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Is trait rumination associated with affective reactivity to the menstrual cycle? A prospective analysis

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Abstract

Background. A minority of naturally cycling individuals experience clinically significant affective changes across the menstrual cycle. However, few studies have examined cognitive and behavioral constructs that may maintain or worsen these changes. Several small studies link rumination with premenstrual negative affect, with authors concluding that a tendency to ruminate amplifies and perpetuates hormone-sensitive affective symptoms. Replication in larger samples is needed to confirm the validity of rumination as a treatment target.

Method. 190 cycling individuals ($M = 30.82$ years; 61.1% Caucasian) were recruited for moderate perceived stress, a risk factor for cyclical symptoms. They completed the Rumination Response Scale at baseline, then reported daily affective and physical symptoms across 1–6 cycles. Multilevel growth models tested trait rumination as a predictor of baseline levels, luteal increases, and follicular decreases in symptoms.

Results. The degree of affective cyclicity was normally distributed across a substantial range, supporting feasibility of hypothesis tests and validating the concept of dimensional hormone sensitivity. Contrary to prediction, higher brooding did not predict levels or cyclical changes of any symptom. In a subsample selected for luteal increases in negative affect, brooding predicted higher baseline negative affect but still did not predict affective cyclicity.

Conclusions. An individual's trait-like propensity to engage in rumination may not be a valid treatment target in premenstrual mood disorders. State-like changes in rumination should still be further explored, and well-powered prospective studies should explore other cognitive and behavioral factors to inform development of targeted psychological treatments for patients with cyclical affective symptoms.

Affective disorders are common in those assigned female at birth (AFAB; Kessler, McGonagle, Swartz, Blazer, & Nelson, 1993), particularly during the reproductive years between puberty and menopause (Kessler et al., 1993). A small but significant subset of AFAB individuals experience menstrually related mood disorders (MRMD), such as premenstrual dysphoric disorder (PMDD) or premenstrual exacerbation (PME), characterized by distressing and impairing symptoms (Cunningham, Yonkers, O'Brien, & Eriksson, 2009; Hartlage, Freels, Gotman, & Yonkers, 2012). These symptom changes reflect an abnormal neurobiological *sensitivity* to the normal hormonal shifts of the menstrual cycle, typically occurring in the luteal phase (Schmidt et al., 2017). While mechanistic biological studies have yielded several effective biological treatments, research on potential cognitive and behavioral mechanisms for behavioral intervention has lagged.

The menstrual cycle

The natural menstrual cycle lasts an average of 28 days and consists of two phases: The *follicular* phase begins with menstrual bleeding and ends after ovulation. This phase is marked by slow-rising estrogen with an abrupt peak just before ovulation, and low progesterone levels. The *luteal phase* follows ovulation and is characterized by the production of estrogen and progesterone by the corpus luteum (i.e., the outer cells that previously enveloped the egg). The late luteal phase is characterized by a rapid withdrawal of estrogen and progesterone premenstrually, which triggers the onset of menses, thus beginning a new cycle.

Disorders characterized by premenstrual affective changes

In some AFAB individuals, this normal hormone flux produces affective, behavioral, or physical symptoms which cause clinically significant distress or functional impairment (APA, 2013;

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Eisenlohr-Moul, 2019). Symptoms typically start to increase in the early-to-mid luteal phase, peak around menses onset, and improve within a few days after the onset of menses. About 5.5% of cycling individuals meet diagnostic criteria for the primary cyclical mood disorder PMDD (Gehlert et al., 2009); however, patients with chronic affective disorders appear to be at elevated risk for premenstrual symptom worsening, with prevalence estimates as high as 58% in depressive disorders (Hartlage, Brandenburg, & Kravitz, 2004). While no current diagnosis is available in these cases, experts have labeled this phenomenon PME (Consensus Group of the International Society for Premenstrual Disorders et al., 2013).

Understanding the role of rumination

Rumination mediates female-biased risk for depressive symptoms (Treynor, Gonzalez, & Nolen-Hoeksema, 2003) and has been widely proposed as a psychological risk factor for cyclical hormone sensitivity (Craner, Sigmon, Martinson, & McGillicuddy, 2014; Dawson et al., 2018; Nayman, Konstantinow, Schricker, Reinhard, & Kuehner, 2023; Welz et al., 2016). Rumination is repetitive, prolonged negative thinking about oneself, emotions, and upsetting experiences without taking action toward positive changes (Nolen-Hoeksema, 1991; Watkins & Roberts, 2020) this interferes with problem-solving, approach behavior, concentration, and executive functioning (Watkins & Roberts, 2020). Rumination prospectively predicts symptoms and diagnoses of many psychiatric disorders, including depression, anxiety, substance abuse, and eating disorders with large effect sizes in meta-analyses (Aldao, Nolen-Hoeksema, & Schweizer, 2010; Nolen-Hoeksema & Watkins, 2011).

This study examines whether rumination may also intensify the influence of the menstrual cycle on negative affective experiences. This investigation draws from the response styles theory of depression (Nolen-Hoeksema, 1987) which posits that an individual's typical style of responding to episodic negative affect influences risk for mood disorders, leading to either stability, intensification, or depreciation of affective states. In the original theory and associated development of the Rumination Response Scale (RRS), two response styles were defined: (1) brooding – an unhelpful repetitive and passive attention on one's negative emotions and (2) reflection – a distracting and problem-solving approach to negative emotions (Nolen-Hoeksema, 1987). In studies exploring the mediating role of rumination, brooding – and not reflection – accounted for sex differences in depression (Treynor et al., 2003). In this study, we hypothesize that participants who report higher brooding will experience an intensification in negative affect across the menstrual cycle. Given that reflection is typically adaptive and does not account for the sex gap in depression, we do not expect reflection to moderate cyclical affective changes.

Empirical studies of rumination as a risk factor for cyclical hormone sensitivity

While existing studies have examined the role of trait rumination in premenstrual disorders, most have key methodological limitations. Several studies used retrospective reports of premenstrual symptoms to identify hormone-sensitive individuals (Beddig, Reinhard, & Kuehner, 2019; Roomaney & Lourens, 2020; Sigmon, Schartel, Hermann, Cassel, & Thorpe, 2009); this approach typically produces a high false-positive rate of PMDD diagnosis (reviewed in Eisenlohr-Moul, 2021). The absence of prospective ratings calls into question whether detected differences in trait rumination are due to true differences in cyclical hormone sensitivity or to the presence of any affective disorder *v.* no disorder. Other studies include individuals on hormonal birth control (Craner, Sigmon, & Martinson, 2015; Craner, Sigmon, & Young, 2016), eliminating the cyclical hormone flux that defines PMDD (Fleischman, Navarrete, & Fessler, 2010). Other studies use prospective methods but are limited in their designs and power. These studies typically truncate the cycle into two phases (premenstrual or postmenstrual) or select a subset of days within each phase (Beddig, Reinhard, Ebner-Priemer, & Kuehner, 2020; Dawson et al., 2018; Nayman, Beddig, Reinhard, & Kuehner, 2022; Welz et al., 2016), reducing symptom measurement granularity.

A handful of studies examined the link between trait rumination and cyclical affective changes in naturally cycling individuals. The first compared a small but prospectively confirmed PMDD sample ($n = 17$) with healthy controls ($n = 45$) and found higher levels of trait rumination in the PMDD group (Craner et al., 2014). However, this work did not speak to whether common comorbidities of PMDD such as major depressive disorder (Critchlow, Bond, & Wingrove, 2001) may account for these differences nor did it address how trait rumination breeds changes in core emotional symptoms across the cycle. Another study examining prospective daily affective ratings in a nonclinical sample ($n = 59$) found that higher trait brooding rumination was associated with lower positive valence and calmness in the late luteal phase (Welz et al., 2016). Other work has found that among individuals demonstrating at least one cyclical PMDD affective symptom in daily ratings ($n = 54$), those with higher trait brooding rumination showed a more rapid premenstrual increase and slower postmenstrual remission of depressive and eating symptoms (Dawson et al., 2018). In contrast, a recent study (Nayman et al., 2022) examining associations between trait rumination and daily affect across the menstrual cycle ($n = 61$ with retrospectively reported PMDD compared to 61 without) suggested that, although rumination was linked with severity of emotional symptoms irrespective of the cycle, lower trait levels of rumination did not offer protection from mood deterioration during the luteal phase. Interestingly, a study prospectively measuring state-like rumination at the daily level revealed that when stress was high, rumination also increased for the subset of individuals retrospectively reporting PMDD symptoms ($n = 61$ with retrospectively reported PMDD compared to 61 without). This pattern held true regardless of the cycle phase, further suggesting that rumination may be a trait-like style when confronted with stress (Beddig et al., 2019).

Taken together, the existing literature does suggest that individuals with premenstrual disorders experience elevated levels of trait rumination, and higher rumination is generally linked to more severe emotional symptoms irrespective of the menstrual cycle. However, when it comes to understanding whether trait rumination is a factor that drives cyclical exacerbation of symptoms, findings are inconsistent, leaving the association between trait rumination and luteal phase worsening of emotional symptoms uncertain. Further validation in a larger prospective sample measured across the entire menstrual cycle is necessary to confirm trait rumination as a potential treatment target for premenstrual disorders.

The current study

This archival analysis examined whether trait rumination is associated with daily symptom change across the menstrual cycle.

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Using multilevel statistics that model both mean levels and cyclical trajectories, we aimed to clarify the relationship between trait rumination and affective cyclicity by addressing the limitations of prior research (i.e., retrospective reports, the inclusion of hormonal birth control users, truncated cycle days, and small sample sizes). Both animal models and human observational studies indicate that stressful experiences correlate with greater affective sensitivity to hormone changes, particularly in the luteal phase (Hantsoo & Epperson, 2020; Namavar Jahromi, Pakmehr, & Hagh-Shenas, 2011), so a high-stress sample was recruited. A total of 190 AFAB individuals with natural menstrual cycles reported trait rumination at baseline and completed daily ratings of affective symptoms across several menstrual cycles. We explored how trait-level rumination predicted cyclical changes in symptoms across the menstrual cycle, with the goal of identifying *when* in the cycle and for *which symptoms* trait rumination predicts cyclical change.

Predictions

(1) Since the sample was recruited for elevated perceived stress (a risk factor for premenstrual affective change), we expected a significant luteal phase symptom increase and follicular phase decrease in the full sample.
(2) Consistent with evidence for individual differences in cyclical hormone sensitivity, we expected to observe significant variability in these symptom changes.
(3) Irrespective of the menstrual cycle, we expected that higher trait brooding would predict higher mean levels of daily affective symptoms (replication of previous findings).
(4) We predicted that higher trait brooding scores would predict a more rapid premenstrual increase in daily affective symptoms.
(5) We predicted that higher trait brooding scores would predict a slower postmenstrual resolution of symptoms.
(6) Additionally, since Welz et al. (2016) (unexpectedly) found that individuals with higher trait reflection experienced greater irritability in the late luteal phase, we conducted exploratory analyses to investigate reflection as an additional moderator of cyclical affective changes.

Methods

Study overview

Data were taken from the baseline phase of a randomized controlled trial testing the efficacy of social support groups and mindfulness-based stress reduction groups on cyclical mood change in patients recruited for elevated perceived stress. The University of North Carolina Institutional Review Board approved this study (NCT01995916). In this archival analysis, we relied on data collected (both baseline measures and daily ratings) before randomization of participants to either group. At an enrollment visit, participants completed informed consent procedures and self-report measures of perceived stress and rumination. Following the enrollment visit, participants rated symptom severity daily every evening until randomized to a group. Participants were paid $625 for completing the entire study.

Pre-registration

The hypotheses and planned analyses were preregistered on Open Science Framework (osf.io/4e5dk). The hypotheses and analyses were preregistered after data collection. All analyses were conducted after the pre-registration was submitted.

Participants

We examined baseline person-level traits and daily symptom ratings prior to randomization (participants provided varying lengths of baseline data, spanning 1–6 menstrual cycles). Participants were recruited from Raleigh, Chapel Hill, and Durham areas using flyers, periodical ads, listservs, and a participant registry. Recruitment materials invited women to participate in the study who 'felt stressed.' Inclusion criteria were (1) 18 to 45 years of age, (2) a natural menstrual cycle (21–35 days), and (3) a self-reported moderate or high-stress level during enrollment (i.e., a score of 20 or higher on the Perceived Stress Scale [PSS; Cohen, Kamarck, & Mermelstein, 1983; see below]). Exclusion criteria were (1) use of any hormonal medication (i.e., birth control), (2) medical history that would impact hormone functioning (i.e., endocrine disorders like diabetes), (3) being pregnant or nursing, (4) use of psychotropic medications, (5) a history of meditation practice, which was considered twice per week for at least 15 min, and (6) self-reported history of psychosis, bipolar spectrum disorders, post-traumatic stress disorder, or pain disorder, and active suicidal ideation during the SCID interview at enrollment.

Measures

During the enrollment visit, participants completed the following self-report measures via Qualtrics.

Perceived Stress Scale (PSS; Cohen et al., 1983). The PSS is a 10-item scale that measures the frequency of events that individuals experienced as stressful within the past month. The items in this scale are intended to measure how often uncontrollable, overwhelming, and unpredictable events in their lives occurred for them for the past month. A five-point scale is used, with 0–*never* and 4–*very often*, with a higher score indicating higher perceived stress. In the present sample, internal consistency was good ($\alpha = 0.81$). Our cut-off for inclusion was 20, which represents moderate stress (Cohen et al., 1983).

Rumination Response Scale- Short Form (Treynor et al., 2003). This is a 10-item scale measuring two dimensions of rumination: brooding and reflection. For each item, participants indicate the frequency that they experience each item on a four-point scale, with 1–*almost never* to 4–*almost always*. In the present sample, the RRS internal consistency was adequate (total $\alpha = 0.76$, brooding subscale $\alpha = 0.71$, reflection subscale $\alpha = 0.71$).

Daily Record of Severity of Problems (DRSP) (Endicott, Nee, & Harrison, 2006). The DRSP is a 21-item scale designed to measure symptoms of PMDD and related impairments across the menstrual cycle. For this study, we used a subset of 9 DRSP items (core affective PMDD symptoms and one physical symptom), including depression, hopelessness, worthlessness/guilt, anxiety, mood swings, rejection sensitivity, anger/irritability, conflicts, and muscle pain. Participants completed these daily items for until randomized to one of the intervention groups. Each day, they rated the severity of each symptom on a 6-point scale, with 1–*Not at all* to 6–*Extreme*.

Analytic strategy

Creating a standardized timeline

A standard menstrual cycle can vary from 21–35 days; the length variation is almost entirely dependent on the follicular phase, while the luteal phase is typically fixed around 12–14 days (Fehring, Schneider, & Raviele, 2006). In this study, we coded

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the menstrual cycle per Schmalenberger et al. (2021) with a combination of 'backward count' (counting backward from menses onset (day 0) to 15 days before menses onset (day −15)) and 'forward count' (counting forwards from menses onset (day 0) to 9 days after menses onset (day + 9)). Backward count days −15 through day −1 capture the luteal phase. The forward count days 0 through + 9 capture the follicular phase. Together, the premenstrual time frame and timeline captures 24 days of the menstrual cycle on a number line ranging from −15 to + 9, centered around menses.

Multilevel growth models

We used multilevel growth models with days (level 1) nested within participants (level 2). Level 2 predictors (i.e., person-level brooding and reflection) were used to predict level 1 DRSP symptoms, including mean levels (intercept) and cyclical changes (i.e., linear and quadratic time slopes) across cycle days (centered around menses). The linear slope captures the symptom increase over the premenstrual time frame, while the quadratic slope (linear slope^2) captures the inverted 'U' shape. We ran individual multilevel growth models predicting each of the nine daily symptoms respectively from the following: (1) linear time, (2) quadratic time, (3) trait-level rumination, (4) the interaction of rumination with linear time, and (5) the interaction of rumination with quadratic time. We used two modeling strategies for both brooding and reflection scales – in the unconditional model, we tested the effects of linear time (premenstrual increase) and quadratic time (postmenstrual decrease) for each DRSP symptom (hypotheses 1 and 2). Then we ran a conditional model testing the interaction of time and rumination subscale (hypotheses 3–6). This allowed us to attribute how much variation in each DRSP symptom's intercept, linear trend (premenstrual symptom increase), and quadratic trend (postmenstrual symptom decrease) are predicted by trait level rumination. In this study design, because this sample was recruited for elevated perceived stress, between-person variability in subject perceptions of stress may be reduced. However, given that stress-related variables are associated with increased reports of premenstrual symptoms, this approach enhances our ability to detect within-person changes in negative affect across the cycle. *Z*-score transformations were performed on participants' RRS subscales (i.e., brooding, reflection) to support model convergence and interpretability of results. We used p value = 0.05 as the cut-off for statistical significance.

Power analysis

Our sample size was 190 participants, with each providing 1–6 cycles of daily ratings (N = 7704 days included in the models). Simulations provided by Arend and Schäfer (2019) indicate that for a cross-level interaction, power was adequate to detect an effect of at least small-to-medium size (Minimum Detectable Effect Size = .24).

Statistical packages

Analyses proceeded in R version 4.0.2 (R Core Team, 2022). The tidyverse suite (Wickham et al., 2019) and dplyr packages (Wickham, François, Henry, & Müller, 2021) were used for data manipulation, organization, and wrangling. The apatables package (Stanley & Spence, 2018) was used to create tables. The lme4 package (Bates, Mächler, Bolker, & Walker, 2015) was used to fit linear and generalized linear mixed-effects models. For missing values, we used the default option in lme4, in which a missing value on any variable in the model was missing from final analyses. The interactions package (Long, 2021) was used to explore statistical interactions in regression models. The CPASS package was used to conduct cycle and person-level analysis (Symul & Eisenlohr-Moul, n.d.).

Results

Descriptive information

Demographic information for the sample can be found in *Table 1*. Out of 15 600 assessments, 7704 were completed, indicating a 49.3% compliance rate. Participants completed daily ratings until randomized (up to 6 months for some). On average participants provided 40.55 days of daily ratings. After conducting cycle-level analysis, 5.7% (n = 11) of participants provided daily ratings for only one premenstrual time frame. In their single cycle, 27% (n = 3) participants showed at least 30% change or more in one of the core emotional symptoms (DRSP 1–8), 9.1% (n = 1) met the criteria for a MRMD (MRMD: DSM-5 PMDD criteria of one emotional symptom), and no one met criteria for the PMDD pattern. The remaining 94.2% (n = 179) participants completed enough ratings to span more than one full cycle and

Table 1. Sample descriptive information (N = 190)

Variable		Mean (s.d.) n (%)
Age		30.82 (7.89)
Age of menarche		12.31 (1.43)
Race	Caucasian	116 (61.1%)
	African American	49 (25.8%)
	Asian	14 (7.4%)
	More than one race	7 (3.7%)
	Declined	4 (2.1%)
Ethnicity	Not Hispanic	176 (92.6%)
	Hispanic	13 (6.8%)
	Unknown	1 (0.52%)
Education	Graduate high school	3 (1.6%)
	Trade or business school	6 (3.2%)
	Some college	25 (13.2%)
	Four-year college	69 (36.3%)
	Postgraduate	87 (46.8%)
Income	Under $ 15 000	27 (14.3%)
	$ 15 000–$ 19 999	7 (3.7%)
	$ 20 000–$ 24 999	9 (4.8%)
	$ 25 000–$ 29 999	12 (6.3%)
	$ 30 000–$ 34 999	12 (6.3%)
	$ 35 000–$ 39 999	8 (4.23%)
	$ 40 000–$ 49 999	35 (18.5%)
	$ 50 000–$79,99	41 (21.7%)
	$ 80 000–$ 99 999	15 (7.9%)
	$ 100 000 or above	23 (12.2%)

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specifically more than one premenstrual time frame (range was between 2 to 6 cycles). In at least one cycle, 42.4% ($n = 76$) participants showed at least 30% change or more in one of the core emotional symptoms, 9.5% ($n = 17$) met the criteria for MRMD, and 1.7% ($n = 3$) met criteria for PMDD. In the entire sample, in at least one cycle, 41.57% ($n = 79$) participants showed at least a 30% change in at least one core emotional symptom, 9.4% ($n = 18$) met criteria for MRMD, and 1.57% ($n = 3$) met criteria for PMDD. Notably, a large percentage had at least one cycle with change (30%, MRMD, or PMDD), but this was not always consistent across two cycles.

Confirmatory hypotheses 1 and 2

Menstrual cycle time and DRSP affective symptoms (unconditional model)

We hypothesized that participants would be at particular risk for premenstrual increases in affective symptoms because participants had elevated stress. We expected to observe significant linear (premenstrual increase) and quadratic (postmenstrual decrease) fixed effects of menstrual cycle time on all DRSP affective items and muscle pain (hypothesis 1). This hypothesis was generally supported (*see models in Table 2*). Most of the symptoms showed a significant premenstrual increase and postmenstrual decrease (*see Fig. 1*). However, there were no significant linear effects for hopelessness or worthlessness. Additionally, there were no significant quadratic effects for depression, hopelessness, or worthlessness. The range of intraclass coefficients (ICC) for the outcomes (0.30 to 0.52, Table 2) indicates substantial variability attributable to the clustering of daily symptoms within individuals.

We also hypothesized that significant random effects of menstrual cycle time on affective symptoms would quantify substantial individual differences in cyclical hormone sensitivity. As illustrated in Fig. 2, this hypothesis was supported; the degree of linear premenstrual change in affective symptoms appeared normally distributed for most outcomes.

Menstrual cycle day, DRSP emotional symptoms, and brooding (conditional model)

We hypothesized that we would replicate prior findings that showed higher trait-level brooding would predict larger intercepts (i.e., mean of daily symptom ratings) for affective symptoms (hypothesis 3). We also expected that trait brooding would show significant cross-level interactions with the linear and quadratic time. Specifically, we predicted that higher trait brooding would predict a more rapid premenstrual increase (i.e., linear effect) and slower postmenstrual decrease (i.e., quadratic effect) on core affective symptoms (hypotheses 4 and 5). Contrary to predictions, these hypotheses were not supported. Higher trait brooding showed no main effect on the intercept and did not interact with the linear or quadratic trend for nearly all DRSP symptoms, except anxiety for which higher brooding did significantly interact with the quadratic trend (*see models in Table 3*).

Exploratory hypotheses

Menstrual cycle day, affective symptoms, and reflection

Since previous studies have found an unexpected negative impact of the reflection subscale of the RRS on cyclical symptom change, we conducted exploratory analyses examining this subscale as a moderator (using the same modeling strategies used for brooding) (hypothesis 6). However, reflection showed no association with baseline levels or a cyclical change in daily symptoms, except for higher levels of reflection predicted high levels of baseline interpersonal conflict (*see Appendix; Supplementary Table 1*).

Menstrual cycle day, affective symptoms, brooding, and a selected sample

The preregistered hypothesis tests suggest that brooding is not a magnifier for affective premenstrual symptoms in a high-risk sample; however, it is possible that rumination only influences premenstrual symptoms among those with some level of cyclical increase in negative affect. Therefore, post hoc analyses were conducted in subsamples of participants ($N = 125$–166) who demonstrated a positive slope of linear time (i.e., any increase in symptoms across the luteal phase) for each symptom. For each affective DRSP item (DRSP 1–8), we created a subsample that demonstrated non-zero premenstrual increase slope by selecting those for whom the fixed + random effect was greater than zero for the linear time slope. We then applied the same modeling strategies as in our primary hypothesis tests. Higher trait brooding did significantly interact with the intercept of anxiety, and linear trend for worthlessness and guilt in the subsample. However, higher trait brooding showed no other interaction with the intercept, linear, or quadratic trend for any DRSP item, even in these subsamples selected for affective cyclicity. This further refutes the idea that rumination is an important exacerbating cognitive factor in those with cyclical affective changes (*see Appendix; Supplementary Table 2*).

Discussion

Few studies have examined the cognitive and behavioral mechanisms that aggravate or perpetuate premenstrual affective symptoms, precluding the development of targeted cognitive-behavioral treatments. Building on evidence from previous studies suggesting that trait rumination may be a risk factor for premenstrual affective symptoms, this prospective, preregistered analysis in a large sample ($N = 190$) aimed to validate trait rumination as a behavioral treatment target. We predicted significant individual differences and variability in symptoms across the menstrual cycle in terms of intercept, premenstrual increase, and postmenstrual decrease of affective symptoms; this was generally supported. However, our hypothesis that rumination would account for some of this variability in cyclical affective change was generally not supported. There were no effects of rumination (brooding or reflection) on the intercept, premenstrual increase, and postmenstrual decrease on affective symptoms. Notably, brooding did significantly interact with the postmenstrual decrease in anxiety. Even with post hoc analyses using the same modeling strategies on a subsample selected for nominal premenstrual increases in symptoms brooding did not predict a premenstrual increase or postmenstrual decrease in symptoms, except for overall anxiety levels and premenstrual increase for worthlessness and guilt. This study used a large sample size, gold-standard daily rating methods, normally distributed hormone sensitivity, a dimensional sample, and a powerful statistical model to demonstrate that rumination is unlikely to be a key player in premenstrual affective change.

Our findings contradict previous smaller studies on the relationship between trait rumination and premenstrual affective changes. We hypothesize that there are two probable reasons for this. First, our sample is larger and more heterogeneous with respect to the degree of hormone sensitivity than prior studies (Craner et al., 2014; Dawson et al., 2018; Welz et al., 2016). Some individuals

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Table 2. DRSP Symptoms and menstrual cycle time

	Depression			Hopelessness			Worthless/Guilt			Anxiety			Mood swings			Rejection sensitivity			Anger/Irritability			Interpersonal conflict			Joint-muscle pain		
Predictors	Estimates	Conf. int (95%)	*p* Value	Estimates	Conf. int (95%)	*p* Value	Estimates	Conf. int (95%)	*p* Value	Estimates	Conf. int (95%)	*p* Value	Estimates	Conf. Int (95%)	*p* Value	Estimates	Conf. Int (95%)	*p* Value	Estimates	Conf. Int (95%)	*p* Value	Estimates	Conf. Int (95%)	*p* Value	Estimates	Conf. Int (95%)	*p* Value
(Intercept)	1.82	1.69–1.94	<0.001	1.54	1.41–1.66	<0.001	1.63	1.51–1.75	<0.001	2.19	2.04–2.34	<0.001	1.63	1.50–1.75	<0.001	1.64	1.51–1.77	<0.001	1.94	1.80–2.07	<0.001	1.60	1.49–1.71	<0.001	1.46	1.34–1.58	<0.001
Linear time (premenses)	0.27	0.06–0.47	0.010	0.13	−0.05–0.31	0.154	0.05	−0.13–0.23	0.568	0.44	0.21–0.68	<0.001	0.47	0.26–0.68	<0.001	0.33	0.11–0.55	0.004	0.44	0.20–0.68	<0.001	0.23	0.04–0.43	0.021	0.34	0.18–0.51	<0.001
Quadratic time (postmenses)	−0.11	−0.23–0.01	0.064	−0.05	−0.15–0.05	0.354	−0.02	−0.12–0.09	0.721	−0.24	−0.37–−0.10	<0.001	−0.21	−0.33–−0.10	<0.001	−0.16	−0.28–−0.03	0.012	−0.26	−0.39–−0.13	<0.001	−0.13	−0.24–−0.02	0.017	−0.16	−0.25–−0.06	0.002
Random effects																											
σ^2	0.85			0.63			0.65			1.03			0.91			0.81			1.04			0.80			0.54		
τ_{00}	0.57			0.59			0.55			0.87			0.50			0.58			0.62			0.35			0.57		
τ_{11}	0.69			0.60			0.57			1.02			0.70			1.05			1.09			0.60			0.44		
	0.24			0.18			0.20			0.32			0.22			0.29			0.30			0.18			0.19		
ρ_{01}	−0.50			−0.53			−0.39			−0.34			−0.30			−0.50			−0.43			−0.32			−0.21		
	0.46			0.49			0.40			0.30			0.26			0.50			0.40			0.33			0.16		
ICC	0.35			0.41			0.43			0.43			0.33			0.37			0.34			0.30			0.52		
N	190			190			190			190			190			190			190			190			190		
Observations	7704			7704			7704			7704			7701			7701			7701			7701			7690		
Marginal R^2/ Conditional R^2	0.002/0.347			0.001/0.415			0.000/0.435			0.002/0.434			0.004/0.335			0.002/0.367			0.002/0.337			0.001/0.302			0.002/0.517		

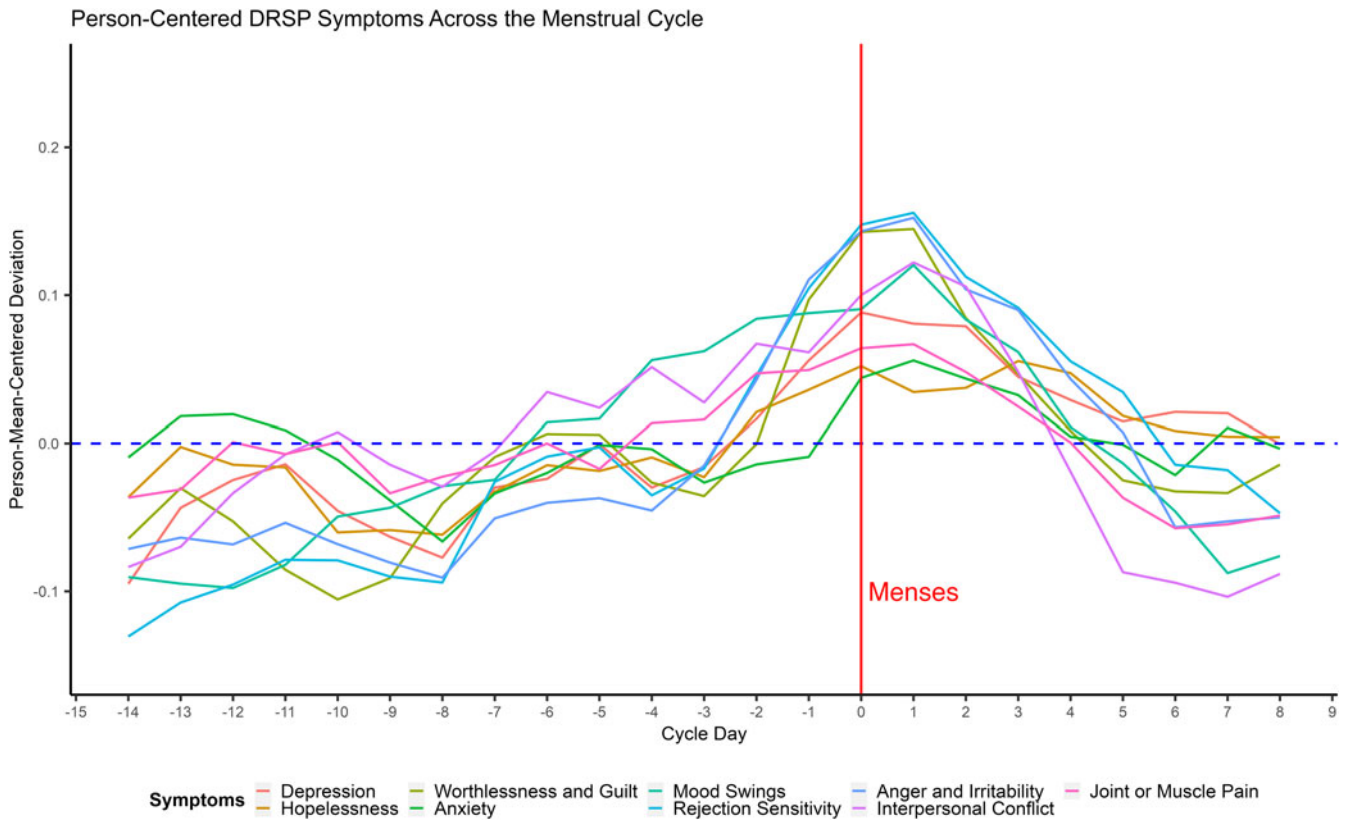


Figure 1. Sample average person-centered DRSP symptoms across the menstrual cycle.

had no cyclical changes, while others had very intense cyclical changes. Along with variation in temporal patterns, we did not select participants based on the number of symptoms endorsed. The other samples were much smaller and more homogenous; one study included only individuals with PMDD (Craner et al., 2014), another required just one cyclical PMDD affective symptom (Dawson et al., 2018), and one included a nonclinical sample (Welz et al., 2016). Trait rumination may contribute to premenstrual affective change only in patients with more severe premenstrual symptoms. However, in post hoc analyses in samples with nominal cyclicity of affect, we still did not find an association, which reduces the likelihood of this explanation. Second, relative to prior studies, our observational and analytic designs provided a more granular test of the hypothesis that rumination contributes to cyclical hormone sensitivity. Two studies used variations of ANOVA which indicated a group difference between individuals selected for premenstrual symptoms and without (Craner et al., 2014) and phase differences in rumination (Welz et al., 2016). Instead, (like Dawson et al., 2018) we used a multilevel modeling approach which allows for more granularity to detect moderation of within-person cyclical affective changes. Therefore, both our sample and statistical modeling strategies differed from prior studies. However, our study provides a stronger, more fundamental test of the hypothesis that trait rumination is an exacerbating cognitive factor in those with cyclical hormone sensitivity.

Clinical significance

These findings provide important insights relevant to the treatment of premenstrual disorders. Often, research studies on cyclical affective symptoms and disorders (i.e., PMDD and PME) conclude that patients should seek out cognitive-behavioral therapy because of an assumption that the psychopathological mechanisms of premenstrual disorders must be similar to those of other affective disorders. However, this study provides evidence that the cognitive mechanisms that maintain and worsen premenstrual disorders may differ from those in other disorders. Rumination is a well-established contributor to the magnification of other affective disorders but may not be a critical factor in cyclical symptom changes. These findings highlight the need to identify or further explore alternative cognitive and behavioral mechanisms before developing treatment. Some of these mechanisms may include cognitive and behavioral responses to physiological symptoms (i.e., anxiety sensitivity), cognitive biases (i.e., attribution bias, self-focused attention), or skills deficits contributing to emotion dysregulation (i.e., lack of emotional clarity). Conducting well-powered prospective research on these mechanisms will allow us to determine which areas to target for intervention.

Strengths

Investigations of symptoms across the menstrual cycle often rely on retrospective data, which are highly unreliable due to the exceedingly high false-positive rate (i.e., participants report premenstrual affective symptoms but do not show any cyclical changes when symptoms are tracked daily). One of the strengths of this study is relying on prospective participant ratings across 1–6 menstrual cycles. Furthermore, we were able to explore hormone sensitivity across a large ($N = 190$) at-risk group (i.e., elevated-stress group), which allowed for a transdiagnostic

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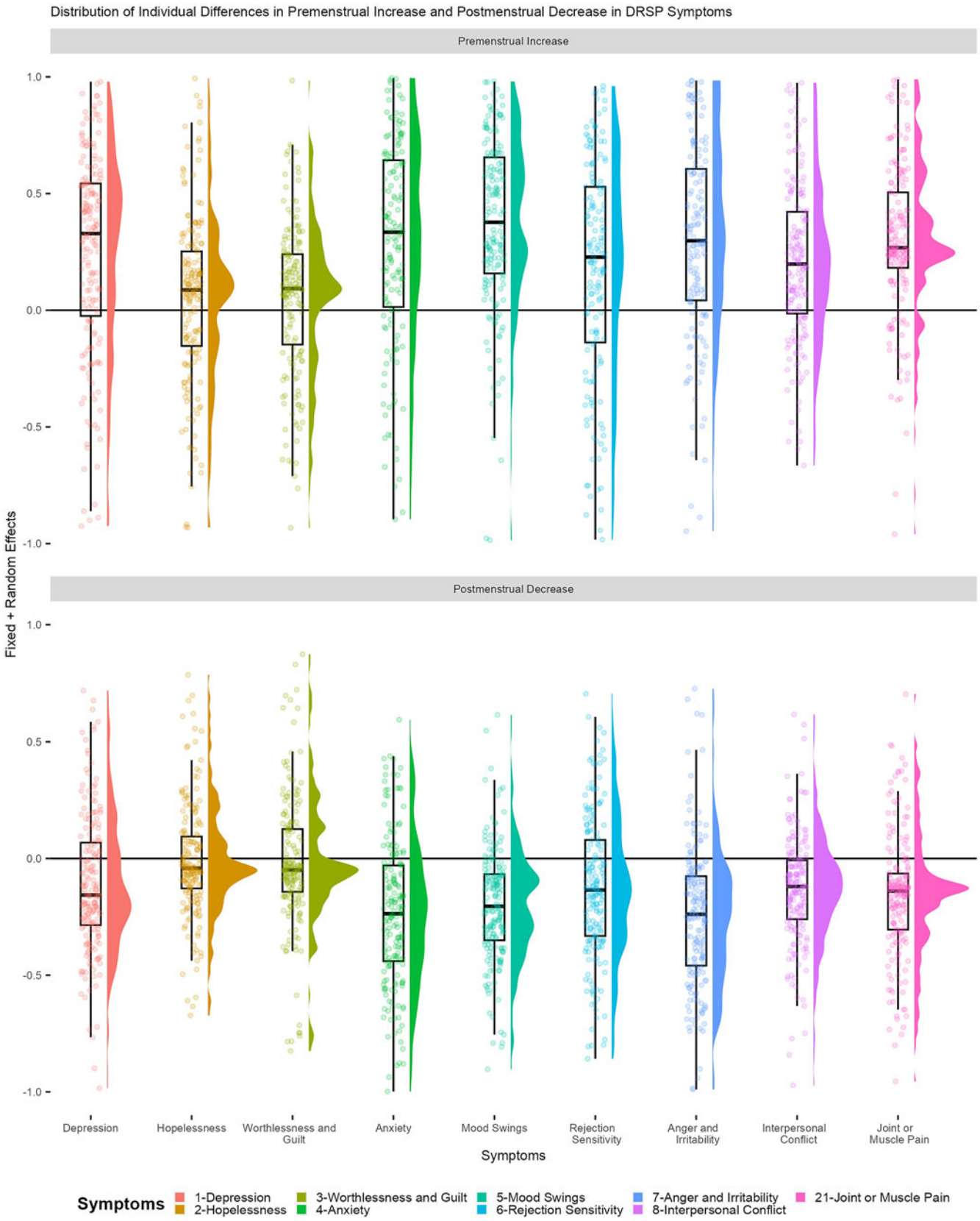


Figure 2. Distribution of individual differences in premenstrual increase and postmenstrual decrease in DRSP symptoms.

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Table 3. DRSP Symptoms, menstrual cycle time, and brooding

	Depression			Hopelessness			Worthless/Guilt			Anxiety			Mood swings			Rejection Sensitivity			Anger/Irritability			Interpersonal conflict			Joint-muscle pain		
Predictors	Estimates	Conf. int (95%)	*p* Value	Estimates	Conf. int (95%)	*p* Value	Estimates	Conf. int (95%)	*p* Value	Estimates	Conf. int (95%)	*p* Value	Estimates	Conf. int (95%)	*p* Value	Estimates	Conf. Int (95%)	*p* Value	Estimates	Conf. Int (95%)	*p* Value	Estimates	Conf. int (95%)	*p* Value	Estimates	Conf. int (95%)	*p* Value
Intercept	1.81	1.69–1.94	<0.001	1.53	1.41–1.66	<0.001	1.63	1.51–1.75	<0.001	2.19	2.04–2.34	<0.001	1.62	1.50–1.75	<0.001	1.64	1.51–1.76	<0.001	1.94	1.80–2.07	<0.001	1.60	1.49–1.70	<0.001	1.46	1.34–1.58	<0.001
Brooding	0.00	−0.12–0.13	0.967	0.06	−0.06–0.19	0.313	0.06	−0.06–0.18	0.338	0.10	−0.05–0.26	0.188	−0.00	−0.13–0.12	0.944	−0.03	−0.16–0.09	0.609	0.02	−0.12–0.16	0.780	0.02	−0.09–0.13	0.699	−0.01	−0.13–0.11	0.862
Linear time (Premenses)	0.27	0.06–0.47	0.010	0.13	−0.05–0.32	0.149	0.05	−0.13–0.24	0.555	0.44	0.20–0.67	<0.001	0.47	0.26–0.68	<0.001	0.33	0.11–0.55	0.004	0.44	0.20–0.68	<0.001	0.23	0.04–0.43	0.021	0.34	0.18–0.51	<0.001
Quadratic time (Postmenses)	−0.11	−0.23–0.01	0.064	−0.05	−0.15–0.05	0.352	−0.02	−0.12–0.09	0.715	−0.23	−0.36–−0.10	0.001	−0.21	−0.33–−0.10	<0.001	−0.15	−0.28–−0.03	0.013	−0.26	−0.39–−0.13	<0.001	−0.13	−0.24–−0.02	0.017	−0.16	−0.25–−0.06	0.002
Brooding × Linear time	0.00	−0.21–0.22	0.965	0.01	−0.18–0.20	0.914	0.02	−0.17–0.20	0.850	−0.20	−0.44–0.04	0.101	−0.03	−0.25–0.18	0.777	0.00	−0.23–0.23	0.999	0.14	−0.10–0.39	0.250	0.05	−0.15–0.25	0.621	−0.04	−0.21–0.12	0.615
Brooding × Quadratic time	0.01	−0.11–0.13	0.879	0.01	−0.10–0.11	0.857	0.01	−0.10–0.11	0.913	0.14	0.00–0.27	0.046	0.03	−0.09–0.16	0.576	0.03	−0.10–0.15	0.670	−0.08	−0.21–0.06	0.260	−0.02	−0.14–0.09	0.680	0.06	−0.04–0.16	0.247
Random effects																											
σ^2	0.85			0.63			0.65			1.03			0.91			0.81			1.04			0.80			0.54		
τ_{00}	0.58			0.59			0.55			0.86			0.50			0.58			0.63			0.36			0.58		
τ_{11}	0.70			0.61			0.58			0.99			0.71			1.07			1.09			0.61			0.44		
	0.24			0.19			0.21			0.30			0.22			0.30			0.30			0.18			0.19		
ρ_{01}	−0.50			−0.54			−0.39			−0.32			−0.30			−0.51			−0.44			−0.33			−0.21		
	0.46			0.49			0.40			0.28			0.26			0.51			0.41			0.34			0.16		
ICC	0.35			0.41			0.43			0.43			0.33			0.37			0.33			0.30			0.52		
N	190			190			190			190			190			190			190			190			190		
Observations	7704			7704			7704			7704			7701			7701			7701			7701			7690		
Marginal R^2/ Conditional R^2	0.002/0.348			0.007/0.416			0.006/0.436			0.005/0.435			0.004/0.337			0.002/0.368			0.005/0.338			0.002/0.303			0.003/0.518		

understanding of symptom changes across the menstrual cycle. Finally, as in prior work, the degree of prospective cyclical mood change was normally distributed in the sample, supporting the feasibility of hypotheses tests as well as the broader scientific concept of individual differences in hormone sensitivity.

Limitations and future directions

Despite the strengths of the current work, it has limitations. First, our rumination measure had modest reliability ($\alpha = 0.71$ for brooding and $\alpha = 0.71$ for reflection), compared to the validation sample of patients with major depressive disorder ($\alpha = 0.83$ for brooding and $\alpha = 0.74$ for reflection; Parola et al., 2017). Second, although this study was preregistered, reliance on archival data made preregistration prior to data collection infeasible. Third, the absence of LH-surge testing may impede detection of anovulation, double LH surge, and other cycle irregularities. However, to mitigate such issues, our sample only included participants with normal cycle lengths, excluding pregnant/breastfeeding/perimenopausal individuals, which reduced the potential for undetected anovulation. Finally, given that participants varied in the number of cycles reported, two issues arose – first, we had a lower-than-expected compliance rate (49.3%) indicating the participant burden, and second, participants who had contributed more cycles had more predictive validity as compared to those with fewer cycles.

Future work will likely benefit from investigating *state* rumination in addition to *trait* rumination. While our study specifically tested trait rumination effects, emerging evidence suggests that rumination may be a time-varying factor. A recent study revealed increased daily rumination during the late luteal phase among individuals with higher, prospectively rated premenstrual symptoms (Nayman et al., 2023). Other recent work suggests that individuals with retrospectively reported PMDD experience increases in rumination late in the cycle and that increased rumination is linked with worsened negative affect in the luteal phase (Beddig et al., 2020). The absence of significant *trait* rumination effects in the current investigation, along with these recent findings, suggests that future work may benefit from studying rumination in premenstrual disorders as a time-varying – rather than trait – factor.

Conclusion

This well-powered prospective study examined associations between trait rumination and daily symptoms of premenstrual disorders. Contrary to predictions, trait rumination was not associated with cyclical affective changes. The current findings suggest the need to identify other cognitive and behavioral mechanisms that may play a role in exacerbating hormone-sensitive affective responses to the menstrual cycle in service of developing targeted psychological interventions for premenstrual disorders.

Supplementary material. The supplementary material for this article can be found at https://doi.org/10.1017/S0033291723003793.

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Competing interest. None.

Ethical statement. The authors assert that all procedures contributing to this work comply with the ethical standards of the relevant national and institutional committees on human experimentation and with the Helsinki Declaration of 1975, as revised in 2008.

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