Table 3, estradiol recovery was high, presumably because of assay bias or pipetting errors. Future studies should, if possible, refer to more precise assay methods, like mass spectrometry (Arslan et al., 2023). Still, our estradiol assay was sensitive enough to pick up on the predicted cycle-related changes in NC women and recent results support the reliability of salivary estradiol radioimmunoassays (Dlugash et al., 2025).

Testosterone levels are influenced negatively by time of day, which could result in intra- and interindividual differences affecting the results (Dabbs, 1990). There were instructions for participants to book their assessments either always before or after noon, but because of organizational reasons, this could not always be guaranteed. In a subset of exploratory analyses, we tested whether time of day influenced hormones, and only in the case of estradiol we were able to find a negative influence (replicating Dlugash et al., 2025). But a second set of analyses showed that this did not alter our motive–estradiol results (see Supplement I in the online supplemental materials). For testosterone and progesterone, no such effects were detectable, which suggests that our assessment schedule was coherent enough within participants. Still, future studies should standardize their assessment schedule, like in the original study (Schultheiss et al., 2003).

Moreover, our study design might not have provided enough time before sampling without food or drink consumption and this might have influenced the quality of our samples. Future studies should adapt their procedure to the recommended 2 hr fasting (Becker et al., 2023).

Another limitation lies within our procedure for determining cycle phases. We used a counting method without including tests of additional biomarkers (e.g., luteinizing hormone tests) to detect ovulation. Despite the counting method being commonly used, there is also mounting criticism (Allen et al., 2016; Blake et al., 2016; Gangestad et al., 2016; Gloe et al., 2023; Gonzales & Ferrer, 2016; Hampson, 2020; Wideman et al., 2013). It is based on its lack of control for within- and between-subject variations of menstrual cycle length, with such variations being driven primarily by the follicular phase (Fehring et al., 2006; Schmalenberger et al., 2021). As a result, estimates of the validity of counting methods range from .43 to .55 (Gangestad et al., 2016). The low validity of the counting method contributes to underpowered studies if sample sizes are not augmented accordingly (Gangestad et al., 2016; Gonzales & Ferrer, 2016). Another frequent criticism is the low reliability of self-reported menses onset and cycle length (Small et al., 2007; Wegienka & Baird, 2005). We tried to alleviate these problems by instructing participants before the study to record the relevant information and bring it to the first session. Apart from that, future studies should also consider including more than just one cycle in their analyses to explore the contribution of intraindividual variations (Hampson, 2020; Schmalenberger et al., 2021).

The PSE picture cues we used differed from those of the original study because we included cues that aimed at the assessment of sexual motivation. Consequently, only seven of our 18 pictures overlapped with those used by Schultheiss et al. (2003). Although we took care to balance the motivational strength between the images and sets, the difference in set composition may have influenced the results. For example, our sample scored high on *n* Affiliation overall, suggesting that our picture cues were particularly suitable for eliciting affiliative imagery and less so for power imagery. Nevertheless, we suggest that our study is adequately labeled as a replication study since we did replicate the most relevant aspects of study design and aimed at testing the previously found associations with a more sophisticated statistical analytical approach than the one used by Schultheiss et al. (2003).

Apart from the improvements in study design that we pointed out, we also encourage further investigations of the relationships between motives and hormones not only in a nonexperimental context as here, but particularly in the context of experimental studies. Schultheiss (2013) already pointed out that the evidence suggests stronger predictive effects of motives on hormone release in the presence of suitable social or situational incentives than in their absence. Our present findings appear to corroborate this conclusion: Even if natural variations in hormones are exploited to search for covariation with motive levels, the strength of such associations found with a correlational design is limited. This may suggest that hormones may have less of a "driving" influence on motives than vice versa. Motive associations with hormones may be particularly likely to be detected in experimental designs that measure initial motive levels and then manipulate (social) incentives (e.g., Oxford et al., 2017) or that even bring the initial motivation level under experimental control by, for instance, using movies to manipulate motive state (see Schultheiss et al., 2004; Walther et al., 2021) and then study the interaction of this variable with subsequently manipulated incentives (e.g., being accepted or rejected; winning or losing a contest) on hormonal changes.

Conclusion

To the best of our knowledge, this is the only longitudinal study attempting to replicate findings originally reported by Schultheiss et al. (2003). While we were able to identify most typical cycle-based hormone profiles, we were for the most part unable to replicate previously reported cycle-associated motive changes in this sample. This should stimulate further research because until now the menstrual cycle has been insufficiently studied in motivational science. Our longitudinal results contrast with a number of cross-sectional studies that have found relationships between steroid hormones and motives. We suggest that our findings should be viewed as a starting point for more research addressing the relationships between motives and hormones in longitudinal and experimental study designs.

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