2-2018

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Bethan A. Roberts
University of Kentucky, bethanroberts516@gmail.com

Tory Eisenlohr-Moul
University of North Carolina at Chapel Hill

Michelle M. Martel
University of Kentucky, michelle.martel@uky.edu

HHS Public Access

Author manuscript

Psychoneuroendocrinology. Author manuscript; available in PMC 2019 February 01.

Published in final edited form as:

Psychoneuroendocrinology. 2018 February ; 88: 105–114. doi:10.1016/j.psyneuen.2017.11.015.

Reproductive Steroids and ADHD Symptoms Across the Menstrual Cycle

Bethan Roberts, Ph.D.,
University of Kentucky

Tory Eisenlohr-Moul, Ph.D., and
University of North Carolina at Chapel Hill

Michelle M. Martel, Ph.D.[†]
University of Kentucky

Abstract

Although Attention-Deficit/Hyperactivity Disorder shows (ADHD) male predominance, females are significantly impaired and exhibit additional comorbid disorders during adolescence. However, no empirical work has examined the influence of cyclical fluctuating steroids on ADHD symptoms in women. The present study examined estradiol (E2), progesterone (P4), and testosterone (T) associations with ADHD symptoms across the menstrual cycle in regularly-cycling young women (*N*=32), examining trait impulsivity as a moderator. Women completed a baseline measure of trait impulsivity, provided saliva samples each morning, and completed an ADHD symptom checklist every evening for 35 days. Results indicated decreased levels of E2 in the context of increased levels of either P4 or T was associated with higher ADHD symptoms on the following day, particularly for those with high trait impulsivity. Phase analyses suggested both an early follicular and early luteal, or post-ovulatory, increase in ADHD symptoms. Therefore, ADHD symptoms may change across the menstrual cycle in response to endogenous steroid changes.

Keywords

reproductive steroid hormones; estradiol; progesterone; testosterone; ADHD

[†]Michelle Martel; Department of Psychology, University of Kentucky, 207C Kastle Hall, Lexington, KY 40506. michelle.martel@uky.edu. Phone: 859-257-8662; Bethan Roberts; Department of Psychology, University of Kentucky, Lexington, KY 40506. bethanroberts516@gmail.com. Phone: 530-636-2384; Tory Eisenlohr-Moul; Department of Psychiatry, University of North Carolina at Chapel Hill, 2218 Nelson Highway, Suite 3, Chapel Hill, NC 27517. t.eisenlohr.moul@gmail.com. Phone: 859-317-0503.

Conflicts of interest: none
All co-authors have seen and agree with the contents of the manuscript and there is no financial interest to report or conflicts of interest. We certify that the submission meets the guidelines for ethical conduct and report of research, is original work, and is not under review at any other journal.

1. Introduction

Attention-Deficit/Hyperactivity Disorder (ADHD) is a common and impairing childhood neurodevelopmental disorder (APA, 2013; Bernfort et al., 2008; Pelham et al., 2007, Polanczyk et al., 2007; Sayal et al. 2017; Thomas et al., 2015) that often persists into adolescence and adulthood with a prevalence of approximately 3% in adults (Faraone & Biederman, 2005; Fayyad et al., 2017; Kessler et al., 2006; Wilcutt, 2012). ADHD is a heterogeneous condition, currently conceptualized theoretically using multiple pathway models (Nigg et al., 2004; Sonuga-Barke, 2005) and most accurately described using two continuous symptom dimensions of inattention and hyperactivity-impulsivity (Haslam et al., 2006; Larsson et al., 2012; Marcus & Barry, 2011). Although ADHD is more frequently diagnosed in males, females with ADHD often become particularly impaired and exhibit comorbid disorders beginning during adolescence (Biederman et al., 1999; Hinshaw et al., 2012; Hosain, et al., 2012; Lahey et al. 1994; Quinn, 2005; Robison et al., 2008). The mechanisms of such sex differences remain unclear yet fundamental to understanding ADHD and sex differences in ADHD.

Prior work suggests a role for organizational testosterone (T) in ADHD symptoms in both sexes (Wang et al., 2017), but particularly males (Martel, 2009; McFadden et al., 2005). Women and girls are under-studied and in particular, activational hormonal effects remain essentially unstudied in ADHD. Case studies have suggested that ADHD symptoms may worsen the week before menstruation (during declining estrogen and progesterone; Quinn, 2005) and improve during pregnancy (during elevated estrogen and progesterone (Nadeau & Quinn, 2002), but empirical work is lacking.

Higher estradiol (E2) and progesterone (P4) have been generally linked to enhanced executive function (EF) and attention (e.g., Hatta & Nagaya, 2009), which appear to improve during cycle phases characterized by elevated E2 and P4 (Gogos, 2013; Howard et al., 1988; Jacobs & D'Esposito, 2011; Lord & Taylor, 1991; Rosenberg & Park, 2002; Segal, 2012; Vranic´ & Hromatko, 2008; Solís-Ortiz & Corsi-Cabrera, 2008; Solis-Ortiz et al., 2004). Further, verbal fluency, verbal learning and memory appear to improve with administration of T in women (Davison et al., 2011; Drake et al., 2000), whereas response inhibition performance decreases (Bjork et al., 2001). Given that weak EF is a prominent correlate and possible marker of ADHD, this prior work suggests a potential role for cycling reproductive steroids in daily ADHD symptom expression.

During adulthood, impulsivity appears to be a particularly prominent marker of ADHD that is underpinned by cyclical steroid effects (Barkley et al., 2010). Studies of adult ADHD suggest robust associations with components of impulsivity (Lynam et al., 2006), including Negative Urgency (negative affect-driven rash action), Lack of Perseverance (inability to persist on a task through completion), and Lack of Planning (action without careful thinking; Miller et al., 2010; Pedersen et al., 2016; reviewed by Berg et al., 2015) with Negative Urgency potentially related to fluctuations in E2 and P4 through its links with affect (Eisenlohr-Moul et al., 2015). Sensation-Seeking (tendency to seek adventure) may be more specifically associated with hyperactivity-impulsivity (Lopez et al., 2015), as well as related to higher T (Campbell et al., 2010; Daitzman & Zuckerman, 1980; Roberti, 2004). Overall,

trait impulsivity appears prominently associated with both adult ADHD symptoms and steroid effects. Therefore, in line with rodent research (Löfgren et al., 2009), impulsivity may be a marker or a route to adult ADHD that is particularly sensitive to steroid effects. Thus, the possibility that steroid effects on ADHD may be apparent particularly for women with high trait impulsivity (particularly Negative Urgency and Sensation-Seeking) was examined herein.

1.1 Goals of the Present Study

The present study was conducted with the intention of examining the within-person covariations of reproductive steroids, including E2, P4, and T, with daily ADHD symptoms across the menstrual cycle. Based on prior work on E2 associations with EF, it was hypothesized that 1) between-women, lower average E2 across the entire menstrual cycle would be associated with higher ADHD symptoms, 2) within-person declines in E2 (i.e., lower-than-average E2 for a given woman) would be associated with increases in ADHD symptoms, and that 3) within-person declines in E2 would be more strongly associated with increased ADHD symptoms, particularly for those with higher levels of trait impulsivity. Additionally, given the evidence for interactive effects of E2 and P4 in other externalizing psychopathologies (Eisenlohr-Moul et al., 2015; Klump et al., 2008; 2013). P4 was included as an exploratory moderating variable given established antagonistic effects on E2, and T was also included as an exploratory moderating variable due to associations of T with ADHD symptoms (Martel, 2009; McFadden et al., 2005) and sensation seeking (Campbell et al., 2010; Daitzman & Zuckerman, 1980; Roberti, 2004). Finally, 4) cycle phase effects were examined to more easily compare results to previous studies and to evaluate whether ADHD risk may be heightened during particular parts of the menstrual cycle exhibiting characteristic hormone profiles, such as the early luteal phase and the perimenstrual timeframe (see Appendix 1).

2. Methods and Materials

2.1 Participants

Participants were 32 naturally-cycling young females between the ages of 18 and 22 (M = 19.43, SD = 1.38) recruited from the local university and surrounding community. The participants' ethnic background broadly matched that of the community: 70.6% Caucasian, 17.6% African American, and 11.8% other ethnic minority. Exclusionary criteria included primary sensorimotor handicap, neurological disorder, pervasive developmental disorder or intellectual disability, history of psychosis, current gynecological or thyroid disorders, irregular cycles (<21 days or >35 days), and current medical use of hormones, psychostimulants, or antipsychotic medications. 3 women reported prescribed SSRIs. Height and weight were measured since body mass index impacts reproductive steroids (Lukanova et al., 2004; BMI *Mean* = 24.37, SD = 6.33). Participants who completed any data collection received $50, those who completed >50% of participation received $75, and those who completed 100% of data collection received $100.

2.2 Procedure

At an initial laboratory visit, participants provided informed consent via IRB-approved procedures and completed measure of study eligibility and trait measures of impulsivity. Eligible women then completed 35 days of morning saliva collection and evening online symptom reports, after which participants returned frozen samples to the laboratory. The number of measures administered was kept to a minimum to reduce participant burden during the lengthy data collection period. E2, P4, and T were assayed every other day, resulting in an average of 17 days of data (steroids and symptoms) per woman.

2.3 Measures

2.3.1. Trait Impulsivity—The *UPPS-P Trait Impulsivity Scale*, a 59-item questionnaire, assesses five components of trait impulsivity: Positive Urgency (positive affect-driven rash action), Negative Urgency (negative affect-driven rash action), Lack of Premeditation (action without careful thinking), Lack of Perseverance (inability to remain with a task through completion), and Sensation Seeking (tendency to seek adventure; Whiteside & Lynam, 2001) The scales demonstrate excellent reliability and validity (Lynam et al., 2006; Cyders et al., 2007). In the current sample, Lack of Perseverance exhibited fair reliability (α = .56) and Lack of Premeditation, Negative Urgency, Positive Urgency and Sensation Seeking exhibited good reliability (α = .82–.93).

2.3.2. Daily ADHD Symptoms—Daily symptoms were measured using the *Current ADHD Symptoms Scale (CSS): Self-report*, a symptom checklist for ADHD symptoms and impairment (Barkley & Murphy, 2006). Participants were instructed to rate their symptoms for the day every day in the evening. Symptom counts were used for analysis rather than diagnosis, as the sample was community-recruited, and ADHD appears best characterized as a continuum of symptoms (Haslam et al., 2006; Marcus & Barry, 2011). Total Hyperactive-Impulsive symptoms ranged from 0 to 9 (M = .32, SD = .66; α = .66), and total Inattentive symptoms ranged from 0 to 9 (M = .20, SD = .65; α = .72). Log transformations were applied and resulted in normally distributed residuals in all analyses.

2.3.3 Reproductive Steroids: 17β-Estradiol (E2), Progesterone (P4), and Testosterone (T)—Saliva samples were collected via passive drool by participants in the morning thirty minutes after waking and were subsequently frozen. Participants were instructed not to eat, drink, brush teeth, or smoke before saliva collection. No participant reported violation of this morning protocol in daily diaries. Samples from every other day were analyzed. Serum E2 (pg/mL), P4 (pg/mL), and T (pg/mL) were determined using enzyme immunoassay kits available through Salimetrics. For E2, the Salimetrics 17β-Estradiol immunoassay kit had a sensitivity of 0.1 pg/mL and high precision (% coefficient of variation ranging from .7 to 14.5). For P4, the Salimetrics immunoassay kits had a sensitivity of 5 pg/mL (from 0) and a precision of percent coefficient of variation between 1.05 and 14.8. For T, the Salimetrics immunoassay kits had a sensitivity of 1pg/dL and precision of percent coefficient of variation between 1.2 and 18.9 All participants showed peak P4 levels consistent with an ovulatory cycle (Howards et al., 2009). Finally, steroids generally showed expected trajectories across the menstrual cycle: E2 demonstrated a

midcycle peak and secondary peak during the midluteal phase, P4 was low during the follicular phase and peaked during the luteal phase, and T showed a small mid-cycle peak.

The following predictors were defined for E2, P4, and T: (1) *steroid averages* across all observations within a participant, representing between-person differences in total exposure across the cycle, (2) *steroid standard deviation* across all observations within a participant, representing between-person differences in within-person variance across the cycle, and (3) *recent steroid levels* relative to one's own average and standard deviation across all observations (within-person levels; Klump et al., 2008)[1], defined as yesterday's value minus the person average, divided by the person standard deviation. The one-day lag for the impact on ADHD symptoms was chosen to correspond to the 24 hour lag for ovarian steroid effects on behavior in animals (Bless, McGinnis, Mitchell, Hartwell, & Mitchell, 1997).

2.3.4. Cycle Phase Coding—Menstrual cycle phase was coded as described by Edler, Lipson, & Keel (2006). We then created an additional phase variable to differentiate pre- and post-ovulatory phases. To do this, we identified four pre-E2-peak and four post-E2 peak days; after identifying the ovulatory E2 peak, the day of the ovulatory E2 peak and the three days prior comprised the "pre-ovulatory" phase, while the four days after the ovulatory peak comprised the "post-ovulatory" phase. Five total phases were coded, with no overlap: Follicular, Preovulatory, Postovulatory, Midluteal, and Premenstrual.

2.4. Statistical Analysis

First, steroid means and standard deviations were correlated with impulsivity and average symptoms using spearman rank correlations (due to skewed distributions) partialling age and BMI. Next, linear mixed-effect models examined cycle phase and within-person steroid variation as predictors. In steroid models, we predicted today's symptoms from BMI, yesterday's person-standardized E2, P4, and T, and the two-way interactions between all steroids. Trait impulsivity variables were considered as moderators. Random slopes were specified for within-person predictors, and an additional term specified an autoregressive covariance structure (day – 1). Coefficients and odds ratios for within-person hormonal effects can be interpreted as the effect of a one person-SD increase in the predictor above one's mean. Visual inspection of distributions and residuals indicated that assumptions of normality and homoscedasticity were met. In order to evaluate their robustness, moderation analyses were also carried out excluding the highest and lowest 10% of observations on the moderator. Using the Intraclass Correlations (ICCs) for each outcome and equations provided by Snijders and Bosker (1999), calculations indicated 80% power to detect conventionally small-to-medium effects (Klump et al., 2013; smallest detectible effects for cross-level interaction were $f^2 = .085 – .091$).

3. Results

ICCs revealed that the majority of variance in symptoms was at the within-person level for Inattentive Symptoms (15% stable between-person variance; ICC = .15, NMI = .18, NMISE

[1]Values on this variable are centered around one's personal average for that steroid; therefore, negative values indicate lower-than-average recent levels, and positive values indicate higher-than-average recent levels.

= .048) and Hyperactive/Impulsive symptoms (10% stable between-person variance; ICC = .10, NMI = .13, NMISE = .031). Therefore, ADHD symptoms were more state-like than trait-like, and analyses focused on within-person variance in symptoms were therefore most relevant to explaining symptom variance.

1) Association between Average Hormone Levels and ADHD Symptoms

Table 1 presents correlations of steroid means and variances with risk variables. Higher average E2 predicted less inattention, and greater E2 variance was associated with lower Negative Urgency. Higher average P4 correlated with lower inattention, Positive Urgency, Sensation Seeking, and Lack of Premeditation, and greater P4 variance predicted lower Negative Urgency, Positive Urgency, Sensation Seeking, and inattention. Greater variance in T predicted higher Positive Urgency and Sensation Seeking.

2) Do Higher or Lower Recent Steroid Levels Impact ADHD Symptoms?

Results of models predicting daily ADHD symptoms from recent steroids and their interactions revealed no significant associations (see Table 2). However, the existence of random effects of E2, P4, and T indicated that the impact of steroids varied as a function of between-person factors.

3) Do Impulsivity Traits Moderate the Impact of Daily Steroids on ADHD Symptoms?

Table 2 provides results of moderator analysis of the UPPS-P subscales on steroid-symptom links. All five UPPS-P subscales moderated at least one steroid-symptom association. However, sensitivity analyses revealed that moderation of steroid effects by Lack of Premeditation and Lack of Perseverance were not robust to elimination of extreme observations. Therefore, we report and discuss only the more robust moderating effects of Negative Urgency, Positive Urgency, and Sensation Seeking.

3a) Moderated Interactive Effects of E2 and P4—Only among women high in Negative Urgency, Positive Urgency, and Sensation Seeking (+1 SD), there were significant interactive effects of E2 and P4 on both inattention and hyperactivity (Figures 1, 2, and 3). These interactions took a similar form in each case: in the context of higher-than-average P4 (the luteal phase), lower-than-average E2 predicted higher symptoms.

3b) Moderated Effects of T and E2 X T—Among women high in Sensation Seeking (+1 SD), higher-than-average T predicted increased hyperactivity/impulsivity; among women low in Sensation Seeking (−1 SD), higher-than-average T predicted decreased hyperactivity/impulsivity. Only among women high in Sensation Seeking, E2 and T interacted to predict inattention; when T was higher than usual, higher E2 predicted lower symptoms of inattention; when T was lower than usual, higher E2 predicted higher symptoms of inattention.

In Figure 3, we provide means plots to illustrate the interactive effects of E2 with *both* P4 and T in predicting inattention across the cycle; smoothed levels of hormones and symptoms are plotted across the cycle among the top 33% of sensation seeking scorers. In Figure 4, we similarly illustrate the impact of T on hyperactivity/impulsivity across the cycle.

4) Does Cycle Phase Impact ADHD Symptoms?

Next, we examined the influence of cycle *phase* on daily symptoms (see Appendix 1). Within-person analysis revealed no significant differences between phases for hyperactivity/impulsivity, but the postovulatory phase was characterized by higher inattentive symptoms than all other phases (all p's < .01).

4a) Do Impulsive Traits Alter the Impact of Cycle Phase on ADHD Symptoms?—We then examined the moderating influence of UPPS-P impulsivity variables on within-person associations of cycle phase with daily symptoms. Only in women *high* (+1 SD) in Positive Urgency or Sensation Seeking, the follicular and postovulatory phases were characterized by greater hyperactivity/impulsivity than the midluteal, premenstrual, and preovulatory phases (all p's < .05). Only in women high on Sensation Seeking, Positive Urgency, and Lack of Premeditation (+1 SD), the follicular and postovulatory phases were each characterized by greater inattentive symptoms relative to all other phases (all p's < .05). Only for women high in Positive Urgency (+1 SD), symptoms in the postovulatory phase were higher than the follicular phase (p < .05).

4. Discussion

In the first study to examine daily reproductive hormone levels with subsequent daily ADHD symptom expression, lower-than-average E2 in the context of higher-than-average P4 or T predicted next day increase in ADHD symptoms. The effect was magnified by high baseline trait impulsivity, suggesting that high trait impulsivity may be a route to ADHD symptoms in young adult women that is particularly sensitive to steroid influence. The within-person effects of decreased E2 during elevated P4 or T were complimented by our cycle phase findings, which suggested postovulatory and follicular elevations in symptoms among vulnerable women. Between-person associations of average E2 and P4 with average ADHD symptoms further indicated that low (and low variance in) E2 and P4 predicted greater symptoms. In addition, greater variation in T was linked with increased ADHD symptoms, whereas average levels were not.

Associations between low E2 and increased ADHD symptoms are in line with evidence that decreased E2 reduces EF (Jacobs et al., 1998; Schmidt et al., 1996; Sherwin, 1997), perhaps particularly among women with genotypic risk for low prefrontal dopamine and elevated trait impulsivity (Jacobs & D'Esposito, 2011). E2 effects on dopaminergic striatal circuits by reducing dopamine receptors and increasing dopamine release may therefore mediate these effects (Archer, 1999; Gibbs, 2010), particularly in the prefrontal cortex (Berman et al., 1997).

Our work replicates antagonistic effects of E2 and P4 in externalizing disorders (Eisenlohr-Moul et al., 2015; Klump et al., 2008; 2013; Singh, Su, & Ng, 2013) and is the first to indicate an antagonistic relationship of E2 and T. Notably, although our interactive steroid findings (high P4, low E2) might be initially seen as suggestive of a premenstrual exacerbation such as those described in case studies (Quinn, 2005), moderated cycle phase findings instead suggest strong postovulatory (rather than premenstrual) worsening of

symptoms with a secondary early follicular peak. To our knowledge, this is also the first study to identify post-ovulatory risk for ADHD symptoms.

Notably, these effects of low E2 on ADHD symptoms were only present during periods of high P4 and T. P4 and T may work in slightly different ways to increase the salience of environmental cues that may facilitate distractibility and risk taking; elevated or increasing P4 heightens attention to social cues relevant to social affiliation in women (Maner & Miller, 2014), while elevated or increasing T facilitates attention to social dominance opportunities (Albert et al., 1993; Eisenegger et al., 2011; Mazur & Booth, 1998). It is possible, then, that heightened levels of either P4 or T set the stage for vulnerability to (social) environmental distractions and opportunities for impulsive behavior, and concurrent drops in E2, with their associated reductions in EF, further increase risk for symptoms. This could function to increase the probability of indiscriminate mating and conception due to increases in impulsive behavior just post-ovulation.

Although this study was the first to directly examine steroids and ADHD symptoms, it is not without limitations. A one-day lag was assumed for the impact of hormones on ADHD symptoms based on a study of rats (Bless et al., 1997). An important area of future work is verifying the time period of effects in humans. In addition, use of a nonclinical sample may limit generalizability of these findings, despite a consensus that ADHD is best conceptualized dimensionally (Barkley, 2006; Haslam et al., 2006; Larsson et al., 2012; Marcus & Barry, 2011). Further, the present study had limited diagnostic information (i.e., one measure of ADHD) due to practical constraints and also did not explore clinical comorbidities (e.g., Borderline Personality Disorder; DeSoto et al., 2003; Eisenlohr-Moul et al., 2015), which might have impacted study findings. Future studies should utilize multiple measures of ADHD symptoms, use or develop a measure designed to measure daily changes in symptoms, and explore or control for potential comorbidities. The present study also relied on self-report. Future studies should utilize other-report and/or neuropsychological testing. Finally, analyses utilized data collected every other day (vs. every day) due to expense of assays; more fine-grained analysis is an important extension of current results. Finally, rodent models suggest that progesterone injection in intact rats leads to hypoactivity (Rodier 1971), and administration of estradiol reverses hypoactivity in ovariectomized rats (Gorzek et al., 2007), effects that appear to be in the opposite direction of the present study's findings. Additional comparative work will be important, although -- in this case -- it might be argued that the study of naturally-occurring cyclic variations in hormones may lead to a very different pattern of results compared to more rigorous examination of ovariectomization and substitution effects on behavior.

5. Conclusions

Results demonstrating steroid effects across the menstrual cycle on ADHD symptoms for vulnerable women suggests the possibility that ADHD symptoms may be more state-like and variable within women than previously thought. If results that ADHD symptoms vary across the menstrual cycle in tandem with steroid changes are replicated, this may suggest the need for clinicians to ask for information about cycle phase, hormonal profiles, use of hormonal birth control, and/or stage of life (i.e., pre- or post-puberty) during ADHD

assessment in women. These results also suggest the possibility that EF and psychostimulant response might vary across the cycle. These represent critical directions for future work.

Acknowledgments

This work was supported by the National Institutes of Health (M.M., UL1R000117), National Institute of Mental Health (T.E., T32MH093315; K99MH109667), and National Institute on Drug Abuse (M.M., DA005312; DA035150). We thank the participants who made this work possible.

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Highlights

- ADHD symptoms are higher when estradiol decreases
- Low estradiol risky for ADHD in context of high progesterone or testosterone
- Associations are stronger for highly impulsive women
- ADHD symptoms increased during early follicular and early luteal phases
- ADHD symptoms change across menstrual cycle in young adult women

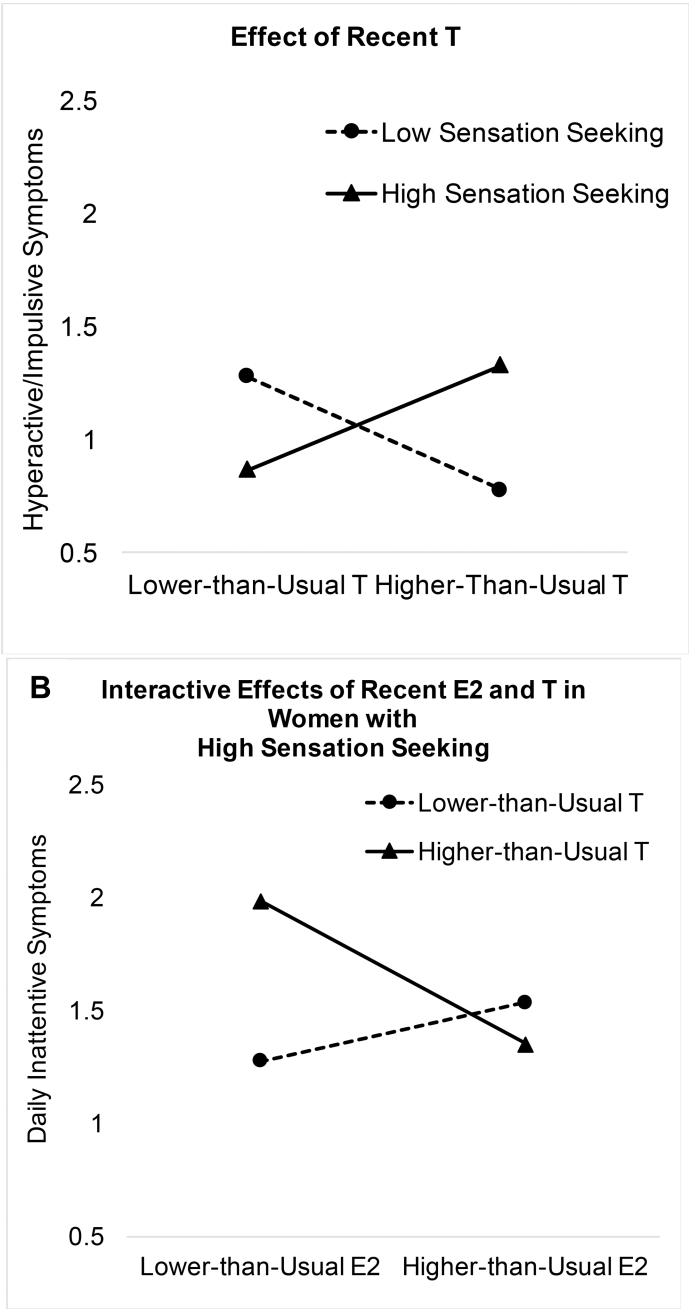


Figure 1.

Moderating Influence of Sensation Seeking on (A) the Effect of Testosterone and (B) the Interactive Effect of Estradiol and Testosterone on Daily ADHD Symptoms

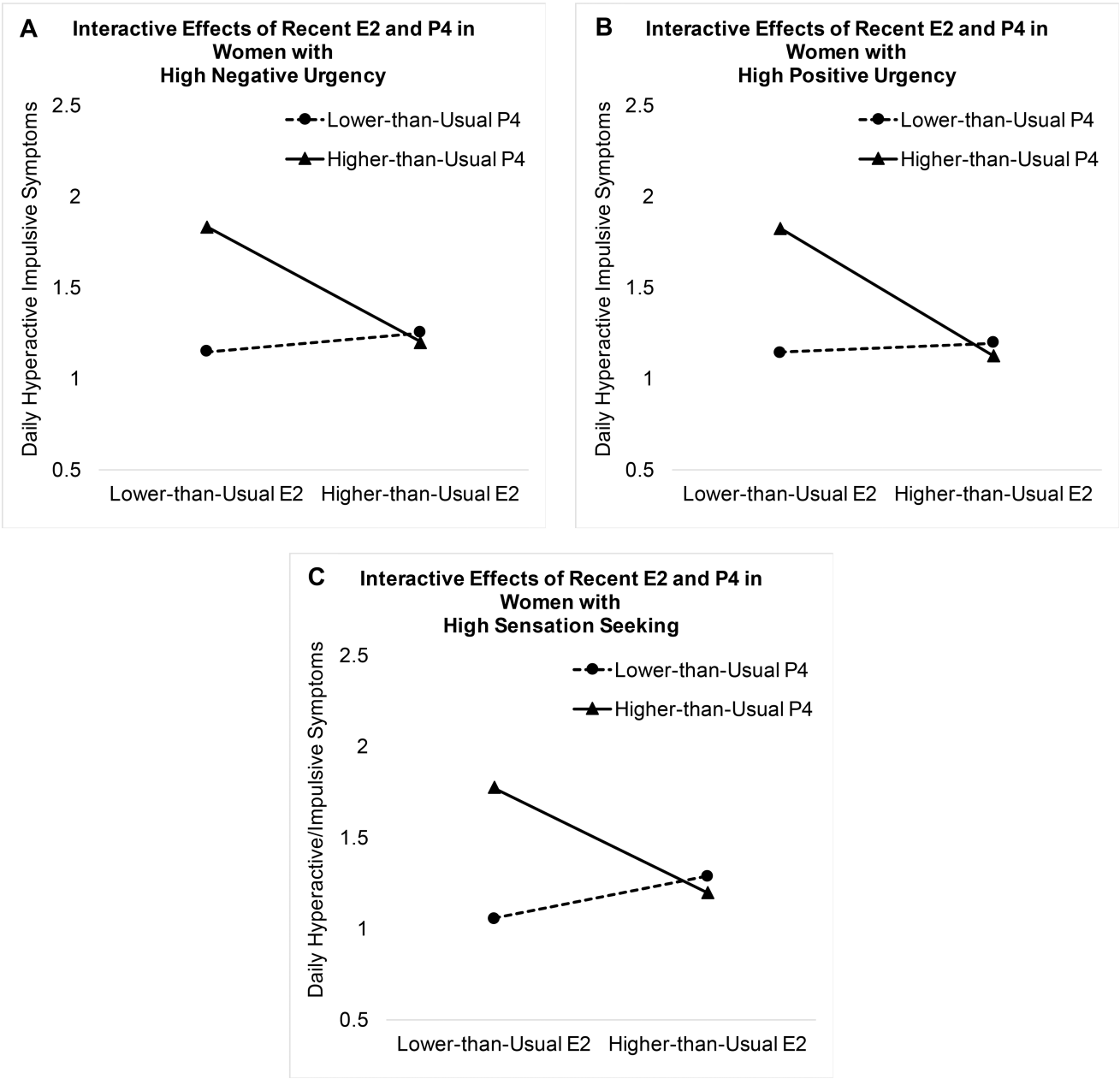


Figure 2.

Moderating Influence of Negative Urgency (A), Positive Urgency (B), and Sensation Seeking (C) on the Interactive Effect of E2 and P4 on Daily *Hyperactive/Impulsive* ADHD Symptoms.

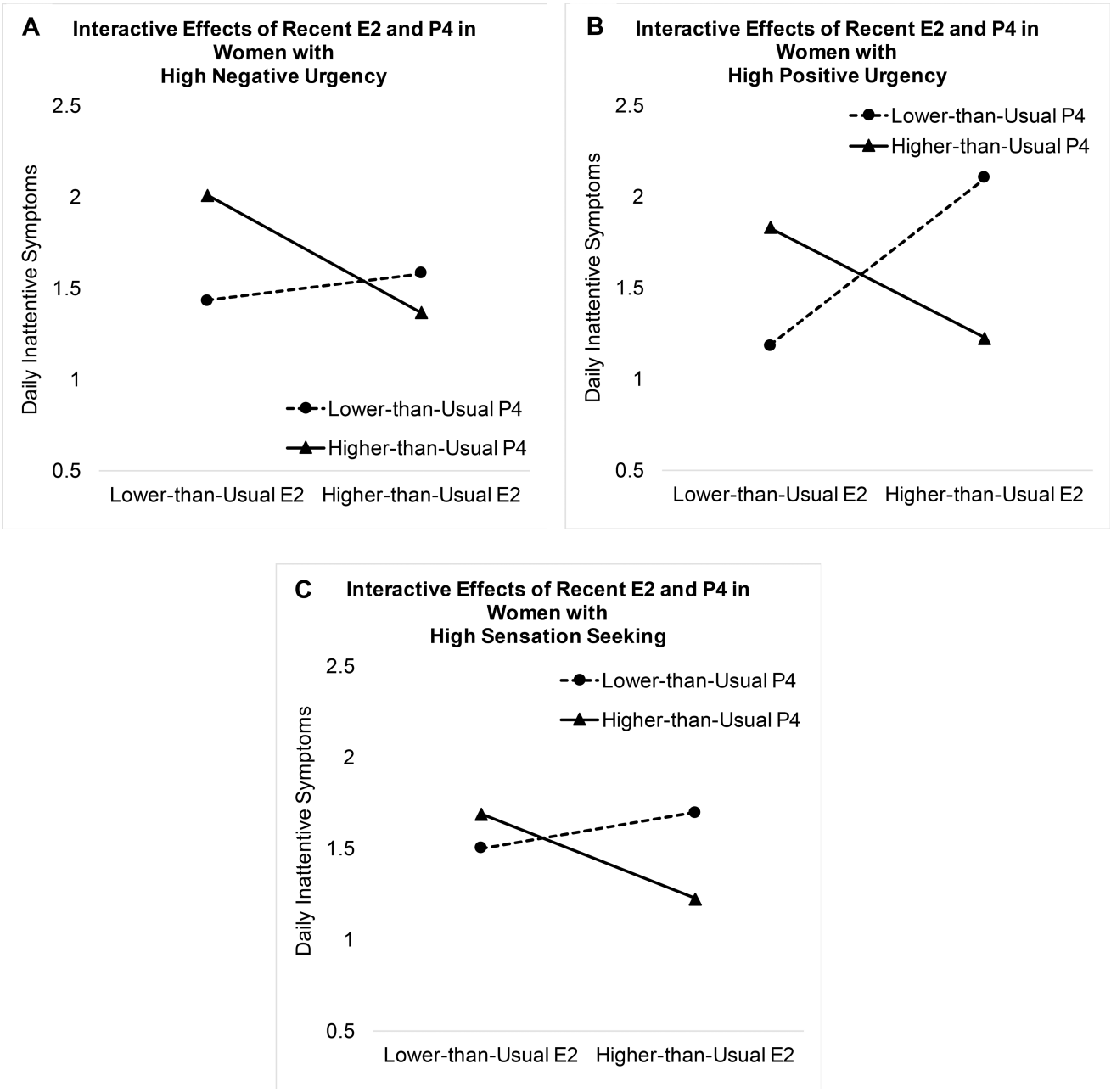
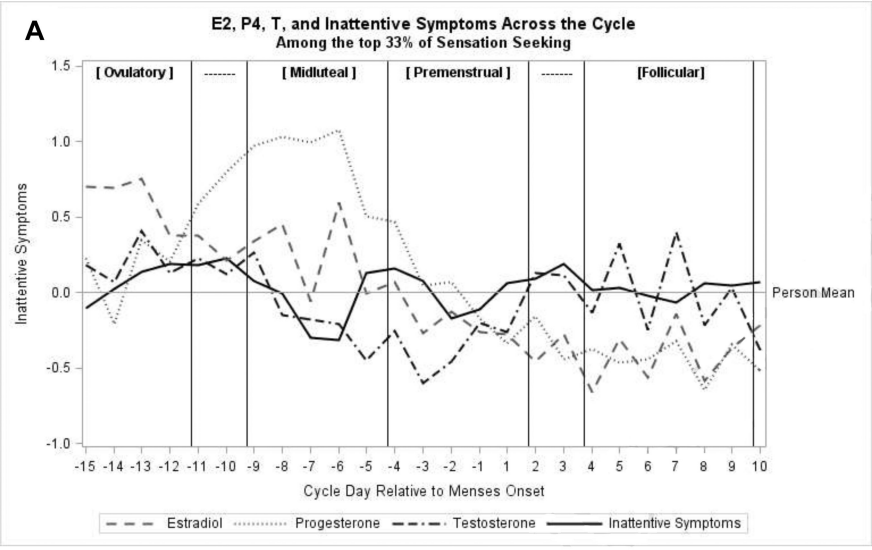
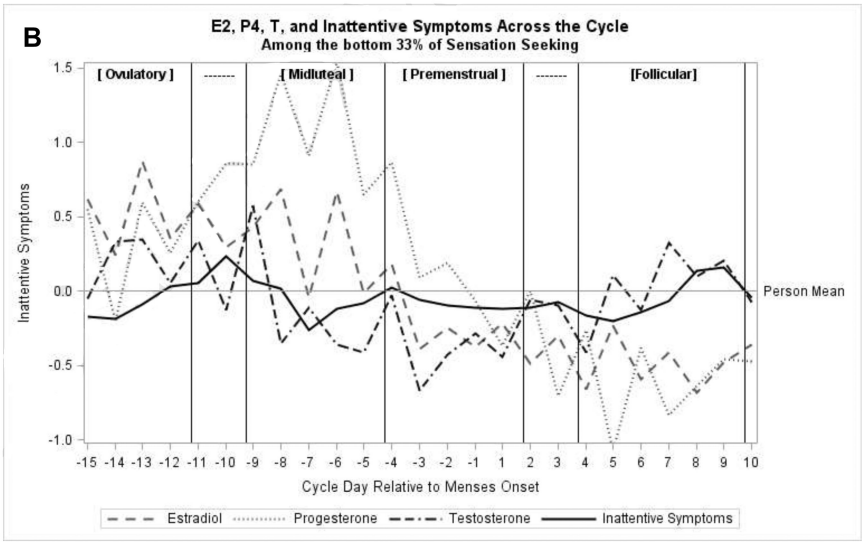


Figure 3.

Moderating Influence of Negative Urgency (A), Positive Urgency (B), and Sensation Seeking (C) on the Interactive Effect of E2 and P4 on Daily *Inattentive* ADHD Symptoms



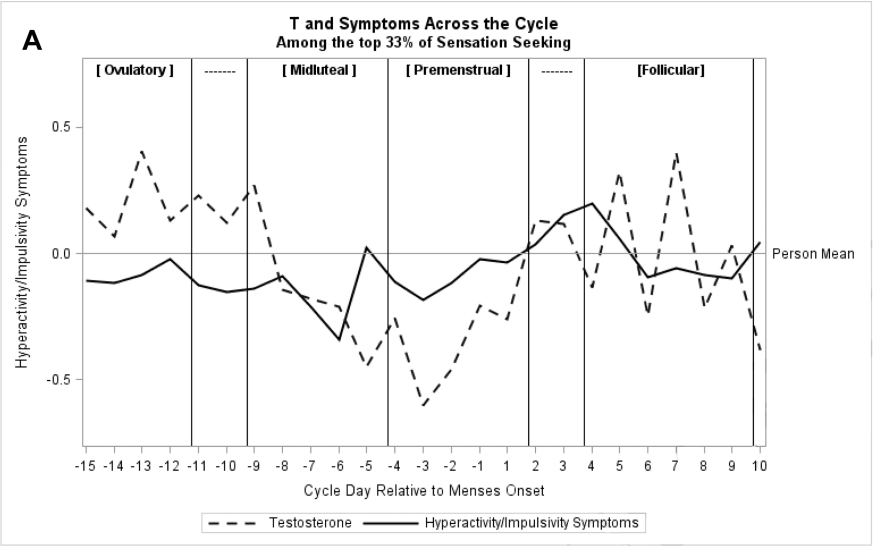
Caption: In high sensation seeking, elevated T during high E2 (post-ovulation) corresponds to greater inattention, whereas elevated T during low E2 (early follicular phase) does not. Also, elevated levels of both E2 and P4 appear protective (see days -9 to -7), whereas simultaneous E2/P4 withdrawal is associated with increased symptoms (e.g., day -5).



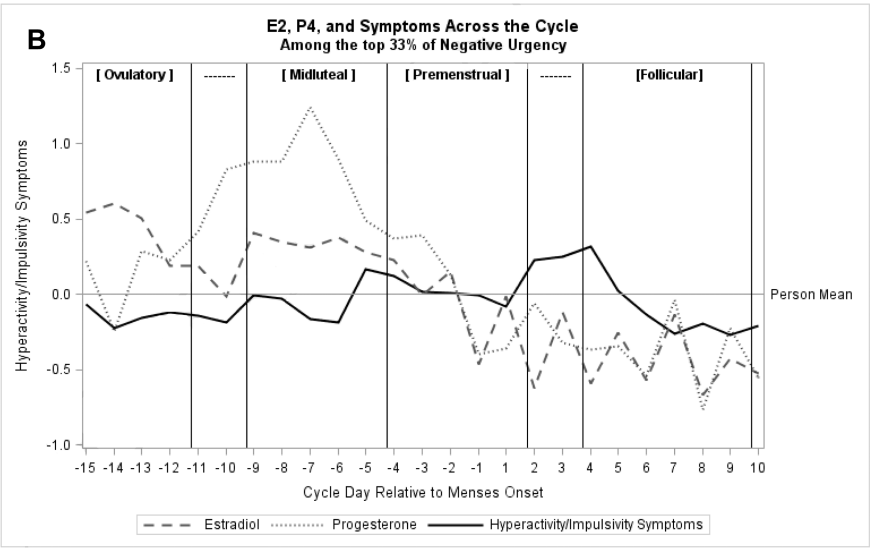
Caption: There were no associations of steroids with inattention in low sensation seeking.

Figure 4.

Means plots illustrating the interactive effects of estradiol with testosterone and progesterone in predicting inattentive symptoms across the menstrual cycle among women high (A) and low (B) in sensation seeking.



Caption: Among those high in sensation seeking, T levels correlate with greater hyperactivity/impulsivity, particularly in the follicular phase.



Caption: Among those high in negative urgency, relative elevations in P4 in the context of relatively lower E2 (in the premestrual week) are associated with greater hyperactivity/impulsivity.

Figure 5.

Smoothed means plots illustrating the effects of testosterone among women high in sensation seeking (A) and the interactive effects of estradiol with progesterone in predicting hyperactive/impulsive symptoms across the menstrual cycle among women high in negative urgency (B).

Table 1

Partial (Controlling for Age and BMI) Spearman Rank Correlations Between Average Steroids, Variance in Steroids, Impulsivity Variables, and ADHD symptoms Across Observations (N=32)

	1	2	3	4	5	6	7	8	9	10	11	12
1. Negative Urgency												
2. Positive Urgency	**.85*****											
3. Sensation Seeking	**.62*****	**.66*****										
4. Lack Premeditation	**.49****	**.59*****	**.37***									
5. Lack Perseverance	**.54****	**.51****	.11	**.67*****								
6. Testosterone Average	.04	.02	.05	−.20	−.10							
7. Estradiol Average	−.13	−.05	−.05	−.20	−.19	.22						
8. Progesterone Average	−.28	**−.43***	**−.37***	**−.42***	−.18	.11	**.55****					
9. Testosterone SD	.28	**.37***	**.42***	.07	.03	**.71*****	.30	−.02				
10. Estradiol SD	**−.30***	−.19	−.10	−.11	−.07	.12	**.45***	.17	.01			
11. Progesterone SD	**−.27***	**−.39***	**−.30***	−.25	−.07	.07	**.30***	**.87*****	.01	.12		
12. Hyp/Imp Sx Average	**.61*****	**.42***	**.50****	**.51****	**.46***	−.22	−.23	−.18	−.09	−.20	−.14	
13. Inattentive Sx Average	**.58*****	**.60*****	**.55****	**.51****	**.41***	−.22	**−.36***	**−.44***	.01	−.23	**−.39***	**.79*****

Note.

$^{*}p < .05$,

$^{**}p < .01$,

$^{***}p < .001$.

Table 2

Models Predicting Daily ADHD Symptoms Person-Standardized Recent Ovarian Steroid Levels

	Daily Outcome			
Parameter	**Hyperactive/Impulsive Symptoms**		**Inattentive Symptoms**	
	Estimate	***SE***	***Estimate***	***SE***
Intercept	0.13	0.03	0.16	0.05
BMI	0.04	0.03	0.04	0.05
E2	−0.02	0.02	0.00	0.02
P4	0.02	0.02	−0.01	0.02
T	0.00	0.02	0.02	0.02
E2 × P4	−0.01	0.02	0.00	0.02
E2 × T	−0.02	0.01	−0.01	0.02
P4 × T	0.01	0.02	0.00	0.02

Models Predicting Daily ADHD Symptoms from the Interaction of Negative Urgency and Recent Ovarian Steroid Levels

	Daily Outcome			
Parameter	**Hyperactive/Impulsive Symptoms**		**Inattentive Symptoms**	
	Estimate	***SE***	***Estimate***	***SE***
Intercept	0.12	0.03	0.17	0.04
BMI	0.00	0.03	−0.01	0.04
E2	−0.02	0.01	−0.01	0.02
P4	**0.04** **	0.01	0.00	0.02
T	−0.01	0.01	0.00	0.02
E2 × P4	**−0.03** *	0.01	**−0.05** **	0.02
E2 × T	0.00	0.01	−0.01	0.02
P4 × T	0.00	0.01	0.04	0.03
Negative Urgency (NU)	**0.10** **	0.03	**0.14** **	0.05
NU × E2	**−0.03** *	0.02	−0.01	0.02
NU × P4	**0.05** **	0.02	0.00	0.02
NU × T	0.01	0.01	0.02	0.02
NU × E2 × P4	**−0.04** *	0.01	**−0.05** *	0.02
NU × E2 × T	0.01	0.01	0.01	0.02
NU × P4 ×	0.00	0.02	0.01	0.02

Models Predicting Daily ADHD Symptoms from the Interaction of Positive Urgency and Recent Ovarian Steroid Levels

	Daily Outcome			
Parameter	**Hyperactive/Impulsive Symptoms**		**Inattentive Symptoms**	
	Estimate	***SE***	***Estimate***	***SE***
Intercept	0.13	0.03	0.18	0.04
BMI	0.02	0.03	−0.02	0.04
E2	−0.02	0.02	0.01	0.02
P4	0.02	0.02	−0.01	0.02
T	−0.00	0.02	0.00	0.02
E2 × P4	−0.01	0.02	**−0.05** **	0.02
E2 × T	−0.02	0.01	−0.02	0.02
P4 × T	0.01	0.02	0.03	0.02
Positive Urgency (PU)	**0.08** **	0.03	**0.17** ***	0.04
PU × E2	**−0.04** *	0.02	0.01	0.02
PU × P4	**0.03** *	0.02	0.00	0.02
PU × T	0.01	0.02	0.00	0.02
PU × E2 × P4	**−0.03** *	0.01	**−0.04** *	0.02
PU × E2 ×	0.01	0.02	−0.02	0.02
PU × P4 ×	0.02	0.02	0.00	0.02

Models Predicting Daily ADHD Symptoms from the Interaction of Sensation Seeking and Recent Ovarian Steroid Levels

	Daily Outcome			
Parameter	**Hyperactive/Impulsive Symptoms**		**Inattentive Symptoms**	
	Estimate	***SE***	***Estimate***	***SE***
Intercept	0.13	0.03	0.17	0.04
BMI	0.04	0.03	0.04	0.04
E2	−0.01	0.01	0.01	0.02
P4	**0.03** *	0.02	−0.01	0.02
T	−0.01	0.01	0.02	0.02
E2 × P4	**−0.03** *	0.01	**−0.05** *	0.02
E2 × T	0.00	0.01	−0.01	0.02
P4 × T	0.01	0.01	0.03	0.02
Sensation Seeking (SS)	**0.09** *	0.03	0.13	0.04
SS × E2	−0.01	0.02	−0.02	0.02
SS × P4	0.03	0.02	0.00	0.02
SS × T	**0.03** *	0.01	0.02	0.02
SS × E2 × P4	**−0.03** **	0.01	**−0.04** *	0.02
SS × E2 ×	0.00	0.01	**−0.04** *	0.02

Models Predicting Daily ADHD Symptoms from the Interaction of Sensation Seeking and Recent Ovarian Steroid Levels

	Daily Outcome			
Parameter	**Hyperactive/Impulsive Symptoms**		**Inattentive Symptoms**	
	Estimate	***SE***	***Estimate***	***SE***
SS × P4 ×	0.02	0.02	0.01	0.02

Note.

* $p < .05$,

** $p < .01$,

*** $p < .001$.

E2 = Estradiol, P4 = Progesterone. T = Testosterone.

Significant fixed effects are shown in bold.