

5. Hidden Patterns of Male Sex Hormones and Behaviour Vary with Life History

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Abstract. Androgens regulate sperm production, the expression of secondary sex characters and behavior in males and also vice versa, androgens are modulated by the male’s interactions with his social environment. In search for a regular internal “cycle” of hormones and behavior in men, the individual time patterns of salivary testosterone and progesterone of adult healthy men, self-reported behavior and their co-occurrence with regular weekly or monthly intervals were studied. Twenty-seven volunteer males (mean age 33 ± 1 years) collected daily morning saliva over a period of 90 days. Evening questionnaires provided daily information on sexual activities, pairbond-specific behavior and life habits. From the saliva, testosterone and progesterone levels were determined using enzyme immunoassay. To detect events in which increases of testosterone were associated with sexual activity and at the same time controlling for regular internal patterns in men, data were analysed using THEME. The social context of the occurrence of specific pattern combinations was elaborated using parameters from the men’s self-reported life history profiles. Time-patterns involving testosterone, sexual activity, and monthly (i.e. 28-day full-moon) intervals were observed among wannabe fathers, but not in singles or those of the paired men who did not have a wish for children with their current partner. The presented data, furthermore, suggested progesterone as a male sex steroid found in large amplitudes in saliva and seemingly of gonadal origin. Co-occurrences of progesterone and sexual activity were particularly observed in “unexpected” or “secret” episodes. Moreover, the parallel nature of individual testosterone and progesterone fluctuations decreased with sexual experience. Using THEME, time-patterns involving progesterone and monthly intervals occurred in “wannabe fathers” but not in singles, similar to the observed testosterone patterns. We compared the patterns of men’s testosterone and progesterone using conventional approaches with THEME analyses. This study demonstrated that the detection of non-random THEME patterns may be regarded as a measure of the interaction between hormones and behavior or of the co-occurrence with an environmental parameter. Therefore, THEME analyses to express real-time response patterns may be an emerging general tool also in behavioural endocrinology.

Keywords: Real-time-patterns; THEME; sexual behaviour; human males; testosterone; progesterone; saliva; hormone behaviour interaction.

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5.1 Introduction

In contrast to the well-known hormonal base of the menstrual cycle in women [1], a regular internal pattern of hormones and behavior in men, for example on a monthly base, has to our knowledge not been studied. The existence of a male “cycle” in terms of hormones and behavior may be considered for a number of reasons. Testosterone (T) plays a role in erectile function, sexual behavior and mood, which may vary from day to day [2], [3, 4] or across the days of a week [5, 6]. Furthermore, unconscious auto-ejaculations during phases of sexual inactivity are common. Finally, physical welfare, concentration, mood and aggressive as well as sexual motivation may vary noticeably in men [7, 8], as observed throughout the female monthly cycle [9-11]. Alternatively, men may be responsive to the hormonal fluctuations and sexual responsiveness of their wives [11] rather than exhibiting a regular internal cycle themselves [12]. Observations from a number of species (including the human male) point at the adaptive value for a (monogamous) male to be hormonally and behaviourally responsive to his partner’s fecundity phases [13-16].

We will present a study that was conducted to examine regular patterns of T and sexual behavior on a daily base over a three months period in healthy adult men. As a consequence a large database on the interactions between T and sexual activity has been accumulated. Peak levels of T were expected in response to sexual activity [8, 17]. Analyses focused on three major questions: (a) whether the males’ T peaks anticipated or followed periods of sexual activity, (b) the social context of the observed interaction patterns, and (c) a potential involvement of regular environmental parameters in the observed time-patterns, which included weekly and monthly intervals [18]. The rates of co-occurrences between T or progesterone (P) peaks and sexual activity were compared with regard to social context and life histories of the candidates.

5.1.1 *Social modulation of androgens*

Androgens play major roles in the conserved vertebrate reproductive axis (i.e. hypothalamus-pituitary-gonads). T, in particular, is essential for spermatogenesis, the maintenance of the genital tract, and the development secondary sexual characters in male vertebrates, including the human male. Early behavioural endocrinology studies in normal human males were focused predominantly on the effects of androgens on sexual activity [19, 20]. Beard growth rate was then observed to increase in anticipation of sexual activity [21], which along with the development of non-invasive saliva assays [22-25] paved the way to study the role of the social environment and of behavior as short-term modulators of T [26-29]. In sum, T was observed to influence and, reversibly, be modulated by sexual interest, arousal and enjoyment [17]. Also paternal investment plays a role. From avian studies we know that T may be regarded as the physiological mediator of the trade-off between investing in male-male aggressiveness or in paternal care [30, 31]. Decreased T levels in response to paternal investment were observed in monogamous fishes, birds and mammals [32-35]. In humans too, the T of new fathers was observed to decrease in response to the birth of their infants [16].

5.1.2 *Progesterone in male vertebrates*

We will also present and discuss the results of measuring P in the human males’ saliva. P is a gestagen known for its role in the female cycle. It induces female sexual behavior and regulates receptivity in intact female mammals [36]. Furthermore, it plays an important role in the priming of maternal behavior [37]. Although less prominent than androgens, P is produced in large quantities in the male testes, as well as in the adrenals [38, 39]. In

birds sex-specific differences were reflected in the seasonal timing of P fluctuations rather than in the amplitudes [38, 40]. In free-living Greylag geese P was higher in unpaired than in paired males throughout the year, in fall the male singletons' P was even double that of all females [41]. The P molecule (C_{21}) is an obligate precursor of androgens (C_{19}), as well as of glucocorticoids (C_{18}). However, this does not explain why male gonads produce (and also excrete) relatively high amounts of P. Thus, its function in male sexual behavior remained an open issue so far. In male rats, mice and lizards copulatory behavior is only expressed when both, T and P act in conjunction, which is facilitated by sexual experience [42]. Studies in male rats suggested that P induces social tolerance [43]. The presented P patterns may add to postulate it as another "male sex hormone" and to unravel its interactions with the social environment.

5.1.3 *The hidden structure of hormone-behavior interactions*

The novel approach we have used to statistically process the interaction between hormones and behavior was the detection of hidden real time patterns using THEME [44, 45]. THEME detects and analyzes repeated non-random time-patterns hidden within complex real-time records. Each time-pattern is a repeated chain of a set of behavioural events characterized by fixed event order and/or co-occurrence. Time distances (≥ 0) between the consecutive events are significantly similar in all occurrences of the chain [44, 45]. In our context, an important aspect of this pattern type is that its definition does not rely on cyclical organization, i.e. the full pattern and/or its components may or may not occur in a cyclical fashion. This method allows processing the repeated measures of a large number of variables per individual. Because it simultaneously takes into account the sequence and the relative timing of events, it enabled us to translate and reduce the accumulation of data into new operational units to be compared between social categories. Thus, in our example, THEME depicted those hormone peaks that were specifically co-occurring with one or more behavioural events over the sampling period, rather than processing all hormone peaks observed in that individual. The pattern characteristics we took into further analyses were (1) the complexity of interaction patterns, (2) the proportion of all time patterns that involved a significant interaction between a T or P peak and a behavioural event (e. g. sexual activity), (3) the sequence of the co-occurring events (i.e. was the behavior observed prior to the hormonal response, or was a hormone peak observed prior to the behavior), and (4) the frequency of occurrence of the most complex pattern. In short, the method as applied in this study may be regarded as a way to reduce the number of variables and process it as individual characters of repeatedly measured time patterns.

One disadvantage of using this approach is that some of the information may get lost. To set up using THEME, the original data have to be translated into temporal events along a time axis, for example, the days with occurrences of peak concentrations in the saliva. With regard to continuous variables such as the salivary hormone concentrations from 90 consecutive days, information may get lost. We chose peaks rather than troughs because the focus of this study was on T responses to sexual activity. For the days between two peaks, however, the only measure processed was the interval between two peak events, while the fine-scale of eventual hormone fluctuations was not taken into account. This is a major disparity to using conventional correlation coefficients. The benefits of applying the hidden time-pattern analysis to study hormone-behavior interactions, however, outweigh this gap by far.

5.2 Study subjects and methods

Twenty-seven adult, anonymous and volunteer males collected daily morning saliva samples for a period of 90 days using salivette devices (Sarstedt). Each candidate was provided with a sampling package, which included 90 salivettes labeled for each day, 90 “daily questionnaires” to be completed every evening and a singular “general questionnaire” to be filled in once. At distribution of the sampling packages, the candidates randomly drew a number, and were thereafter treated anonymously. The anonymity of the candidates was an essential feature to communicate at this point. Self-reported male sexual activity rates are likely to be overrated or spurious. Additionally, it seems that almost everyone ever sampled wanted to have a lot of T [46]. Therefore, we pointed out to the candidates that we were interested in studying the days in which they felt stronger or weaker, and not who was the “superman” as compared to the others. Mean age of the candidates was 33 ± 1 years (ranging from 23 to 47 years). We included men from various professions (workers, employees, students, and professors) and from different environments, eighteen candidates lived in urban settings (Vienna, Austria and Bergamo, Italy), and eight lived in a rural environment (Austria; hometown with less than 5000 inhabitants).

5.2.1 Hormone sampling

The mode of saliva collection was introduced to the males. To standardize variation due to daytime [12, 47] and to avoid contamination of the samples by food, drink or toothpaste, saliva was collected every morning right after waking up. Candidates stored the samples at their houses at -20°C until further processing. All of them started their sampling periods between May and June 1998 to minimize the potential effects of season on T patterns [48].

Immunoreactive T and P equivalents were assayed from a total of 2190 saliva samples by enzyme immunoassay (EIA) following the methods as outlined in Hirschenhauser et al. ([18] for T; [41] for P).

5.2.1.1 Gonadal origin of progesterone

In male vertebrates the source of P may be gonadal or extra-gonadal. In addition, P is an obligate precursor for both, T, an androgen secreted from the hypothalamus-pituitary-gonads axis, and cortisol, a glucocorticoid secreted from the hypothalamus-pituitary-adrenals stress axis. To clarify the origin of the salivary P measures, we recruited another nine men (mean age 42 ± 4 years) to collect daily morning saliva for seven days. From each of these samples, we assayed T, P and cortisol equivalents. The results clearly indicated that the P levels measured in the saliva were correlated with the gonadal T levels, rather than with the adrenal glucocorticoid levels (Figure 5.1). We are, therefore, confident that the observed P patterns were secreted by the gonads.

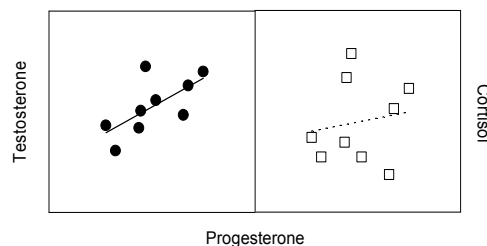


Figure 5.1 Men’s salivary progesterone levels were correlated with testosterone (left panel: $r_s = 0.7$, $p < 0.05$) but not with cortisol (right panel: $r_s = 0.6$, NS). Individual median levels in ng steroid per ml saliva are shown ($N = 9$).

5.2.2 Behavior sampling

Self-reports of each day's eventual sexual activities (including masturbation) were recorded using a "daily questionnaire" to be completed every evening. Furthermore, the candidates were asked whether sexual activity occurred with a familiar partner, and had to indicate the intensity of the sexual activity by intuitively placing a mark along a scale of 50mm, where "0" represented low intensity and "50" indicated very intensive sexual activity. As environmental parameters, weekends and full moon intervals were coded post-hoc by the authors. Daily behavioural events, as well as the environmental parameters were then analyzed for their co-occurrence with T and P peaks.

A singular "general questionnaire" was collected to assess information on the males' life history traits, such as being paired, the pairbond duration, whether they were fathers already, whether they had the wish to have children with their current partner ("wannabe fathers") or "not with this partner", on sharing the household, polygynous mating strategy (men who had reported sex with more than one partner during the 6 months preceding the sampling period), and on their sexual history (up to 5, up to 10, or more than 10 previous sexual partners). The life history traits were used as social categories for the elaboration of the social context of the occurrence of non-random hormone-behavior patterns.

5.2.3.1 Hormone-behavior interactions: conventional approach

To underline the benefits of using THEME to analyze hidden real-time patterns we also demonstrate how far we could get by analyzing the data with conventional analyses of variance and correlation statistics. Because we had to deal with a large number of variables sampled repeatedly over a 90-day period we were restricted to calculate with derived measures of individual variability, such as individual mean hormone levels, the individual maximum amplitude observed, or the individual coefficient of variation throughout all days sampled. Using these measures one may conclude about the hormonal status of some general demographic and life history prototypes.

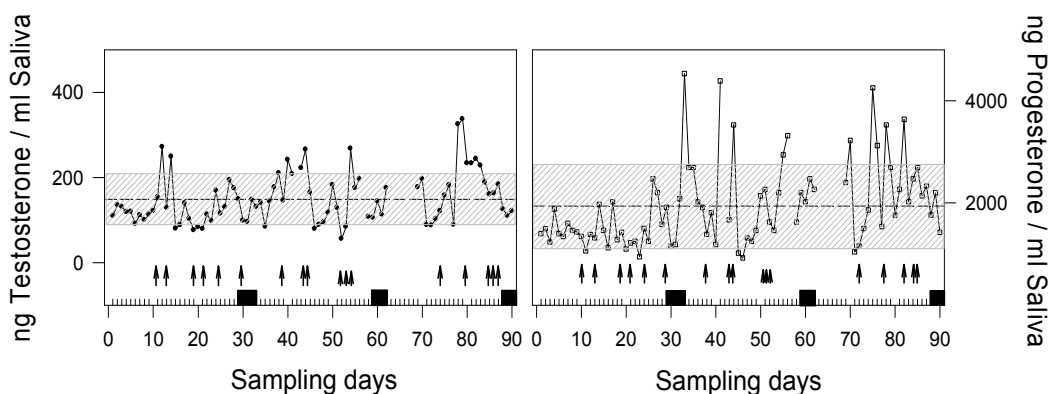


Figure 5.2 Example of one individual's testosterone and progesterone patterns over the 90-day sampling period. Shaded areas represent the individual mean \pm standard deviation. Peaks were defined as testosterone and progesterone levels greater than or equal to the individual mean plus standard deviation. Arrows indicate days with reported sexual activity of intensity greater than 35 and black bars are the menstruation periods of the female partner.

5.2.3.2 Hormone-behavior interactions: Time-patterns

Days with peak occurrences were recoded from all hormonal and behavioural variables, and thereby between-males variation of amplitudes was not subject of the subsequent

analyses. A peak was defined as a T or P level \geq individual mean + standard deviation [49] (Figure 5.2) and as sexual activities of intensities greater than 35 (data above the third quartile).

To perform THEME-analyses on the repeated measurements of each individual the number of actors was one in this study. A minimum of three repeated pattern occurrences throughout the 90 days sampled and a $p < .05$ significance level were specified. THEME identified time periods when, for example, T peaks and sexual activity co-occurred. The detection of a non-random time-pattern may, thus, be regarded as a measure of the interaction between T and sexual behavior or of the co-occurrence with an environmental parameter. From the numerous detected non-random time-patterns per individual the “frequency of occurrence” (N occurrences divided by the total duration of the sampling period) of each male’s most complex pattern within the 90 days was derived. The frequency of occurrence was compared between those 22 candidates in whom THEME detected patterns involving both, hormonal and behavioural variables.

5.2.4 *Social and environmental context of observed testosterone- and time-patterns*

To compare an estimate of the individual degree of hormonal responsivity to a specific behavior, the proportion (%) of all time-patterns that involved a significant interaction between the focal questioned hormone-behavior interactions was determined per individual. In order to elaborate a possible prevalent direction of the interaction, time-patterns ranking the T peak before the behavior were distinguished from those ranking the behavioural event before the T peak. To compare observed time-patterns that involved regular environmental parameters, the number of detected time-patterns that involved weekly intervals (i.e. Saturdays) and monthly intervals (i.e. the 28-days intervals between full moons) were determined per individual and compared between life history categories.

Number of individuals may vary among the different analyses because the “daily questionnaires” of five candidates were not returned and thus, missing, and two “general questionnaires” were incomplete. Therefore, time-patterns involving hormones and behavior were available from 22 males; comparisons between different social categories could be performed among 21 males, and comparisons between children-related parameters among 20 males. Phenologies and “environmental parameters”, such as weekly or monthly intervals, were independent of the number of returned daily questionnaires and, therefore, available from 27 males. Means \pm standard errors were used for all descriptives. To control for the possibly confounding effects of season, sampling time, age [24, 48], and pairbond duration, Spearman’s rank correlations were employed. Temporal sequences of the observed interactions between T and behavior were compared using Wilcoxon tests matched for individuals. The comparisons between social categories were performed using Mann-Whitney U tests. All probabilities were two-tailed.

5.3 **Results and Discussion**

5.3.1 *Phenology of hormone patterns*

5.3.1.1 *Testosterone*

On average 86 of the 90 requested daily morning saliva samples were delivered ($N= 27$). Amplitudes of the observed individual T fluctuations varied to a high extent over the sampling period (1100 ± 100 ng/ml) with a mean coefficient of variation of 50%. However, the T variation observed in this data set was not due to effects of season,

sampling time, age or pairbond duration [18]. Thus, although not ideal, these data reflect daily patterns of morning T levels in 27 healthy men monitored over a three months period.

5.3.1.2 Progesterone

Also the amplitudes of the observed individual P fluctuations varied to a high extent over the sampling period (4400 ± 500 ng/ml) with a mean coefficient of variation of 45%. Remarkably the amplitudes of the salivary P levels were on average 4-times those of the T amplitudes measured from the same samples (Figure 5.2). As with T, the P variation observed in this data set was not confounded by season, sampling time, age or pairbond duration.

5.3.2 Hormone-behavior interactions: Conventional approach

5.3.2.1 Social context of testosterone and sexual behavior

The comparison of simple mean T levels and of individual coefficients of variation did not yield any difference between the assessed life history profiles. However, the individual T peaks of men from rural environments were generally larger than of men living in urban settings. There were no differences between the individual T amplitudes due to any of the other social categories.

A general interaction of T with parameters in a direct sexual context was observed. For example, in the seven men who reported sexual activity with an unfamiliar partner salivary T of the next morning was on average 25 ± 14 % (ranging from -30 to 230 %) higher than their individual average levels. Even more amplified, T amplitudes of the six candidates who reported sexual activities with more than one partner within the preceding 24 hours were on average 120 ± 29 % (ranging from -20 to 360 %) larger than their individual average T levels.

In rural towns anonymity is missing and communicative interactions are more limited to the available actors. The large T peaks we found among rural inhabitants may reflect a strong sensitivity to, for example, sexual, territorial or competitive stimuli. The fact that urban men had lower T peaks is plausible in the light of the anonymity, hyper-stimulation (from advertisement walls to fashion style), and higher physical densities that men in urban settings have to cope with. As men living in urban settings are permanently exposed to these stimuli, their responsivity was probably more saturated than in the countryside men. Imagine a woman passing by in short skirt and skinny top on a hot summer day. If this took place in a rural village, it would provoke a clear response among the men of any age. If the same lady was walking along the streets of a big city, it would not necessarily be extraordinary or provoking, because in cities this simply happens more often.

Surprisingly, we did not find higher T levels in singles than in married men, which have been suggested in the literature [50]. However, Booth & Dabbs had shown in this long-term study that high T levels were prerequisites of the life history rather than being modulated by the men's social environment. Although such results are of interest, they simply deal with the characters of one variable, i.e. T levels, not taking into account the potential modulators of the focal variable. We will present in chapter 5.3.3. how different the THEME approach worked.

5.3.2.2 Social context of progesterone and sexual behavior

Although human males' P was not necessarily predicted with a direct sexual context, we observed some curious P responses to "unexpected" sexual activities. For example, if the men reported sexual activity with an unfamiliar partner, salivary P of the next morning was on average 40 ± 19 % higher than their individual average levels (ranging from -20 to 300 %). Moreover, in cases where they reported sex with more than one partner within the

preceding 24 hours, P peaks were on average 50 ± 23 % of their individual average level (ranging from -50 to 350 %).

As with the T data, comparing simple mean P levels did not show any differences between the assessed life history profiles. However, the individual P variability (coefficients of variation) was higher in singles than in paired men, and the P peaks of men who had rated their relationship as “unofficial” (secret partner) were larger than those of men with official commitment to their relationship .

Human males’ P was indeed involved in sexual behavior, which matched the results from rats [42]. Although this was observed particularly in “unexpected” or “secret” episodes, so far, we had found no effect of sexual experience, and a direct measure of “social tolerance” was not provided by our questionnaires. At this point drawing a consensus from our results would have been highly speculative. Yet, we were puzzled by the unknown degree of interaction between T and P levels. Therefore, we assembled individual correlation coefficients between each male’s T and P levels over the total sampling period. In 82% of all males the T-P correlation coefficients were significant. Comparisons between life history parameters revealed that the parallel nature of the T and P fluctuations was decreasing with sexual history. Men who had reported to have known more than ten previous sexual partners had on average correlation coefficients of $0.2 (\pm .06)$ as compared to an average of $0.6 (\pm .04)$ among those men who reported up to ten previous sexual partners. Thus, there may be potential insights in focusing on the interaction between male T and P levels, rather than analyzing each hormone per se.

5.3.3 *Hormone-behavior interactions: Time-patterns*

5.3.3.1 *Testosterone*

Structure of time-patterns involving testosterone. THEME detected a total of 1641 non-random time-pattern combinations that involved T (75 ± 16 per individual, $N = 22$). The percentages of all detected time-patterns involving T (*diversity*) occurred more frequently in “wannabe fathers” than in those males who had no partner or did not want to have children with their current partner. No variation of the time-pattern diversity was observed due to any of the other investigated social categories. This pattern will return in the following steps of analyses, as we are yet going to filter out those time-patterns which involved T peaks specifically related to intense sexual activity, rather than elaborating any event combination ever observed.

THEME detected a large variety of numbers of co-occurring events in the most complex time-pattern (with a range of 3 to 28 events; *complexity*). However, none of the assessed social categories explained any of the observed time-pattern complexities. In the majority of candidates (19 from 22 males) the most complex patterns occurred with a frequency of .03, i.e. three times throughout the sampling period (Figure 5.3).

Social context of time-patterns involving testosterone. An interaction between T and sexual activity was detected in 75% of all time-patterns that involved T (59 ± 13 per individual; total number = 1238). The proportions of all time-patterns that involved T and sexual activity were not different between singles and paired men, and also not between non-fathers and fathers. However, the specific interactions between T and sexual activity were more frequent among “wannabe fathers” as compared with men who had no partner or did not want to have children with their current partner (Figure 5.4AC).

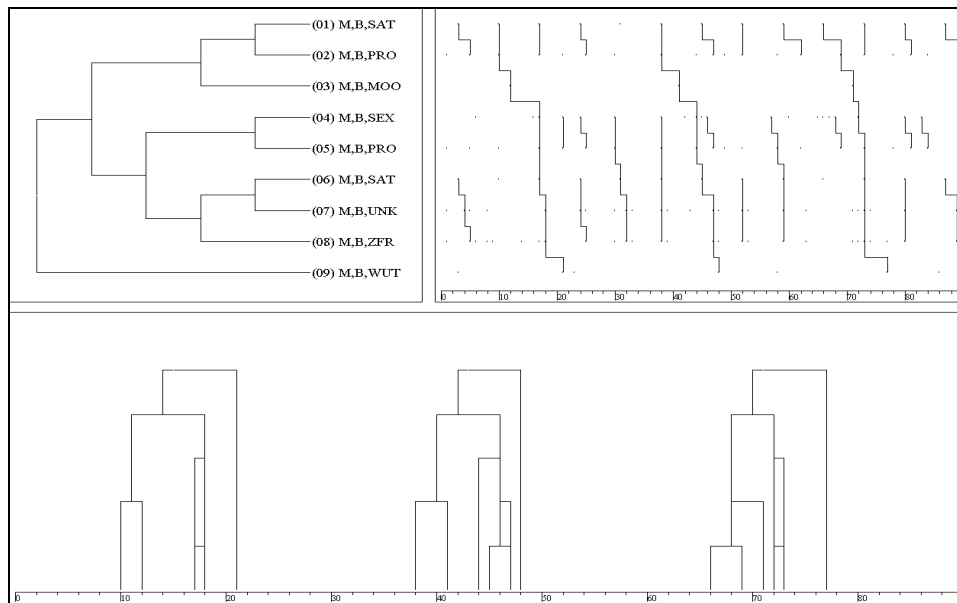


Figure 5.3 Example of a complex time-pattern involving nine event types with a monthly frequency of occurrence (i.e. three times during the sampled 90 days). Upper left panel shows how the pattern was detected level by level. Upper right panel gives the occurrence times of each event type as a series of points. The lines connecting the occurrence times show, how the pattern has been gradually built up. Lower panel visualizes the frequency of occurrence along the total sampling period.

To elucidate the temporal sequence of the observed interactions, the proportions of all observed time-patterns that involved the morning T peak preceding a behavioral event during the day were compared with those that involved the behavior reported from the day preceding a next morning's T peak (for an example see Figure 5.2) in all candidates. Interactions between sexual activity and T were observed at equal rates in either direction [18]. Therefore, the presented time-patterns were not to be regarded as interactions with one prevalent direction, but rather represented a high degree of a two-way type of interaction between sexual behavior and T levels in all males sampled.

Environmental modulation of time-patterns involving testosterone. Time-patterns involving T and weekly intervals (i.e. Saturdays) were observed in 89% of all males. THEME, furthermore, detected time-patterns involving T and monthly intervals (i.e. the 28 days period of full moon phases) in 15 of 27 males, ranging from one to 15 pattern combinations per individual. Because this interval echoes the average length of the female cycle, we expected to find this interaction in paired rather than in unpaired men. Surprisingly, the observed variation of male monthly time-patterns could not be explained by being paired or not (Fig. 5.5A). However, as already observed for the interaction with sexual activity, also the T peaks interacting with monthly intervals occurred significantly more frequent in "wannabe father" as compared to those men who had no partner or did not want to have children with their current partner (Figure 5.5C). There was no difference between the occurrences of monthly T patterns of non-fathers or fathers and also not due to any of the other investigated life history parameters.

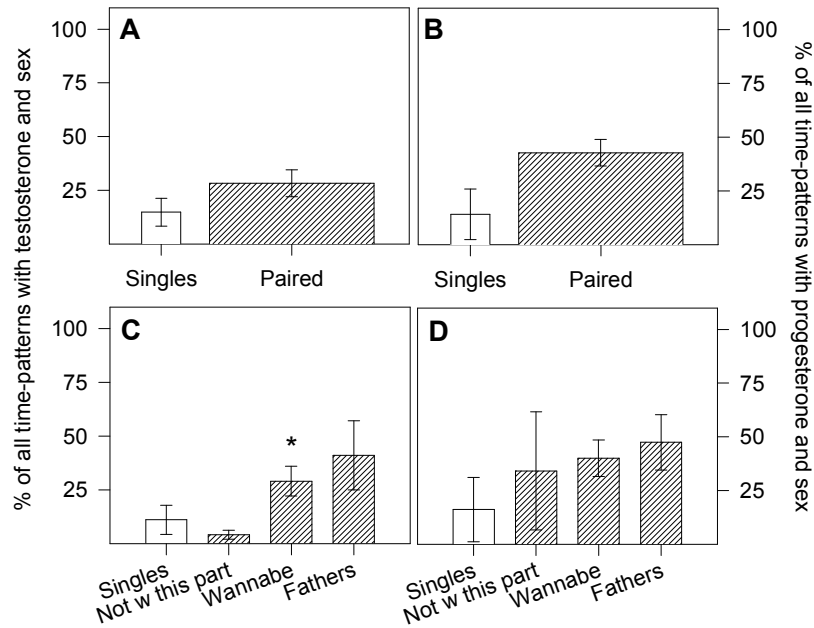


Figure 5.4 Proportion of all time-patterns involving (A) testosterone (T) or (B) progesterone (P) and sexual activity occurred at equal rates in singles and in paired men. (C) “Wannabe fathers” showed a larger proportion of time-patterns that involved T and sexual activity (in either sequence) than singles or those who did not have the wish to have children with their current partner. This was not the case with (D) the proportion of time-patterns involving P and sexual activity. Asterisk indicates a significant effect ($p < 0.05$).

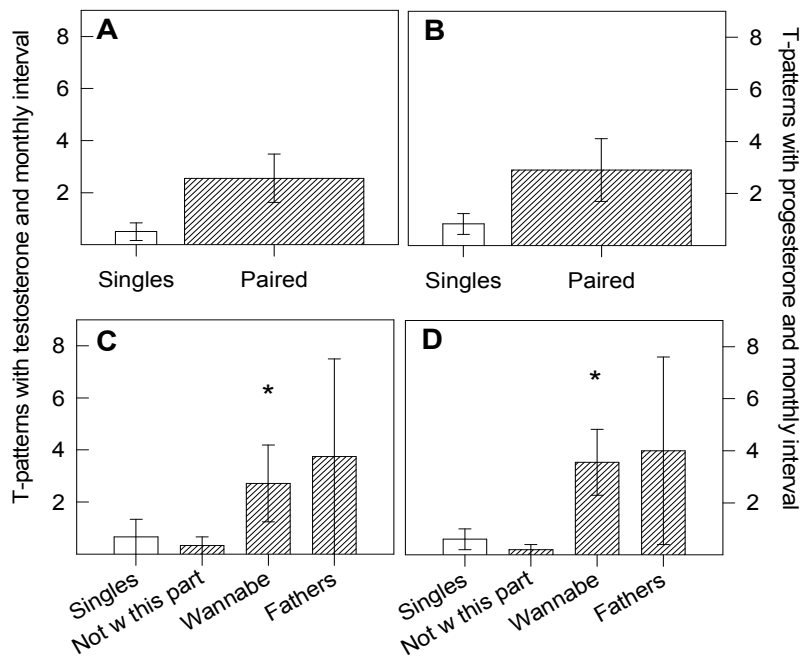


Figure 5.5 The number of detected time-patterns that involved A) testosterone (T) peaks or B) progesterone (P) peaks at monthly intervals per individual. The differences between singles and paired men were not significant. In “wannabe fathers” THEME detected more time-patterns that involved C) T and D) P at monthly intervals than in singles or those who did not wish to have children with their current partner. Asterisks indicate significant effects ($p < .05$).

5.3.3.2 Progesterone

Structure of time-patterns involving progesterone. THEME detected a total of 1895 non-random time-pattern combinations that involved P (86 ± 18 per individual, $N= 22$), which was an even larger number than with the time-patterns involving T. The percentages of all time-patterns involving P increased with the men's commitment to the relationship, with single men at the lower end and wannabe fathers and fathers at the upper end. However, this was less pronounced than with T. Interestingly, we observed a higher proportion of time-patterns with P among monogamous ("faithful") men than among polygynous men. In contrast, the P diversity was equal in singles and paired men as we had already observed with the time-patterns involving T.

Social context of time-patterns involving progesterone. An interaction between P and sexual activity was detected in 66% of all time-patterns that involved P (59 ± 12 per individual; total number = 1247). The proportions of all time-patterns that involved P and sexual activity did not differ between singles and paired men, and also not with regard to wannabe fathers (Figure 5.4BD). Monogamous ("faithful") men had a higher degree of interaction between P peaks and sexual activity than the three men who had sex with more than one partner during the six months preceding the sampling period ("polygynous"), however, this result was flawed by the very small sample size. Sexual history, rural or urban living, and shared or own household had no effects on the proportion of time-patterns with P and sex.

Environmental modulation of time-patterns involving progesterone. Varying numbers of time-patterns with P peaks at weekly intervals (i.e. Saturdays) were observed in 82% of all males. Time-patterns involving P peaks at monthly intervals were detected in 15 of the 27 candidates, with a range from one to 22 pattern combinations per individual. As with the T and monthly interval patterns, also the P and monthly intervals patterns were not simply due to being paired or not (Figure 5.5B), but were clearly more frequent among wannabe fathers than in singles or those men who did not wish to have children with their current partner (Figure 5.5D). None of the other investigated life history parameters had an effect on the occurrence of P peaks at monthly intervals.

5.4 Conclusions

5.4.1 Facultative potential for monthly patterns of hormones and sexual behavior

The social context of androgen fluctuations is not a new concept in non-human behavioral endocrinology [6, 30, 34, and 51]. However, studies on the social modulation of T response patterns in human males suffer from the complexity of social interactions and from the ethical restriction of designing controlled studies in our own species. Here, the application of THEME analyses [44, 45] resulted in time-patterns that may be regarded as measures of the co-occurrence of T with sexual behavior. Such time-patterns also provide information on the temporal sequence of the parameters involved. Dabbs and Mohammed [28] found that sexual activity affected T more than initial T affected sexual activity, where saliva samples had been collected immediately before and after sexual activity. In this study, on a daily morning base, no prevalent direction of the relationship between T peaks and sexual behavior was detected, rather there seems to have been a high degree of mutual interaction.

The existence of a regular cycle of hormones and sexual behavior in human males was an open question so far and the results of this study did not support the hypothesis. The known peak of sexual intercourse in couples around weekends [5] was reflected in the presently observed co-occurrences of sexual activity and T with weekends. This does not point at a male cycle in any parameter, but rather at the males' hormonal responsiveness to sexual activities. With regard to a potential male responsiveness to the 28-days interval of the female's menstrual cycle, one would expect to observe such response patterns in paired men rather than in singletons. Our results, however, did not confirm this prediction. The occurrences of observed time-patterns that involved T at monthly intervals differed due to the reproductive context of and commitment to the males' relationship to a regular partner, rather than to being paired per se. In specific, the wish to have children with a current partner explained both, the observed degree of interaction between T and sexual activity, as well as the occurrence of monthly intervals in the males' T fluctuations. Thus, men who had revealed a reproductive context to the sexual activities with their partners showed different T response patterns than men who reported sexual activities without commitment to reproduction.

As 75% of all time-patterns involved an interaction between T and sexual activity one may argue that these similarly emerging pictures are to be regarded as simple artifacts of a higher diversity of time-patterns in general. However, there was no similar result observed with time-patterns that involved T and weekly intervals or with the frequency of occurrence. Furthermore, an effect of using oral contraceptives, which affects the regularity of the female's 28-days period, may be excluded from this study, because its use was only reported in two cases. We also controlled for a possible effect of sharing the household with a partner, but there was no difference in any of the parameters between paired men living in shared households versus paired men living in own (single) households. Therefore, the observed patterns between T and sex, and the monthly interval of these interactions in "wannabe fathers" may point at the males' facultative hormonal and behavioral responsiveness to their female partner's cycle. We suggest that our results reflected the indirect responses of "wannabe fathers" to their female partners' regular monthly cycles, rather than internal male rhythms. However, we want to clearly point out that the speculation that men who have no wish to have a family with their current partner might remain hormonally and psychologically unresponsive to their partner's fertility phase seems not trustworthy. This is by no means an option for contraception, and it also does not solve the causality of unsuccessful trials to have a baby or shift it to the male side.

5.4.2 Progesterone as another male sex steroid

Both, T and P characteristically co-occurred with sexual activity in a large proportion of the sampled men, which suggests regarding P as another male sexual steroid. Particularly, P-responses were involved in "unexpected" or "secret" episodes. P is an obligate precursor for T, found in up to 10-fold larger amplitudes than the T in saliva (Figure 5.2), and the levels of both were positively correlated in our sample (in 82% of all males sampled). We, furthermore, explored whether life history parameters would explain any of the observed variation of the degree of correlatedness. Fascinatingly, the males' sexual history had an effect on the parallel nature of the T and P fluctuations, with those men who had reported more than ten previous sexual partners at the lower end. This gave a first indication that sexual experience may be involved in human males' P, as was postulated for rats before [43]. It remains open to test the social component of human males' T-P-interactions in further detail. However, using THEME, an effect of social categories was only found for the interaction between T and sexual activity, with larger proportions in wannabe fathers than in singles. The detected time-patterns involving P and sexual activity did not vary due

to any of the presently investigated life-history parameters (Figure 5.4CD). We concluded that, although P peaks were co-occurring with sexual activities in more than thousand time-patterns, no social component was related with it.

On the other side, the occurrence of time-patterns involving P peaks at monthly intervals was clearly increasing with the males' commitment to their current relationship. Thus, without including sexual activity events the P patterns were matching the observed time-patterns involving T at monthly intervals (Figure 5.5). At this point it is important to mention that the 28-day full moon intervals did not have to indicate that the sexual activities were peaking exactly in those full moon nights. The interval simply worked as a *Zeitgeber*, we may as well have detected regular events at half moon, or new moon, for example. The same applies for Saturdays that were used as *Zeitgeber*s for a possible weekly interval in hormones and behavior. The curiously large proportions of candidates with regular weekly patterns of T (89%) and P (82%) were not necessarily representing the "Saturday night fever". The weekly interval may as well have indicated that it was, for example, Tuesday or Friday evenings or mornings. Which day of the week ever, the men in our sample seemed to have rather regular life-styles, at least concerning their sexual lives.

5.4.3 *"It takes two to tango": future directions*

Alternatively, the candidates' wives may have been the ones living at a regular pace, and the male patterns we measured would then reflect the men's responsivity to their partner's pace. The current study exclusively sampled the male side. However, this probably represented only half of the picture and including the female side into a follow-up study should be the logical next step from here. As "it takes two to tango" it would be most exciting to investigate the "within-pair" patterns of hormones and behavior by monitoring the female partner's cycle and asking her details in daily questionnaires simultaneously with what we had asked from the men in the current study.

The concept that males may potentially respond and adapt to their partners' hormonal and fecundity phases, has been proposed before. In small mammals rapid, but long-lasting oxytocin increases were found in both partners during pair formation [13, 14]. In a socially monogamous bird the within-pair T co-variation between the male and the female partners' seasonal levels was reflecting the pair's reproductive success [15]. Human males' T was shown to correspond with the partner's sexual responsivity scores [11]. Recently, Storey et al. [16] reported that T of expectant fathers was specifically related to the women's hormone levels, rather than to the time before birth. Taken together, these phenomena are based on mechanisms associated with social monogamy, including affiliation, paternal care and pair bonding. The males' wish for children with a specific partner, which led to the distinction of "wannabe fathers" in this study, may be regarded as one possible approach to express the intensity and the subjective perception of a pair bond in human males. One might even speculate that "wannabe fathers" had to invest into mate-guarding more intensively and therefore, were responding more specifically to their partners' behavior than, for example, men who had a sexual partner but were not willing to invest into parental care with this partner. This "mate-guarding hypothesis" among human males remains one more exciting field for future research.

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