Temperament and ovarian reproductive hormones in women: Evidence from a study during the entire menstrual cycle

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A B S T R A C T
Personality and temperament were hypothesized to function as important factors affecting life history strategies. Recent research has demonstrated the association between temperamental traits and reproduction in humans, however, the underlying mechanisms are still poorly understood. This study presents evidence for an association between temperamental traits and woman’s fecundity, as indicated by levels of ovarian steroid hormones during the menstrual cycle. On a large sample of urban, reproductive age women (n=108) we demonstrated that activity, endurance and emotional reactivity are associated with levels of estrogen and with a pattern of change of progesterone levels. Women high in activity, high in endurance and low in emotional reactivity had up to twice as high estradiol levels and more favorable progesterone profiles as women low in activity, low in endurance and high in emotional reactivity. The temperamental traits we measured highly overlap with extraversion, neuroticism and negative emotionality that were reported to correlate with reproductive success. Our findings thus suggest a possible explanation for these relationships, linking personality and women’s reproductive success through a hormonal pathway.

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Introduction

Recent advances in behavioral ecology suggest that personality is associated with life history strategies (Biro and Stamps, 2008; Nettle, 2006). Among others, personality and temperamental traits were demonstrated to predict characteristics directly related to reproductive success in men and women (Alvergne et al., 2010a; Jokela et al., 2009, 2010, 2011). Extraversion and sociability were shown to positively correlate with marital status, number of mates, age at birth of first or second child and total number of children, while neuroticism and emotionality were shown to correlate negatively with most of those characteristics (Jokela et al., 2009, 2010, 2011 but see Alvergne et al., 2010a). The same traits were also indicated as important mate choice criteria, with higher extraversion and sociability increasing while higher neuroticism decreasing the chances of being chosen as a mate (Buss et al., 1990; Figueredo et al., 2006; Simpson and Gangestad, 1992).

Most explanations of these findings refer to social and behavioral characteristics of personality trait beholders (Alvergne et al., 2010a; Jokela et al., 2009). However, variation in reproductive success among individuals that differ in personality or temperament might be also explained via pathways other than behavioral or social, especially for women. Success of conception, pregnancy and childbearing is largely explained by the relationship between these characteristics and women’s fecundity.

Although relationships between temperament and fecundity have been demonstrated in animal studies (Blache and Bickell, 2011; von Borell et al., 2007) and studies on human males (Alvergne et al., 2010b;
To explore the relation between ovarian function and temperament, we rely on Strelau’s Regulative Theory of Temperament (RTT) (Strelau, 1995, 2008). This biologically based, functional theory posulates that temperament should be understood as a constellation of energetic and temporal characteristics of behavior which help individuals in adapting to the environment (Strelau, 1996). Apart from being explicit about the function of temperament, RTT is also to some extent explicit about the physiological mechanisms underlying temperament. It proposes that differences in temperamental traits between individuals result from their specific level of reactivity to environmental stimulation, which is in turn determined by ‘neuro-hormonal individuality’ (Strelau, 1996), a specific configuration of biochemical and neurophysiological mechanisms.

Given these assumptions, we asked whether individual differences in temperament among women are associated with intra-individual variation in their ovarian hormone levels. We also argued that the observed relationship between reproductive success and personality and temperamental traits might be based on the relationship between these traits and women’s fecundity. As neuroticism and extraversion had been demonstrated to predict reproductive success in women (Alvergne et al., 2010a, 2010b; Jokela et al., 2010), we hypothesized that temperamental traits correlated with these characteristics should be related to ovarian steroid levels.

Materials and methods

Study group

One hundred and fourteen women of reproductive age (M = 29.5, SD = 3.57) from the city of Wrocław, South-Western Poland took part in the study. Women were recruited from the general city population by newspaper and television advertisement published early in the spring 2008 and 2009. They were included in the sample based on the following criteria: regular menstrual cycles from 24 to 36 days, not being pregnant or lactating for at least 3 months prior to the study, not using hormonal contraceptives, having good health, and in particular, not being diagnosed with any reproductive or endocrinological diseases. Participants collected daily, first morning urine samples for one entire menstrual cycle and filled in the temperament questionnaire. Urine samples were collected to plastic vials delivered together with the set of questionnaires. Immediately after taking, samples were marked with name and collection date, closed and stored in subjects’ home freezers set to the lowest possible temperature until the end of the sampling period. After the end of the sampling period (last day of the menstrual cycle), research assistants collected samples from participants’ homes and transported them on ice to the laboratory for analysis.

Anthropometrical measurements of body height, weight, fat content and waist, hips, breasts and under-breast circumferences were also taken. Additionally, once during the study period women completed a general questionnaire collecting information about their reproductive history, education, employment, marital status, number of children, smoking and alcohol drinking, and temperamental questionnaire. Each woman gave written consent for the participation in the project. Study protocol was approved by the appropriate committee of the Ministry of Science and Higher Education.

Temperament assessment

Temperament was assessed with the Formal Characteristics of Behavior — Temperament Inventory (FCB-TI) (Strelau and Zawadzki, 1995). This questionnaire measures six temperamental traits postulated by the Regulative Theory of Temperament: Briskness (BR), Perseveration (PE), Sensory Sensitivity (SS), Emotional Reactivity (ER), Activity (AC) and Endurance (EN). Although less in use than the popular NEO-FFI (Costa and McCrea, 1992) the FCB-TI is a highly reliable method of temperament assessment. Details for FCB-TI are presented in Supplementary materials.

Scores for the six temperamental traits were calculated following published procedure (Zawadzki and Strelau, 1995). Furthermore, participants’ constellations of temperamental traits were assessed (Strelau, 2008; Zawadzki and Strelau, 1995) based on the scores of three traits describing energetic aspect of behavior: EN, AC and ER. Scores for these traits describe the ability of a person to process environmental stimulation. High ability to process stimulation individuals (HAPS) are those characterized by above median value of EN and AC and below median value of ER. Low ability to process stimulation individuals (LAPS) are those characterized by below median value of EN and AC and above median value of ER. Based on these three traits, there are eight possible groupings described in the literature (Strelau, 2008; Zawadzki and Strelau, 1995). The validity of identifying such trait configurations and, specifically, focusing on these two groups has been confirmed in empirical studies on temperament and response to stress. In these studies, out of the eight possible groupings, LAPS exhibited the highest reactivity and HAPS exhibited the lowest reactivity to chronic and traumatic stress, as evidenced by symptoms of job burnout and post-traumatic stress disorder (Strelau, 2008). Thus, the LAPS and HAPS groups represent the extremes of the continuum of reactivity to environmental stimulation. Based on the relations between traits postulated by RTT and Big Five models of personality, these two groups, LAPS and HAPS, would correspond, respectively to neurotic-introverted vs. emotionally stable-extraverted individuals in Big Five terminology (Strelau, 2008; Strelau and Zawadzki, 1995). Applying the above mentioned criteria resulted in 26 women identified as LAPS and 26 women identified as HAPS.

Hormonal analysis and data preparation

The urinary concentration of estrone glucuronide (E1G) and pregnanediol glucuronide (PdG) were analyzed using commercially available competitive enzyme immunoassay kits from Immunometric Ltd. (London, UK) with protocol of analysis as described by the producer. The Estrone-3-Glucuronide EIA used an anti-Estrone-3-Glucuronide rabbit antibody and alkaline phosphatase labeled Estrone-3-Glucuronide. Pregnanediol-3α-Glucuronide EIA used an anti-Pregnanediol-3α-Glucuronide rabbit antibody and alkaline phosphatase labeled Pregnanediol-3α-Glucuronide. Intra- and interassay coefficients of variation were less than 8% for all assays. Eighteen daily samples for follicular and luteal E1G concentrations and fourteen daily samples for luteal PdG concentrations were analyzed for each women menstrual cycle.

E1G and PdG daily values data were corrected for differences in urine concentration using method by Miro et al. (2004). Missing E1G and PdG daily values were replaced using smooth cubic splines (Brumback and Rice, 1998). This routine was performed only in cases where the number of missing daily values was less than three in a sequence. There was only one subject in the described sample for whom this condition was not fulfilled and this subject was removed from analyses.

Cycles were assigned as ovulatory when PdG daily values were at least three times higher when compared to the baseline and this increase in concentrations persisted for at least three days (Kassam et al., 1996). The day of ovulation was inferred from changes in E1G to PdG ratio during the cycle using the day of luteal transition algorithm (DLT). (Baird et al., 1991) with modification for low concentrations of PdG (Wall et al., 1998). Based on these methods, cycles of 108 out of 114 women were assigned as “ovulatory” and for those cycles the day of ovulation was estimated. Further, menstrual cycles were aligned on the estimated day of ovulation which was designated as “day 0”. For E1G, days of follicular phase were given negative numbers and days of luteal phase positive numbers. The following indices of ovarian activity were calculated: E1G cycle (mean E1G for days from-9 to 8), E1G...
folicular (mean E1G for days from −9 to −1), E1G luteal (mean E1G for days from 0 to 8), E1G midcycle (mean E1G for days from −2 to 2). For PdG, last fourteen daily values were taken as the index of luteal phase. In contrast, no significant correlations were found for any of the temperamental traits and mean levels of PdG (Table 1).

Results

We found positive correlations between the levels of E1G during the menstrual cycle and the temperamental traits of endurance and activity, and a negative correlation between emotional reactivity and the levels of E1G during the luteal phase. In contrast, no significant correlations were found for any of the temperamental traits and mean levels of PdG (Table 1). Results of regression analysis where body fat was entered as an independent predictor to the model, in addition to the temperamental traits (Table 2). After entering body fat, endurance remained significantly positively related to the average E1G levels during the whole cycle ($\beta = 0.18, p < 0.05$) and during the luteal phase ($\beta = 0.19, p < 0.05$). Activity was significantly positively related to the average levels of E1G during the whole cycle ($\beta = 0.213, p < 0.05$), the midcycle ($\beta = 0.20, p < 0.05$), follicular phase ($\beta = 0.20, p < 0.05$) and luteal phase ($\beta = 0.21, p < 0.05$). All other tested relationships were statistically non-significant. Additional evidence for the association between temperament and ovarian hormone levels comes from the comparisons between groups of women characterized by low and high ability to process stimulation. HAPS women had significantly higher levels of E1G during the whole cycle ($t(50) = -2.38, p < 0.05$), the midcycle ($t(50) = -2.28, p < 0.05$), follicular phase ($t(50) = -2.04, p < 0.05$) and luteal phase ($t(50) = -2.01, p < 0.05$).

Table 1

<table>
<thead>
<tr>
<th>N = 108</th>
<th>In E1G cycle</th>
<th>In E1G follicular</th>
<th>In E1G luteal</th>
<th>In E1G midcycle</th>
<th>PdG cycle</th>
<th>PdG luteal</th>
<th>PdG midluteal</th>
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<td>β</td>
<td>R²</td>
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<td>β</td>
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<tr>
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<tr>
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<tr>
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<tr>
<td>Activity</td>
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E1G = estrone glucuronide, PdG = pregnanediol glucuronide.

*p < 0.05.

**p < 0.01.

Statistical analysis

Natural logarithms were calculated for single values and mean indices of E1G during the cycle to assure normality of the distributions where necessary. Relationships between temperamental traits and ovarian metabolites were assessed using correlation analysis (Pearson correlation for AC, ER and Spearman correlation for BR, PE, SS and EN) and linear regression models with body fat percentage as the additional independent factor, as it was found to have a negative influence on levels of E1G.

Independent samples t-tests were used to assess the differences in mean levels of E1G and PdG during the cycle between LAPS and HAPS women. Additionally, independent samples t-tests were used to assess the differences in mean levels of E1G and PdG during the cycle to assure normality of the distributions where necessary. Relationships between temperamental traits and ovarian metabolites were assessed using correlation analysis (Pearson correlation for AC, ER and Spearman correlation for BR, PE, SS and EN) and linear regression models with body fat percentage as the additional independent factor, as it was found to have a negative influence on levels of E1G.

Results of regression analysis where body fat was entered as an independent predictor to the model, in addition to the temperamental traits (Table 2). After entering body fat, endurance remained significantly positively related to the average E1G levels during the whole cycle ($\beta = 0.18, p < 0.05$) and during the luteal phase ($\beta = 0.19, p < 0.05$). Activity was significantly positively related to the average levels of E1G during the whole cycle ($\beta = 0.213, p < 0.05$), the midcycle ($\beta = 0.20, p < 0.05$), follicular phase ($\beta = 0.20, p < 0.05$) and luteal phase ($\beta = 0.21, p < 0.05$). All other tested relationships were statistically non-significant. Additional evidence for the association between temperament and ovarian hormone levels comes from the comparisons between groups of women characterized by low and high ability to process stimulation. HAPS women had significantly higher levels of E1G during the whole cycle ($t(50) = -2.38, p < 0.05$), the midcycle ($t(50) = -2.28, p < 0.05$), follicular phase ($t(50) = -2.04, p < 0.05$) and luteal phase ($t(50) = -2.01, p < 0.05$). This difference remained significant after adjusting for body fat percentage in the analysis of covariance (for the average levels of E1G during the whole cycle, $F_{1,51} = 5.05, p < 0.05$, the midcycle, $F_{1,51} = 4.55, p < 0.05$, and the luteal phase $F_{1,51} = 6.28, p < 0.02$) (Table 3). The LAPS and HAPS groups did not differ significantly with respect to any of the measured anthropometric, demographic or life-style factors such as age, age of menarche, height, weight or physical activity.

In addition, a comparison of the E1G menstrual profiles by a mixed model analysis of variance showed significantly higher levels of E1G in HAPS women when compared to LAPS women (main effect of temperamental group: $F_{1,51} = 5.06, p < 0.05$). In terms of untransformed values of E1G, HAPS women had up to twice as high levels of E1G during the cycle as LAPS women (Fig. 1A). The same analysis for PdG profiles in the luteal phase revealed an interaction effect of temperamental group and day of luteal phase ($F_{1,367} = 3.21, p < 0.05$), which was approximated by a quadratic trend, as indicated by a within-subjects contrast
Nepomnaschy et al. (2004). They both point to the possibility that mones, while in our results this association is clearly present.

However, it should be noted that Netter and colleagues did not demonstrate a direct link between personality traits and ovarian hormones. As high midluteal PdG concentrations are crucial for implantation (Wilcox et al., 1999), maintaining lower levels of midluteal PdG may be one way of preventing pregnancy in unfavorable psychosocial contexts.

Other confirmative evidence comes from studies on the genetic basis of temperament and personality. Firstly, it was demonstrated that personality traits depend on polymorphisms in genes for estrogen receptors and estrogen metabolism. In particular, neuroticism was related to a single nucleotide polymorphism or a dinucleotide repeated polymorphism in estrogen receptor 1 gene (ESR-1) (Miller et al., 2010). Women with higher neuroticism had at least one recessive allele in different loci of the ESR1 gene. The same polymorphism is related to the levels of estradiol during the menstrual cycle (Sowers et al., 2006), suggesting that lower level of estradiol is associated with higher neuroticism. Secondly, polymorphisms in genes CYP17 and CYP2C19, regulating activity of cytochrome P450, were found to be associated with several personality traits in Japanese women (Ishii et al., 2007). Cytochrome P450 is responsible for metabolizing testosterone, estradiol and progesterone. Several studies, including our own (Haiman et al., 2007; Jasienska et al., 2006a; Small et al., 2005), show that polymorphism in CYP17 and CYP19 is related to the levels of estradiol in women.

Thirdly, relevant evidence includes studies linking temperamental and personality traits with polymorphism in the 5-HTT serotonin transporter gene (Sen et al., 2004) and 5-HT2A serotonin receptor binding (Frokjaer et al., 2008), Dragun and Oniszczzenko (2006) for instance, reported a relationship between polymorphism in 5-HTT and temperamental traits of endurance and activity assessed with FCB-TI in Polish women. Women who had at least one recessive allele of the serotonin transporter gene scored significantly higher on endurance and activity than women with both dominant alleles of this gene. Frokjaer et al. (2008) demonstrated positive association between neuroticism and 5-HT2A receptor binding in frontolimbic region of the human brain.

Serotonergic system is highly and positively influenced by ovari-an reproductive hormones (Lasiuk and Hegadoren, 2007). Studies demonstrated that estradiol can increase synthesis and decrease metabolism of serotonin in human brain (Osterlund, 2010). Moreover it down-regulates pre- and postsynaptic 5-HT1A receptors and up-regulates postsynaptic 5-HT2A receptors (Osterlund, 2010). Together with the aforementioned evidence on the relationship between serotonergic system and temperament and personality this constitutes a viable explanation for the results observed in our study.

Given the correlational nature of our study, it is possible that the observed association between temperament and ovarian hormones might be explained by other, mediating factors. Indeed, animal studies point to the possibility that nutritional status and energy balance might influence this association. In particular, it was demonstrated that temperamental traits (boldness, activity, aggressiveness) were positively related to food intake and, in consequence, to nutritional status in animals (for review see Biro and Stamps, 2008). Nutritional status and energy balance were also found to influence ovarian steroid hormones in humans (Jasienska et al., 2006a, 2006b, 2006c; Ziomkiewicz et al., 2008). In the present study, we controlled nutritional status by measuring body fat content. Body fat was also included as a covariate in all analyses assessing the differences between temperamental groups with respect to ovarian steroid levels. Results of these analyses excluded the possibility that the association between temperament and reproductive hormone levels is mediated by body fat. However, less evident differences between the temperamental groups, e.g. in energy balance, might still contribute to the observed association.

Our findings shed light on the possible hormonal basis of the recently demonstrated relationship between personality traits and reproductive success in women. Studies by Jokela et al. (2009, 2011) in two industrial populations (contemporary Finns and Americans) showed a negative effect of emotionalism and neuroticism, and a positive effect of extraversion on the probability of having children and on completed fertility in
women. Although we did not measure emotionality (Russ and Plomin, 1984), neuroticism or extraversion (Costa and McCrea, 1992), the traits we assessed are closely related to these characteristics. In particular, Activity and Extraversion correlate positively (r = 0.63), Emotional Reactivity and Neuroticism also correlate positively (r = 0.66) and Endurance and Neuroticism correlate negatively (r = −0.52) (Strelau and Zawadzki, 1995; for other relevant correlations see Supplementary material). High correlations between these traits allow us to infer the possible hormonal link between personality traits measured by Jokela et al. (2009, 2011) and reproductive success in women. Lower activity and lower endurance (associated with higher neuroticism and lower extraversion) was in our sample related to lower levels of estradiol during the cycle and less favorable profiles of progesterone. In contrast, higher activity and higher endurance (associated with higher extraversion and lower neuroticism) was related to higher levels of ovarian hormones favoring conception and implantation. In both cases the strongest effect was observed when these traits were taken together with emotional reactivity.

Our results suggest that high extraversion and low neuroticism in women can both be related to higher reproductive success via higher potential fertility indicated by high levels of reproductive hormones.

Maintaining high levels of ovarian hormones is costly and can be advertised in morphological traits as a signal of good biological quality, as was demonstrated by us (Jasienska et al., 2004, 2006b.) and others (Law Smith et al. 2006). The present study shows that ovarian hormone levels are also associated with behavioral characteristics, commonly assessed as temperament.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at doi: 10.1016/j.yhbeh.2012.01.017.

References


