Physiology & Behavior 123 (2014) 119–126

Contents lists available at ScienceDirect

Physiology & Behavior

journal homepage: www.elsevier.com/locate/phb

The type of implicit motive enactment is modulated by sex hormones in naturally cycling women

Anna Ball *,[a], Claudia C. Wolf [a], Sebastian Ocklenburg [a], Martin Brüne [b], Oliver T. Wolf [c], Onur Güntürkün [a], Marlies Pinnow [a]

[a] Institute of Cognitive Neuroscience, Biopsychology Department, Faculty of Psychology, Ruhr-University Bochum, Germany
[b] Psychiatry, Psychotherapy, Psychosomatics and Preventive Medicine Department, LWL University Hospital of the Ruhr-University Bochum, Germany
[c] Cognitive Psychology Department, Faculty of Psychology, Ruhr-University Bochum, Germany

HIGHLIGHTS

- We tested the association between menstrual cycle phase and implicit motives as measured with the OMT.
- Effects were only observed in the form of motive enactment, not in basic motive levels.
- The incentive-based inhibition of the power motive was significantly reduced at the time of ovulation.
- The results indicate a specific hormone effect on behavioral inhibition.

ARTICLE INFO

Article history:
Received 13 November 2012
Received in revised form 11 September 2013
Accepted 26 September 2013
Available online 7 October 2013

Keywords:
Menstrual cycle
Implicit motives
Operant motive test (OMT)

ABSTRACT

Sex hormones have been reported to dynamically modulate the expression of implicit motives, a concept that has previously been thought to be relatively stable over time. This study investigates to what extent the need for affiliation, power, and achievement, as well as the form of enactment of these needs as measured with the Operant Motive Test (OMT), is affected by cycle-phase dependent sex hormone fluctuations. In addition to measuring the strength of motive expression, the OMT also captures different forms of motive enactment. In an intra-subject design with repeated measures, no evidence for cycle-phase related variation in overall motive scores was found. However, when different forms of motive enactment were considered, an effect of menstrual cycle was observed. The incentive-based inhibition of the power motive was significantly reduced at the time of ovulation, compared to the menstrual and to the mid-luteal phase, in naturally cycling women. In women with relatively stable hormone concentrations (due to using hormonal contraceptives), no significant changes in the form of motive enactment were evident. The results indicate a specific hormonal influence on motive-related cognitive processes that are related to inhibitive processes in behavior control.

1. Introduction

To a large extent, human behavior is accomplished outside of conscious awareness. Building on the pioneering work of Atkinson [2], motivational psychology claims that the behavioral output is mainly influenced by two distinct entities: One comprises momentary situational cues, including both internal states like hunger or fatigue, and social contexts. The other encompasses enduring personal preferences for affectively charged incentives. The latter are considered as the basis of implicit motives, a network of experiential knowledge acquired during early, partly preverbal childhood [27]. From the 1940s onwards, researchers have investigated implicit motive systems and developed diverse approaches to empirically measure inter-individual differences in motive characteristics [29,37,42]. The prevailing measurement techniques are based upon content analysis of written reports in response to motive-arousing picture cues. These are based on the rationale that when a need is activated, a particular configuration of the mental apparatus is aroused that supports need-specific cognition and behavior [16]. High levels of motive-related contents recorded under neutral conditions, that is, in the absence of experimentally induced motivational arousal, are considered as chronically aroused needs [26]. According to this view, there are large inter-individual differences in the extent to which people associate positive feelings with the striving and realization of three basic motives: The affiliation motive (e.g., the need for secure and harmonious relationships with others), the power motive (e.g., the need to have impact on others), and the achievement motive (e.g., the need to accomplish and to be good at what one is doing) (for an overview, see [39]).

* Corresponding author at: Department of Biopsychology, Faculty of Psychology, Ruhr-University Bochum, D-44780 Bochum, Germany. Tel.: +49 234 32 26804; fax: +49 234 32 14377.
E-mail address: anna.ball@rub.de (A. Ball).

0031-9384/$ – see front matter © 2013 Elsevier Inc. All rights reserved.
http://dx.doi.org/10.1016/j.physbeh.2013.09.016

The emphasis on the rewarding nature of goal attainment, and on the role of positive and negative affective states in behavior control, suggests a significant neurobiological involvement in motivational processes. In particular, sex hormonal effects on behavior control are well established and can best be demonstrated whenever significant changes in sex hormone concentrations occur (e.g., during puberty, pregnancy, post-partum, or during menopause). Rapid de- or increases in sex hormone levels, even the comparably small hormone fluctuations in the course of the menstrual cycle, have repeatedly been shown to affect mood [19,28,34]. Although the interindividual variability in the degree to which women experience affective changes across the menstrual cycle seems to be large, the pharmacological effects of reproductive hormones are well established. While high doses of progesterone are generally associated with beneficial effects on mood, such as sedation and anxiolysis [1], additional high doses of estradiol (that is, a progestogen–estrogen combination) commonly lead to increased tension, irritability, and depressed mood [7,13]. However, these effects seem to depend on the dose of pharmacological hormones, as well as on individual differences in response to these steroids [17]. Further evidence exists about hormonal influence on other motivation-modulated processes, like executive functions [6], memory functions, in particular with regard to social cues [18,25,31,44,45], and the general neural reactivity to emotional stimuli, regardless of the valence of the stimuli [32]. Inter alia, the finding of characteristic sex differences in the expression of the three basic motives, with women displaying on average stronger affiliation motives than men, and men displaying on average stronger power motives than women [30,38], has fostered the notion that sex hormones play a role in the formation and enactment of implicit motives. Consequently, effects of sex hormones on the strength of implicit motives have been investigated. Schultheiss et al. [40] reported elevated levels of affiliation motivation, and decreased levels of power motivation in women at the time of ovulation. Across three different cycle-phases, the authors found positive correlations between the power motive and testosterone levels in men, and estradiol in women, accordingly. Estradiol has also been linked with attachment and caregiving behavior in both women [12] and men [5], and estradiol is positively associated with intimacy motivation [11]. Furthermore, Schultheiss et al. [41] provided evidence that there is a bi-directional relation between hormone levels and motive scores: when the affiliation motive was experimentally aroused, increases in progesterone levels were observed.

Studies depicting motive-hormone associations have hitherto relied on classical content coding measurement techniques, such as the thematic apperception test (TAT; [29]) or the Picture Story Exercise (PSE; [42]). However, these instruments neither assess the affective content, nor the degree to which pre-conceptual motives are connected with self-regulatory functions (e.g., self-determined versus more incentive-focused forms of motivation). A more recent method that considers functional properties of positive and negative affect is the Operant Motive Test (OMT) developed by Kuhl and Scheffer [21]. This approach claims to extend the TAT by including an assessment of the extent to which motives are integrated in self-referential representations [4]. It is based on the Personality Systems Interaction (PSI) theory, according to which positive and negative affect play an important role in activating and inhibiting motivational states and the degree of self-regulated versus incentive-based motive enactment (for a more detailed introduction, see [4,23]). According to PSI theory, behavioral adaptation to situational demands depends on both behavioral activation and inhibition. This is reflected in the construction of the OMT, in that the scoring key considers not only the three basic motives affiliation, power, and achievement (e.g., what a person is striving for), but also the five levels of interaction between motives and volitional functions (e.g., how a person is striving to meet his or her goals) [4]. The construction of OMT- levels reflecting different types of motive enactment is informed by theoretical considerations about the integration of self-regulatory processes into motivation psychology [20]. For each motive, the OMT-levels of motive enactment differentiate between four motive approach components and one motive avoidance component (i.e., hope for motive satisfaction versus fear of motive frustration). The four approaching components result from the combination of two affective sources of motivation (positive versus negative affect) and self-determined versus incentive-based forms of motivation [4]. Furthermore, the conceptualization allows for a distinction between motivational states that facilitate spontaneous behavior (OMT-level 2 and 4), and those that reflect stronger behavioral inhibition (OMT-level 1 and 3; see Table 1). Similar to other measures of implicit motives, participants are presented with ambiguous line drawings with one or more persons (Fig. 1) that have been shown to be interpreted as affiliation-, power-, or achievement-related [35].

Although the notion of hormone/mood/behavior interactions is generally accepted and considered as a promising route of investigation, research linking human natural hormone levels to motivational processes is still relatively rare. The present study set out to explore for the first time the relationship between sex hormones that fluctuate across the menstrual cycle in young women (progesterone, estradiol, testosterone, luteinizing hormone (LH) and follicle stimulating hormone (FSH)), and the different basic motive's forms of enactment as measured with the OMT. On the basis of previous findings, a positive association between progesterone and estradiol levels and the overall affiliation motive, and a negative association between these hormones and power motive scores were predicted. Accordingly, affiliation motivation was expected to be stronger expressed and power motivation was expected to be less strongly expressed in high-hormone phases of the menstrual cycle (preovulatory phase at mid-cycle, mid-luteal phase) than in a low-hormone phase (menstrual phase). By contrast, no fluctuations in motive scores were expected to be found in women with stable hormone levels due to hormonal contraceptive use. Furthermore, also the achievement motive was included in the analysis to explore potential associations between hormone fluctuations and different achievement OMT-levels. High levels of progesterone have been associated with increased behavioral inhibition [1], whereas high levels of estradiol have been observed to impair behavioral inhibition in a STROOP-paradigm [10]. As mentioned above, there are two OMT-levels that reflect the motivational basis for facilitated behavioral activation (OMT-levels 2 and 4). Therefore, we expected OMT-levels 2 and 4 to be positively associated with high levels of estradiol (during the preovulatory phase). The inhibiting neuromodulatory properties of the combined progesterone/estradiol effect in the mid-luteal phase were expected to be negatively associated with OMT-level 2 and 4 scorings.

2. Methods

2.1. Participants and design

Two groups of participants were examined: Group 1 consisted of 33 women who reported to have regular menstrual cycles ranging from 26 to 30 days, and that they had not experienced any kind of hormonal intervention for at least six months prior to testing. Group 2, which functioned as a control condition, consisted of 33 women who reported having used a vaginal ring (Nuva®Ring) as a hormonal contraceptive for at least six months prior to testing. This prescription drug delivers an average of 0.12 mg etonogestrel and 0.015 mg ethinyl estradiol per day over a three-week period of use [33]. All participants had a German university-entrance diploma, and verbal intelligence quotients above 80 as measured with the Mehrfachwahl Wortschatz Intelligenztest (MWT), a standard German intelligence test [24]. In addition to this, all subjects were neurologically and psychologically healthy, as indicated by t-values < 60 in the positive symptom distress index from the Symptom Check List-90-Revised. We asked all participants to state their current relationship status (no partner or in a relationship for less than six months, or in a relationship for more than six months).

Table 1
Illustration of the OMT's coding system.

Form of enactment	Motive		
	Affiliation	Achievement	Power
Level 1: PA (self-regulated)	Intimacy, affective sharing	Flow	Guidance
Level 2: PA (incentive- based)	Sociability	Inner standards	Status
Level 3: NA (self-regulated)	Coping with rejection	Coping with failure	Coping with power-related threat
Level 4: NA (incentive-based)	Avoiding insecurity	Pressure to achieve	Inhibited power and/or inhibited dominance
Level 5: low PA and high NA (passive fear, rumination)	Dependence	Failure	Powerlessness

PA = positive affect: NA = negative affect. Table adapted from [4].

Each woman was invited to three testing sessions. For participants in group 1, these sessions were scheduled in such a way that one session took place during naturally cycling women's menses (cycle days 2–5) when all sex hormones were expected to have low concentrations. Another session was scheduled to capture the preovulatory estradiol surge, and eventually the characteristic LH-peak (cycle days 11–15, corrected for individual cycle-length). A third session took place in the mid-luteal phase between cycle days 19 and 23 (also corrected for individual cycle-length), when progesterone levels were expected to be highest and estradiol levels were expected to have a second peak. The definition of these three cycle phases was based on reference values for the involved sex hormones reported by Stricker et al. [43], and allowed for the evaluation of estradiol effects (preovulatory) separated from the combined estradiol/progesterone effect (mid-luteally). Testing dates were calculated in a similar way for participants in group 2, but with the day of applying a new vaginal ring as day 1 of the (ring-) cycle. One third of participants entered the testing series while being in the menstrual phase (or at the beginning of a Nuva®Ring cycle), one third entered while in the preovulatory phase (or in the middle of a Nuva®Ring cycle), and one third entered testing while in the mid-luteal phase (or at the end of a Nuva®Ring cycle). Time of day was held constant (either 9 a.m. or 1 p.m., respectively) across all test sessions for each participant to minimize the effects of circadian variability in hormone releases.

Anonymity was guaranteed at all times. The study protocol was approved by the ethics committee of Ruhr-University Bochum, and all subjects gave written, informed consent before participation. They were reimbursed for participation after every test session.

2.2. The Operant Multi-Motive Test

Implicit motives were assessed with the seven-picture short version of the OMT. The main difference between the OMT and standard methods like the TAT and the PSE exist in the response format. While participants are required to write full short stories in the TAT and PSE, they are instructed to think of a short story and to select one person in each picture as the protagonist, but to write down only keynotes to the following questions: (1) What is important for the person in this situation and what is the person doing? (2) How does the person feel? (3) Why does the person feel this way? (4) How does the story end? in the OMT. Participants were instructed to write down their first association and spontaneous answers to the four questions, no matter if they had thought about the same story at the last session(s) or came up with a new story. The authors claim that this alteration of the response format reduces distortions caused by logical reasoning, and, moreover, saves both administration and scoring time [4]. The coding procedure differs from earlier motive assessment methods: First, the notes to the four questions are screened for indicators of one out of the three basis motives. If no motive can be identified unequivocally, the item gets a null coding (hence, the respective item will be excluded from analysis for the particular participant). As soon as the coder has labeled the response as affiliation, achievement, or power motive, he or she again screens responses to the four questions, this time checking for hints indicating approach or avoidance behavior. If an approach tendency is evident in the response, the coder screens the text again for signs of positive versus negative affect, and for internal or self-regulatory processes versus external triggers or incentives from the outside world. If positive affect and internal triggers are found, Level 1 is coded. If positive affect and external triggers are found, Level 2 is coded. If negative affect and internal triggers are found, Level 3 is coded; and if negative affect and external triggers are found, Level 4 is coded. If an avoiding tendency is detectable, the motive code is complemented with a '5', because OMT Level 5 represents the motive avoidance components. For the affiliation motive, this would include descriptions of feeling lonely, rejected, and hopeless. For the achievement motive, Level 5 is coded when fear of failure, or feeling stressed, helpless, or disappointed is described. Level 5 for the power motive encompasses feelings of powerlessness, guilt, or obedience in the OMT. For an overview of the five OMT Levels, as well as examples for each of the 15 cells (three motive contents by five levels), see Table 1. No correction for protocol length is needed in the OMT because only one out of 15 cells is coded per picture. This way, the overall expression of the three basic motives

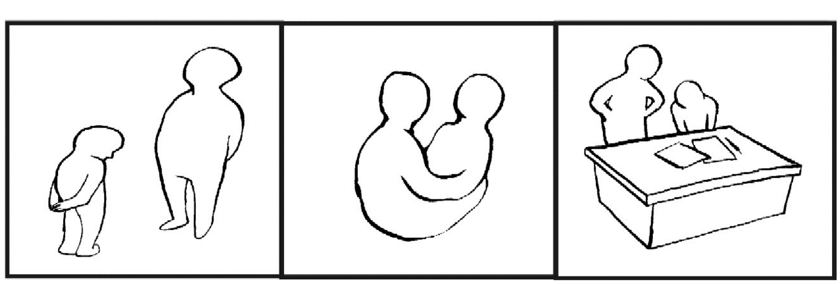

Fig. 1. Sample pictures from the OMT, chosen to arouse implicit power motivation (left side), affiliation motivation (middle plane), and achievement motivation (right side). Reprint with permission from the copyright holder (Julius Kuhl).

(sum of all motive scorings, irrespective of the corresponding OMT level scorings), the overall occurrence of the different OMT-levels (sum of levels 1–5 scorings, irrespective of the respective motive theme), and the distribution of motive/level combinations can be interpreted. Measures of classical test theory have been applied to the OMT, and a sufficient internal consistency (Cronbach's Alpha) of 0.74, 0.70, and 0.78 across the four levels of affiliation, achievement, and power, respectively, have been reported [35]. The retest stability was reported with $r = .72$ [22]. The validity of the OMT to predict spontaneous behavior related to the corresponding basic motive theme has been demonstrated in several publications ([36]; Baumann et al., 2005; [9]; Baumann & Scheffer, 2006; Kuhl & Kazén, 2008; Wegner et al., 2010; Wegner, 2012).

All OMTs were analyzed by a well-trained and certified scorer who had reached sufficient reliability (above 0.85) across several studies [15]. Moreover, the scorer was naive to the purpose of the study, as well as to sex and hormonal state of the participants. This procedure was chosen to reduce distortions caused by experimenter effects, and the scorer was paid for her expenses. The same seven ambiguous line drawings were used in the same order in every testing session. Because subjects never repeated the exact wording when thinking about the same story, this procedure was considered sufficient in detecting cycle phase dependent variation in the motive expression.

2.3. Hormone assays

Testing women during distinct phases of their menstrual cycle requires a confirmation of the self-reported cycle phases by means of exact hormone determination. Earlier work on the relation between implicit motives and gonadal steroid hormones (e.g., [40]) used non-invasive saliva samples to analyze hormone levels. However, those authors pointed out some limitations of saliva-based hormone determination, such as the rapid fluctuations of steroid hormone concentrations in saliva, or the impossibility to partition hormone levels into endogenous and exogenous portions in women using hormonal contraceptives. Therefore, hormone data were recorded by means of less distraction-prone blood serum analysis, which allows for more accurate, total hormone level determination. Following every individual test session, 5–7 ml venous blood was taken from every participant in a medical praxis on campus. The processing of the samples took place in the associated endocrinological laboratory. After the cellular parts of each sample had been centrifuged, blood serum was analyzed. Estradiol, progesterone, testosterone, LH and FSH were determined by a solid-phase, competitive chemiluminescent enzyme immunoassay (Siemens Diagnostic GmbH, Munich, Germany). This assay features intra- and interassay coefficients of variation for a low point of the standard curve of 3.1–7.9% and 4.1–7.8%, respectively. The cycle phases of interest were defined according to the following hormonal inclusion criteria: In the preovulatory phase, progesterone levels of <2.0 ng/ml, estradiol levels of >34 pg/ml, LH levels of >5 IU/l, and FSH levels of >4 IU/l were included. In the mid-luteal phase, progesterone levels of >2 ng/ml, and estradiol levels of >30 pg/ml were included. To check whether the naturally cycling women were actually free of hormonal medication, the sex hormone binding globulin (SHBG) was analyzed and only participants with SHBG levels of >120 nmol/l were included. On the other hand, in the hormonal contraceptive control group, SHBG levels of >120 nmol/l was considered as group inclusion criterion.

2.4. Statistical procedures

All statistical analyses were conducted with PASW Statistics 18.0. To assess whether OMT-motive scores were modified by cycle phase (or test session in women using hormonal contraceptives), repeated measures analyses of variances (ANOVA) were carried out with the within-subject factors 'cycle phase' (menses, preovulatory phase, and mid-luteal phase), 'motive' (affiliation, power, achievement), and 'OMT-level' (1–5). Relationship status and order of test session (cycle phase at study entrance) were entered in the analysis as covariates. The association between hormone concentrations and motive expressions was tested using Pearson's bivariate correlation analyses. Directional hypothesis concerning hormone-OMT levels 2 and 4-associations were tested one-sidedly, and all other correlations two-sidedly. Post-hoc tests were carried out using the Wilcoxon signed-rank test.

3. Results

3.1. Hormonal validation of cycle phases

In the group of naturally cycling women, 12 out of 33 women did not meet the hormonal inclusion criteria (seven women were already in their early luteal phase when expected to be in the preovulatory phase, and five women showed unusually low progesterone levels in the mid-luteal phase). Another five women did not complete all three testing sessions due to schedule difficulties. Thus, the final sample of naturally cycling women consisted of 16 participants, with a mean age of 24.1 years (S.D. = 2.6), and a mean average cycle length of 28.94 days (S.D. = .1). In this sample, eight women stated that they were in a relationship, and eight women stated that they were singles.

From 33 tested contraceptive using women, five did not complete all three testing sessions due to schedule difficulties. Two more had to be excluded from analysis due to mismatch with the hormone inclusion criteria. The remaining 26 women had a mean age of 23.7 years (S.D. = 2.9). In this group, 17 women reported to be in a relationship, and 9 women did not have a partner at the time of testing.

Valid measurement thresholds of the hormone assays where at 0.2 ng/ml for progesterone, 20 pg/ml for estradiol, 20 ng/dl for testosterone, and 0.1 U/l for LH and FSH. For all cases of hormone levels below these thresholds, values were placed at the threshold value minus 0.1. This commonly accepted procedure reduces variance in minimal values. Table 2 depicts mean values and standard deviations for all hormone levels in naturally cycling women and women using the Nuva®Ring. All hormone levels were in the normal range for the according cycle phase [43]. A 3 (cycle phases) × 5 (serum values of progesterone, estradiol, testosterone, LH, and FSH) repeated measures ANOVA with group as between subject factor yielded a significant cycle phase by hormone by group interaction, $F(8, 256) = 19.17$, $p < .01$, partial $\eta^2 = .38$. As expected, there was no significant variance of hormone concentrations across the three testing sessions in women using hormonal contraceptives (main effect of cycle phase, $F(8, 176) = 2.55$, $p > .05$).

3.2. Covariates and between-subject factors

Neither in the ANOVAs, nor in the correlation analysis, entering relationship status as a between-subject factor and/or order of test session as a covariate contributed significantly to the explained variance. Neither in the group of naturally cycling women, nor in the control group of women using hormonal contraceptives, partnered women differed significantly from single women (all $ps > .6$). Furthermore, there was no evidence for carry-over effects in neither group. Therefore, these factors were no further considered.

3.3. Association between cycle phase, motive scores, and OMT-levels

The internal consistency of OMT-motive scores in the present data was comparably large as in previous reports (see above): Across all participants and all three testing sessions, Cronbach's alphas were 0.70 for affiliation, 0.51 for achievement, and 0.62 for power motive scores.

The global ANOVA (see 2.4) revealed a significant main effect of motive ($F(2, 80) = 18.68$, $p < 0.001$, partial $\eta^2 = 0.36$) and a significant main effect of OMT-level ($F(4,160) = 35.97$, $p < 0.001$, partial $\eta^2 =$

Table 2
Descriptive statistics of hormone concentrations.

Group	Cycle phase	Progesterone (ng/ml)		Estradiol (pg/ml)		Testosterone (ng/dl)		FSH (U/l)		LH (U/l)	
		Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Naturally cycling	Menstrual	0.28	0.09	31.76	13.78	29.3	12.12	6.81	2.13	4.98	2.09
women (N = 16)	Mid-cycle	0.57	0.83	108.01	58.99	40.89	18.38	5.89	1.49	9.11	3.51
	Luteal	7.2	2.29	99.67	34.27	32.23	11.3	3.31	1.05	5.38	5.24
Contraceptive	Session 1	0.23	0.07	26.22	7.9	29.24	13.66	4.62	4.07	4.25	3.83
women (N = 26)	Session 2	0.21	0.09	21.88	5.78	24.89	10.92	6.72	13.43	1.38	2.21
	Session 3	0.23	0.1	21.65	2.72	24.94	9.5	1.64	2.1	3.63	7.69

0.52. All participants scored highest in power motivation ($m = 6.7 \pm 2.6$), followed by affiliation motivation ($m = 5.6 \pm 2.0$), and lowest in achievement motivation ($m = 3.57 \pm 1.0$, see Fig. 2). All participants had most level 4 scorings ($m = 8.06 \pm 1.2$), followed by level 5 ($m = 4.97 \pm 2.7$), level 2 ($m = 4.46 \pm 1.9$). Levels 1 ($m = 0.66 \pm 1.2$) and 3 ($m = 1.8 \pm 1.7$) were significantly less often than the other levels. There was a significant cycle phase ∗ motive ∗ level ∗ group interaction ($F (16, 627) = 2.16$, $p < 0.05$, partial $\eta^2 = 0.06$). There were no further main effects or interactions in the global ANOVA (all $Fs < 1.4$). Follow-up analysis revealed that in the group of naturally cycling women, the three basic motives did not vary across the menstrual cycle (cycle phase ∗ motive score: $F (4, 60) = 0.43$, $p > 0.05$, partial $\eta^2 = 0.028$). However, there was a trend in the data indicating that OMT-levels were affected by cycle phase in this group (cycle phase ∗ level: $F(8, 120) = 1.8$, $p = 0.082$, partial $\eta^2 = 0.11$). The three-fold interaction cycle phase ∗ motive score ∗ level was significant ($F (16, 240) = 2.82$, $p < 0.001$, partial $\eta^2 = 0.16$). A post-hoc test revealed that the level 4 power motive was significantly reduced ($F (2, 30) = 6.74$, $p = 0.004$, partial $\eta^2 = 0.31$) in the preovulatory phase ($m = 0.75 \pm 0.6$), compared to the menstrual ($m = 1.38 \pm 0.8$) and the mid-luteal phase ($m = 1.5 \pm 0.9$). Because level 4 was the overall most often scored level (thus, this data was not normally distributed), we checked this effect using non-parametric Wilcoxon signed-rank test. This confirmed that power motivation level 4 scorings were significantly more frequent during menses ($m = 1.38$) and during the mid-luteal phase ($m = 1.5$) than during the preovuloatory phase ($m = .75$), $z = -2.23$, $p < .05$, $r = -.32$ (menses-preovulatory), $z = -2.4$, $p < .05$, $r = -.35$ (preovulatory–mid-luteal). The scores did not differ between menses and mid-luteal phase, $z = -0.82$, $p = .87$, $r = -.12$.

In the control group of women using the Nuva®Ring, there was no evidence for a varied motive/level interaction across the three testing sessions (test session ∗ motive score ∗ level: $F(16, 288) = 0.73$, $p > 0.05$, partial $\eta^2 = 0.04$) (Table 4).

3.4. Motive-hormone associations

To test if naturally cycling women's hormone fluctuations were linked with motive or OMT-level scores, bivariate correlation analyses were calculated (Table 3). There was evidence for a significant relationship between progesterone levels and the number of OMT-level 2 and level 3 scores: during the preovulatory phase, progesterone was significantly correlated with overall-level 2 (incentive orientation), $r = -.61$, with overall-level 3 (self-regulated coping), $r = .56$, and particularly with level 3 power motivation (coping with power-related threat), $r = .59$ (all $ps \leq .05$). In the mid-luteal phase, progesterone was significantly correlated with the achievement motive, in particular with

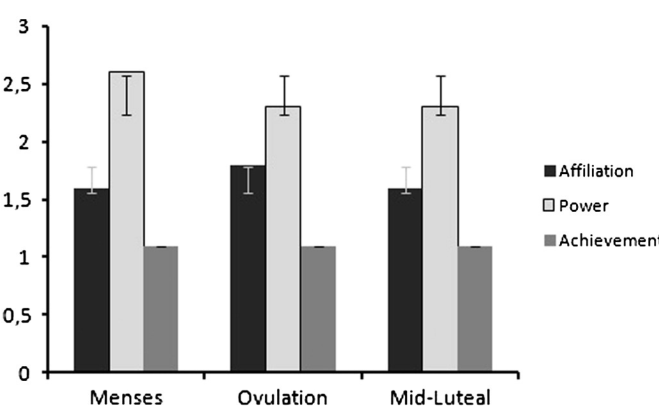

Fig. 2. Distribution of motive scores in naturally cycling women at three distinct cycle phases. Significant variation was not observed in any motive. Error bars indicate standard deviation (S.D. = 0.3 for achievement motive distribution).

Table 3
Correlations between naturally cycling women's hormone levels and overall motive/OMT-level scores at three distinct phases of the menstrual cycle. Gray rows reflect one-sided, all other rows two-sided hypothesis testing. Asterisks indicate significant correlations.

Menstrual Phase	Progesterone	Estradiol	Testosterone	LH	FSH
Affiliation	r=.03, p=.92	r=-.07, p=.8	r=.30, p=.26	r=.47, p=.07	r=.26, p=.34
Power	r=-.43, p=.10	r=.32, p=.23	r=-.02, p=.93	r=-.30, p=.26	r=-.38, p=.15
Achievement	r=.23, p=.39	r=-.34, p=.21	r=-.33, p=.21	r=-.59*, p=.02	r=-.49, p=.05
Level 1	r=.48, p=.06	r=-.35, p=.19	r=.38, p=.15	r=.2, p=.47	r=.-.08, p=.77
Level 2	r=-.18, p=.25	r=-.10, p=.36	r=-.17, p=.26	r=.04, p=.44	r=-.22, p=.21
Level3	r=-.22, p=.43	r=-.15, p=.58	r=.11, p=.69	r=-.24, p=.36	r=-.16, p=.56
Level 4	r=-.22, p=.21	r=.12, p=.35	r=-.16, p=.27	r=.01, p=.49	r=.01, p=.48
Level 5	r=.31, p=.25	r=.13, p=.62	r=.11, p=.69	r=.24, p=.37	r=.25, p=.34
Preo vulatory Phase					
Affiliation	r=-.28, p=.29	r=-.23, p=.39	r=.23, p=.39	r=.02, p=.95	r=-.22, p=.41
Power	r=.31, p=.24	r=-.03, p=.93	r=-.21, p=.43	r=.04, p=.88	r=-.02, p=.96
Achievement	r=-.07, p=.8	r=.22, p=.42	r=-.25, p=.34	r=-.12, p=.66	r=.03, p=.92
Level 1	r=-.22, p=.41	r=.18, p=.50	r=-.29, p=.29	r=-.16 p=.56	r=.-.44, p=.09
Level 2	r=-.61*, p=.01	r=-.00 p=.5	r=.16, p=.28	r=.06, p=.42	r=-.19, p=.25
Level3	r=.56*, p=.02	r=.07, p=.78	r=.32, p=.23	r=.09, p=.73	r=.13, p=.62
Level 4	r=-.04, p=.44	r=-.04, p=.45	r=-.47*, p=.04	r=.04, p=.45	r=.08, p=.38
Level 5	r=.23, p=.38	r=-.42, p=.10	r=.06, p=.81	r=-.17, p=.53	r=-.15, p=.58
Mid-Luteal Phase					
Affiliation	r=.24, p=.37	r=.32, p=.23	r=.08, p=.77	r=.03, p=.92	r=-.01, p=.97
Power	r=-.31, p=.24	r=-.18, p=.50	r=.08, p=.76	r=.03, p=.90	r=-.28, p=.30
Achievement	r=-.01, p=.97	r=.18, p=.50	r=-.31, p=.24	r=-.19, p=.48	r=-.37, p=.16
Level 1	r=.14, p=.61	r=.34, p=.20	r=-.23, p=.39	r=-.28 p=.30	r=.-.05, p=.85
Level 2	r=-.08, p=.39	r=-.30 p=.14	r=.37, p=.08	r=.52*, p=.02	r=.18, p=.26
Level3	r=-.65, p=.01	r=-.04, p=.90	r=-.09, p=.75	r=-.24, p=.38	r=-.27, p=.31
Level 4	r=.19, p=.24	r=.23, p=.20	r=-.18, p=.25	r=-.14, p=.31	r=-.08, p=.38
Level 5	r=.10, p=.71	r=-.25, p=.35	r=-.06, p=.83	r=-.10, p=.71	r=.04, p=.90

level 3 achievement (self-regulated coping with failure), $r = -.65$, and with level 5 achievement (passive fear of failure), $r = -.52$. Level 5 achievement motivation was also correlated with estradiol, $r = -.52$ (all $ps < .01$) in the mid-luteal phase.

Table 4
Distribution of motive and OMT-level scores at three distinct phases of the menstrual cycle in naturally cycling women, compared to Nuva®Ring using women's scores at three test sessions. Standard deviations are given in brackets.

Menstrual phase	Naturally cycling women	Women using Nuva®Ring
Affiliation	1.6 (0.9)	2.0 (0.9)
Power	2.6 (0.9)	2.3 (1.1)
Achievement	1.1 (0.3)	1.2 (0.6)
Level 1	0.6 (0.3)	0.1 (0.3)
Level 2	1.6 (0.8)	1.8 (0.8)
Level3	0.7 (0.8)	0.7 (0.8)
Level 4	2.4 (0.7)	2.4 (0.7)
Level 5	1.6 (1.1)	1.6 (1.1)
Preovulatory phase		
Affiliation	1.8 (0.8)	1.8 (1.1)
Power	2.3 (0.9)	2.3 (1.5)
Achievement	1.1 (0.4)	1.4 (0.6)
Level 1	0.2 (0.4)	0.2 (1.1)
Level 2	1.6 (0.9)	1.6 (1.0)
Level3	0.9 (1.1)	0.9 (1.1)
Level 4	2.3 (1.0)	2.3 (1.0)
Level 5	1.7 (1.1)	1.7 (1.1)
Mid-luteal phase		
Affiliation	1.6 (0.7)	1.9 (0.8)
Power	2.3 (1.3)	2.0 (1.1)
Achievement	1.1 (0.3)	1.3 (0.5)
Level 1	0.6 (0.4)	0.2 (0.4)
Level 2	1.6 (0.9)	1.8 (0.9)
Level3	0.4 (0.6)	0.4 (0.6)
Level 4	2.9 (1.2)	3.0 (1.2)
Level 5	1.4 (0.9)	1.4 (1.0)

4. Discussion

This study explored whether cycle phase associated changes in the expression of implicit motives can be demonstrated using a novel measurement approach, the OMT. Indeed, type of motive enactment as the key feature of the test applied here turned out to be modulated by cycle phase. In the preovulatory phase, the dominance or inhibited power reflecting category (OMT-level 4) was significantly less often scored, compared to the menstrual and to the mid-luteal phase in naturally cycling women. Similarly, bivariate correlation analysis displayed significant relationships between hormone concentrations and OMT-levels, rather than with the three basic motive values per se. In contrast to findings derived with the PSE [40], the implicit need for affiliation, power, and achievement was not subject to cycle phase effects in the current study. There are several other aspects of divergence between the present study and earlier findings, which are discussed separately below.

While sex hormone fluctuations across the menstrual cycle were not associated with changes in the motive scores, cycle-phase associated changes in motive enactment were evident in naturally cycling women. This finding corroborates the conceptual distinction of motive themes and forms of motive enactment that constitutes the OMT. According to our finding, it is not the conceptually rather stable motivational topic that is modulated by hormone fluctuations. In fact, the construction of five OMT-levels reflects cognitive and emotional processes that are likely to be sensitive to sex- and cycle phase dependent variation. The OMT offers the opportunity to distinguish between motive approach and motive avoidance, which is fundamental in predicting people's spontaneous behavior. Other content coding methods, such as PSE and TAT, do not account for this distinction in the same extent as the OMT does. For instance, motive enactment on level 4 is characterized by negative affect and external triggers, which can be seen as a form of active behavioral or cognitive avoidance (e.g., striving for positive affect through the avoidance of negative affect in the sense of negative reinforcement). In this context, fluctuating hormone concentrations can act as internal triggers for behavioral approaching/avoiding tendencies, and the reduced tendency to express negative affect and incentive-based motivation at mid-cycle can be interpreted as reduced motive avoidance.

Higher scores of those levels that reflect incentive-based, active forms of motive enactment (OMT levels 2 and 4) were expected in the pre-ovulatory phase. In fact, those OMT-levels were generally stronger expressed than OMT-levels that reflect higher degrees of self-regulation (OMT-levels 1 and 3). Instead of a stronger expression of incentive-based forms of motive enactment, there was evidence for a partly inverted pattern during the high-estradiol mid-cycle phase, that is, a decrease in dominance and inhibited power (OMT level 4). Thus, the OMT-result pointed towards a selective reduction in avoiding power motive frustration at the time of highest likelihood of conception. In accordance with this result, no such variation in level 4 scorings was evident in the control group of women with exogenously suppressed and stable hormone concentrations. This result can be interpreted as reflecting an association between the rapid change of estradiol concentration on the physiological level, and concurrent change in the way that basic motivational needs are fulfilled on the psychological level. Albeit no direct link between estradiol concentration and number of level 4 scorings was observed, women in the control group (who used the Nuva®Ring and displayed significantly reduced endogenous estradiol levels) displayed higher level 4 scores throughout the three testing sessions. Because the total (exogenously applied) hormone concentration in those women was much higher (see 2.1), it can be assumed that high levels of estradiol are associated with a less rigid enactment of the power motive. Activating effects of estradiol may in this context lead to a more flexible dealing with external context conditions. Earlier investigations found a positive association between estradiol and expression of power motivation in women (e.g., [14]). The fact that we did not exactly replicate this association with a different measurement technique coincides with the observation of a low convergent validity between PSE and OMT [8]. Differing findings concerning the association between estradiol and power motive expression may be due to the fact that the hormonal state acts as internal trigger, affecting not only what a person is striving for in a given situation, but also how she is trying to pursue her needs or goals. It is conceivable that the estradiol surge at mid-cycle is associated with an increase in the implicit need for power (on a preverbal level as measured with the PSE), and at the same time with a reduced tendency to enact this motive in an incentive-based way (in particular, outcome-focused enactment of the power motive as reflected by the OMT's level 4 power motive category). This emphasizes the importance of considering both aspects of motivation when investigating the influence of hormonal states on motivational outcomes.

The theoretical construction of OMT levels intends to predict spontaneous behavior. From a neuropsychological point of view, both excitatory (approach) and inhibitory (avoidance) processes are involved in behavior control. According to Bancroft and Graham [3], individuals differ in their propensity for one of these processes, and it is suggestive that there is also intra-individual, potentially hormone-driven variability in approaching or avoiding behavior tendencies. It can be proposed that the generally activating effects of estradiol may reflect an interaction of excitation and inhibiting processes that finally lead to reduced inhibition. Thus, the estradiol peak in the preovulatory phase would act as a brake release in behavior control at the time of highest likelihood of conception. From an evolutionary point of view, it is conceivable that the hormonal actions regulating the biological reproductive process simultaneously affect psychological processes that facilitate conception. The reduced tendency to enact power needs in an open and dominant way may thus reflect such an evolutionary adaptation. However, because the gonadotropins FSH and LH reach their highest concentrations in concert with the estradiol peak at the preovulatory phase, caution is warranted in inferring causal relationships. It remains an open question to what extent these hormones affect the reduced fear of motive frustration and how these hormones might interact to produce this effect.

In contrast to existing evidence, the relationship between progesterone/estradiol and affiliation motivation/attachment behavior, as well as higher affiliation than power motivation in women, is not reflected in the current results. One possible explanation for the lack of a strong association between motive themes and hormone concentrations is the conceptual difference in motive assessment methods. Although both the previously used PSE and the newly applied OMT have been subject to thorough methodological validation and proved to excel sufficient internal consistency and reliability, they may not measure exactly the same constructs. The PSE was developed in order to capture motives as basal needs, whereas the focus of the OMT lies on the enactment of needs. In addition, due to the methodological differences in motive coding, it can be assumed that the PSE is more sensitive to intra-individual variation (because intra-individual variation can be estimated across all pictures), whereas the OMT is likely to be more sensitive to inter-individual variation (only one motive per picture). From an evolutionary perspective, the increased need for having impact on others (=PSE power coding) is plausible against the background of a need to attract potential mates at the time of ovulation. This implicit need can potentially be achieved by hormone-driven, physiological processes (such as odor secretion or modification of optical markers by changed blood supply), and without conscious, self-regulatory behavioral effort. Thus, the decreased tendency to enact this need in a dominant, power-displaying way (=OMT-level 4 power coding) can be interpreted as an evolutionary stable strategy, too, because (a) external incentives are not necessarily required to fulfill the motivational need and (b) displaying dominant behavior does not seem to be an adaptive female strategy. This interpretation could be tested and the remaining potential confound caused by conceptual differences could be ruled out by conducting a study using both instruments and comparing PSE and OMT motive scores. Generally, the conceptual dissociation between differing types of motive enactment should be accounted for in future hormone–motive-association studies.

Besides the motive measurement technique, the current study differs from other available evidence in two more methodological issues: First, while previous work used three parallel sets of motive arousing pictures, the OMT coding procedure allowed for using the same seven pictures at every testing session. The impact of this methodological difference could be controlled for by replacing the within-subject design (which implies repeated-measures designs) by a between-subject design. However, given the large interindividual difference in both the scope of hormone fluctuations and motivational schemes, a within-subject design should be preferred in order to control for pre-existing differences. Second, while blood serum hormone values were used in the current study, the more confounding-prone saliva-based hormone analysis was used previously. The advantage of saliva-sampling lies in the non-invasive, more readily available sampling method, which might also facilitate the recruitment of larger samples. In addition, saliva-derived hormone values reflect only the unbound and bioavailable portions of the circulating steroids. However, saliva-derived values are sensitive to distortion from food aliment or mouth micro-injury residues, as well as hormone/hormone-binding protein interactions. Therefore, total hormone levels derived from blood serum analysis can be considered as the more accurate measure, albeit it requires more organizational effort.

An important methodological limitation has to be taken into account when interpreting the results of the present study: Due to the low number of women in the free-cycling group, the present study had low statistical power to detect small hormonal effects on motives. Thus, replication of the present results in a larger cohort would be interesting in order to look for potentially undetected relationships between hormone levels and motives/OMT-levels.

In summary, the results of this study further support the assumption that gonadal sex hormones act as internal stimuli on the formation of social motivation. Similar to fluctuations in glucose levels acting as internal stimulus on behavior systems related to hunger and food intake, sex hormones seem to have a modulating effect on the intuitive control of a range of social behaviors, such as attachment, affiliation, cooperation, or competition. Although implicit motives are defined as enduring personal preferences for affectively charged incentives, what is measured in content analytic procedures seem to depend on both external arousal and internal, physiological incitement. Because both internal and external motive inducements are variable, it is conceivable that a change or manipulation of triggers lead to a change in the motive outcome. The OMT has been shown to be a suitable methodological extension in the study of the psychoendocrinological background of motivation. Especially because of its consideration of different emotional states and different forms of motive enactment, the OMT is a promising instrument for future research attempts to disentangle the complex inter-relation of hormonal states and motive-driven behavior.

References

[1] Andréen L, Nyberg S, Turkmen S, van Wingen G, Fernández G, Bäcckström T. Sex steroid induced negative mood may be explained by the paradoxical effect mediated by GABAA modulators. Psychoneuroendocrinology 2009;34:1121–32.

[2] Atkinson JW. An introduction to motivation. Princeton, N. J.: van Nostrand; 1964.

[3] Bancroft J, Graham CA. The varied nature of women's sexuality: unresolved issues and a theoretical approach. Horm Behav 2011;59:717–29.

[4] Baumann N, Kazén M, Kuhl J. Implicit motives: a look from personality systems interaction theory. In: Schultheiss OC, Brunstein JC, editors. Implicit motives. New York: Oxford University Press; 2010.

[5] Berg SJ, Wynne-Edwards KE. Changes in testosterone, cortisol, and estradiol levels in men becoming fathers. Mayo Clin Proc 2001;76:582–92.

[6] Berman KF, Schmidt PJ, Rubinow DR, Danaceau MA, Van Horn JD, Esposito G, et al. Modulation of cognition-specific cortical activity by gonadal steroids: a positron-emission tomography study in women. Proc Natl Acad Sci U S A 1997;94:8836–41.

[7] Björn I, Sundström-Poromaa I, Bixo M, Nyberg S, Bäckström T. Increase of estrogen dose deteriorates mood during progestin phase in sequential hormonal therapy. J Clin Endocrinol Metabol 2003;88:9–18.

[8] Chasiotis A, Hofer J. Die Messung impliziter Motive in Deutschland, Costa Rica und Kamerun (Measurement of implicit motives in Germany, Costa Rica, and Cameroon) Research report do the German Research Foundation (DFG); 2003.

[9] Chasiotis A, Hofer J, Campos D. When does liking children lead to parenthodd? Younger siblings, implicit prosocial power motivation, and explicit love for children predict parenthood across cultures. J Cult Evol Psychol 2006;72:218–32.

[10] Colzato LS, Hertsig G, van den Wildenberg WPM, Hommel B. Estrogen modulates inhibitory control in healthy human females: evidence from the stop signal paradigm. Neuroscience 2010;167:709–15.

[11] Edelstein RS, Stanton SJ, Henderson MM, Sanders MR. Endogenous estradiol levels are associated with attachment avoidance and implicit intimacy motivation. Horm Behav 2010;57:230–6.

[12] Fleming AS, Ruble D, Krieger H, Wong PY. Hormonal and experiential correlates of maternal responsiveness during pregnancy and the puerperium in human mothers. Horm Behav 1997;31:145–58.

[13] Freeman EW. Treatment of depression associated with the menstrual cycle: premenstrual dysphoria, postpartum depression, and the perimenopuase. Dialogues Clin Neurosci 2002;4:177–91.

[14] Hall JL, Stanton SJ, Schultheiss OC. Biopsychological and neural processes of implicit motivation. In: Schultheiss OC, Brunstein JC, editors. Implicit motives. New York, NY: Oxford University Press; 2010.

[15] Kaschel R, Kuhl J. Motivational counseling in an extended functional context: personality systems interaction theory and assessment. In: Cox WM, Klinger E, editors. Handbook of motivational counseling: Concepts, approaches, and assessment. New York: Wiley & Sons; 2004.

[16] Kazén M, Kuhl J. Intention memory and achievement motivation: volitional facilitation and inhibition as a function of affective contents of need-related stimuli. J Pers Soc Psychol 2005;89:426–48.

[17] Kiesner J. One woman's low is another woman's high: paradoxical effects of the menstrual cycle. Psychoneuroendocrinology 2011;36:68–76.

[18] Kinsley CH, Lambert KG. Reproduction-induced neuroplasticity: natural behavioural and neuronal alterations associated with the production and care of offspring. J Neuroendocrinol 2008;4:515–25.

[19] Klaiber EL, Brovermann DM, Vogel W, Peterson LG, Snyder MB. Individual differences in changes in mood and platelet monoamine oxidase (MAO) activity during hormonal replacement therapy in menopausal women. Psychoneuroendocrinology 1996;22:575–92.

[20] Kuhl J. A functional-design approach to motivation and volition: the dynamics of personality systems interactions. In: Boekaerts M, Pintrich PR, Zeidner M, editors. Self-regulation: Directions and challenges for future research. New York: Academic Press; 2000.

[21] Kuhl J, Scheffer D. Der operante multi-motiv-test (OMT): manual [the operant multi-motive test (OMT): manual]. Germany: University of Osnabrück; 1999.

[22] Kuhl J, Scheffer D, Eichstaedt J. Der operante motivtest (OMT): ein neuer ansatz zur messung impliziter motive [the operant multi-motive-test (OMT): a new approach to the assessment of implicit motives]. In: Rheinberg F, Stiensmeier- Pelster J, editors. Diagnostik von Motivation und Selbstkonzept [Diagnostic of motivation and self-concept]. Göttingen, Germany: Hogrefe; 2003.

[23] Kuhl J, Kazén M, Koole SL. Putting self-regulation theory into practice: a user's manual. Appl Psychol 2006;55:408–18.

[24] Lehrl S. Mehrfachwahl-wortschatz-intelligenztest (MWT) [multiple choice vocabulary intelligence test]. Erlangen, Germany: Straube; 2005.

[25] Maki PM, Rich JB, Rosenbaum RS. Implicit memory varies across the menstrual cycle: estrogen effects in young women. Neuropsychologia 2002;40:518–29.

[26] McClelland DC, Atkinson JW, Clark RA, Lowell EL. The achievement motive. New York: Appleton-Century-Crofts; 1953.

[27] McClelland DC. Biological aspects of human motivation. In: Halisch F, Kuhl J, editors. Motivation, intention, and volition. Berlin: Springer; 1987.

[28] Metcalf MG, Livesey JH, Wells JE, Braiden V. Mood cyclicity in women with and without the premenstrual syndrome. J Psychosom Res 1989;33:407–18.

[29] Murray HA. Thematic apperception test. Cambridge, Mass.: Harvard University Press; 1942.

[30] Pang JS, Schultheiss OC. Assessing implicit motives in U. S. college students: effects of picture type and position, gender and ethnicity, and cross-cultural comparisons. J Pers Assess 2005;85:280–94.

[31] Phillips SM, Sherwin BB. Variations in memory function and sex steroid hormones across the menstrual cycle. Psychoneuroendocrinology 1992;17:497–506.

[32] Protopopescu X, Pan H, Altemus M, Tuescher O, Polanecsky M, McEwen B, et al. Orbitofrontal cortex activity related to emotional processing changes across the menstrual cycle. Proc Natl Acad Sci U S A 2005;102:16060–5.

[33] Roumen F, Apter D, Mulders T, Dieben T. Efficacy, tolerability and acceptability of a novel contraceptive vaginal ring releasing etonogestrel and ethinyl oestradiol. Hum Reprod 2001;16:469–75.

[34] Rubinow DR, Hoban CM, Grover GN, Galloway SD, Roy-Byrne P, Andersen R, et al. Changes in plasma hormones across the menstrual cycle in patients with menstrually related mood disorder and in control subjects. Am J Obstet Gynecol 1988;158:5–11.

[35] Scheffer D, Kuhl J, Eichstaedt J. Der operante motiv-test (omt): inhaltsklassen, auswertung, psychometrische kennwerte und validierung [The Operant Motive Test (OMT): contents, scoring, psychometric values, and validation]. In: Stiensmeier-Pelster J, Rheinberg F, editors. Diagnostik von Motivation und Selbstkonzept [Diagnostic of motivation and self-concept]. Göttingen, Germany: Hogrefe; 2003.

[36] Scheffer D. Implizite motive [implicit motives]. Göttingen, Germany: Hogrefe; 2005.

[37] Schmalt HD. Assessing the achievement motive using the grid technique. J Res Pers 1999;33:109–30.

[38] Schultheiss OC, Brunstein JC. Assessment of implicit motives with a research version of the TAT: picture profiles, gender differences, and relations to other personality measures. J Pers Assess 2001;77:71–86.

[39] Schultheiss OC, Brunstein JC, editors. Implicit motives. New York: Oxford University Press; 2010.

[40] Schultheiss OC, Dargel A, Rohde W. Implicit motives and gonadal steroid hormones: effects of menstrual cycle phase, oral contraceptive use, and relationship status. Horm Behav 2003;43:293–301.

[41] Schultheiss OC, Wirth MW, Stanton SJ. Effects of affiliation and power motivation arousal on salivary progesterone and testosterone. Horm Behav 2004;46:592–9.

[42] Smith CP, Feld SC, Franz CE. Methodological considerations: steps in research employing content analysis systems. In: Smith CP, editor. Motivation and personality: Handbook of thematic content analysis. Cambridge: Cambridge University Press; 1992.

[43] Stricker R, Eberhart R, Chevailler MC, Quinn FA, Bishof P, Stricker R. Establishment of detailed reference values for luteinizing hormone, follicle stimulating hormone, estradiol, and progesterone during different phases of the menstrual cycle on the Abbott ARCHITECT analyzer. Clin Chem Lab Med 2006;44:883–7.

[44] Walf AA, Rhodes ME, Frye CA. Ovarian steroids enhance object recognition in naturally cycling and ovariectomized, hormone-primed rats. Neurobiol Learn Mem 2006;86:35–46.

[45] Wolf OT, Kudielka BM, Hellhamer DH, Torber S, McEwen BS, Kirschbaum C. Two weeks of transdermal estradiol treatment in postmenopausal elderly women and its effect on memory and mood: verbal memory changes are associated with the treatment induced estradiol levels. Psychoneuroendocrinology 1999;24:727–41.