

Tiziana Perini

Biopsychology of Transition to Fatherhood



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Nonnenstieg 8, 37075 Göttingen

Telefon: 0551-54724-0

Telefax: 0551-54724-21

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Abstract

The focus of this work was on fathers across the transition to fatherhood. The purpose of the empirical studies was to explore the association of testosterone (T) and paternal investment including interpersonal differences in personality traits and relationship quality. Providing paternal care is associated with a reduced likelihood of engaging in competitive or mating behavior and also of providing protection when necessary. T is a psychobiological marker of reproductive behavior.

Recent studies found decreasing T levels in males across the transition to fatherhood, in order to reduce mating effort in favor of providing paternal care. In addition, there is empirical evidence for reducing relationship quality in parents across the transition to parenthood. Therefore, a direct association of T level and relationship quality was suggested. Moreover, researchers have assumed that sensation seeking (SS) is associated with both mating effort and T. For this reason, the personality trait SS was included in further investigations of the second study of this work.

Thirty-seven fathers and 38 men in committed romantic relationships without children (controls) were recruited. On two days (four weeks prior to (t1) and eight weeks after birth (t2) for fathers, and three months after the first measurement day for controls), all subjects repeatedly collected saliva samples for T measurement at three times of the day, filled in a protocol of activities and completed online questionnaires.

In the two empirical studies presented in this work, the following main results were obtained: In line with recent studies, fathers showed significantly lower T levels (AUCg-T) than controls at t2; moreover, fathers showed a significant decrease in relationship quality, whereas relationship quality of controls did not change significantly over time. In particular, the values of the subscale Tenderness decreased significantly in fathers from t1 to t2. Furthermore, the T level at t1 interacted with the change in T level from t1 to t2. This interaction was

associated with the extent of decrease in Tenderness during the transition to fatherhood. Since Tenderness, including sexuality, might reflect aspects of mating effort, these results corroborate the “challenge hypothesis” in humans, whereby T level is positively associated with mating effort and negatively related to paternal activities. In the second study, linear regression revealed a significant interaction between group and SS, meaning that SS moderates T levels across the transition to fatherhood. Fathers with low SS showed a significant change in the diurnal fluctuation of T from t1 to t2, whereas the diurnal fluctuation of T in fathers with high SS did not change significantly. In conclusion, the transition to fatherhood is associated with a reduction in the extent of diurnal fluctuation of T for fathers with low scores in SS.

Given the inconsistencies in empirical evidence in research on the transition to fatherhood and the potential importance for understanding paternal behavior, with its correlates of endocrinological aspects, the studies of this work are the first to combine psychological and endocrinological aspects in a longitudinal design and to compare potential changes and associations with a matched sample of men without any children as controls.



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1 Introduction

Few mammals show paternal care, and humans are among those that do. The fewer the number of offspring over the lifetime, the more important the paternal care, including many specific kinds of behavior. So far, a wide range of research has been conducted on the transition to parenthood. Research has focused mainly on parents and the influence on the development of the child during pregnancy (i.e. course of pregnancy, age of mother, and drug abuse during pregnancy) or after the birth (i.e. attachment of mother and child, personality factors of mother) (for an overview: Bleich, 1996).

A psychobiological marker of paternal behavior is testosterone. Recent research found that testosterone in fathers-to-be decreases from the time before the birth of their first child to the time after the birth. Storey, Walsh, Quinton and Wynne-Edwards (2000) found 33% lower T levels three weeks after compared with three weeks before the birth of their child. Moreover, Gray, Kahlenberg, Barrett, Lipson and Ellison (2002) found a significant decrease in T levels one week after as compared to one week before birth. No psychosocial variables were included in these analyses.

In animal research, there is clear evidence that differences in specific reproductive strategies are strongly associated with either monogamous or non-monogamous living species (Wynne-Edwards & Reburn, 2000). Basically, a distinction is made between the reproductive strategies of species with few offspring (qualitative reproductive strategy) and of species with many offspring (quantitative reproductive strategy). Especially from the male perspective, there are large differences in the specific behavior depending on reproductive strategy. For example, in mammals, which have few offspring, paternal investment sometimes is very intense in order to enhance the survival rate of the offspring. Some specific hormones are assumed to affect pair bonding and paternal investment. In males, this refers primarily to androgens and especially testosterone.

Humans pursue a qualitative reproductive strategy, since they can only have a small number of offspring in their life. Therefore, high paternal investment makes sense and is of absolute importance in order to support the survival of the offspring. Although cultural and social aspects play an important role in human behavior, there are also interindividual differences in the amount of paternal investment in the same culture. Beside cultural aspects and social circumstances, hormones such as T affect specific reproductive behavior in men. An interaction between hormones and behavior is suggested. On the one hand, hormones do not affect behavior directly, but constitute a disposition that makes different specific behaviors possible depending on situational and psychosocial context, and on the other hand, specific behavior affects hormones.

Pair bonding and relationship status are important psychosocial variables, with previous research finding an association between relationship status and T. Different studies demonstrated lower T levels in men living in a committed romantic relationship compared with single men (Burnham, Flynn, Chapman, Gray, McIntyre, Lipson and Ellison, 2003; Gray, Campbell, Marlowe, Lipson & Elliot, 2004; Mazur & Michalek, 1998; van Anders & Watson, 2006b). However, there is no evidence for a direct influence of a romantic relationship on T, since recent research found inconsistent results about cause and effect of T levels and relationship status. For example, Van Anders and Watson (2006) conducted a longitudinal study and verified the hypothesis that T level acts as a trait rather than as a state. They found that men with lower T levels at a first measurement point ended up to be more likely to live in a committed romantic relationship about one year later, compared with men with higher T levels at the first time of study assessment. In addition, Burnham et al. (2003) found even lower T levels in fathers compared with men in a committed romantic relationship without children.

The aforementioned association of decreasing T levels in males across the transition to fatherhood has been intensively examined in animals, and most studies corroborate this association. Early on, Wingfield, Hegner, Dufty and Ball (1990) developed the challenge hypothesis, and this effect was also found in humans. Several studies were able to verify the decreasing T levels in fathers-to-be (e.g. Storey, Walsch, Quinton & Wynne-Edwards, 2000; Gray, Kahlenberg, Barrett, Lipson & Ellison, 2002).

The purpose of this work was to explore the interaction of T and paternal investment by taking into account interpersonal differences in personality traits and relationship quality. The focus of the study refers to the transition to fatherhood, because this sensitive phase represents an important challenge and demands adaptation processes in the context of paternal investment. As there are cultural differences concerning pair bonding and paternal care, we focus on the culture in Middle Europe, i.e. the subjects of the studies all live in Switzerland and most are Swiss-born citizens.

Following this, we compared a sample of fathers-to-be with a sample of men (controls) living in a committed romantic relationship without children and in which the female partner is not pregnant. In our first study, we explored the effect of the transition to fatherhood on T levels, relationship quality, and the association between T levels and relationship quality in men over the period of transition to fatherhood. These effects are analyzed in a longitudinally designed study, by assessing data on two days, one before and one after the birth of their first child, respectively, and analogously for controls with three months in-between.

In a second study, we were interested in different effects of transition to fatherhood depending on the personality trait of SS, as SS is assumed to reflect mating effort and to be related to T level. As there is evidence that providing paternal care is associated with a reduced likelihood of engaging in competitive or mating behavior and with a reduction in T levels, we hypothesized that the transition to fatherhood has a different impact on T level

depending on the SS score of fathers. Again, these assumed effects were analyzed in a group of fathers-to-be and new fathers, respectively, in contrast to a control group with men in a committed romantic relationship without any children.

This work is structured in three parts. The first part provides a theoretical background containing definitions and discussions about current theories as well as a review of the state of research in this field. The second part will describe the two empirical studies; the first study is about T and relationship quality, and the second study refers to SS and T, both in relation to the transition to fatherhood. The final part of this work provides a summary of the key findings, which are further discussed. To finish, an outlook for prospective studies will be provided.

2 Theoretical Background

The aim of this chapter is to provide a theoretical background of the psychological factors and constructs as well as the endocrinological processes that are important in relation to the transition to parenthood and in particular to fatherhood. Moreover, this chapter provides a review of the state of research in this field, upon which the two empirical studies in the second part of this work are based. This chapter is structured according to psychological factors concerning romantic relationship, relationship quality, transition to parenthood, and the personality trait of sensation seeking and biological factors mainly concerning T and associations of psychological and endocrinological factors.

2.1 Romantic Relationship

2.1.1 Definition

The evolutionary function of romantic relationships in humans can be seen in sharing support in raising the offspring. Up to the late nineteen sixties, partnership and marriage were often 'partnerships of convenience', with the aim of shared duties of production and nurturing, including sexuality and reproduction. While reasons for romantic relationships have changed a great deal over the last few decades, they are still deemed as the most important social relationships. Mostly, romantic relationships are ranked as the most important value.

In a survey by Bodenmann (2003) with 300 young Swiss students, ninety-seven percent rated close friendship and romantic relationships as the most important issue, followed by health (89%), education and vocational career (81%), and money combined with prestige (35%). In the same survey, expectations of romantic relationships were explored. In this respect, participants rated fidelity and intimacy as the most important issues of a romantic relationship. Also important were issues such as compassion, appreciation, satisfying

sexuality and emotional security. Financial security and family were only rated as very important issues by fewer than 40% of the participants.

In this regard, Shaver, Hazan, and Bradshaw (1988) therefore described three systems: the attachment system, the care system, and the sexual system. Sexual attraction is important for the constitution of a relationship, and attachment and nurture are needed for stabilization of the relationship. Nowadays, if one of these three systems is lacking, or if the aforementioned expectations are not satisfied, partners feel unhappy, estimate their relationship as unsatisfactory and even break up. Therefore, research on romantic relationship quality is very important and is described in the next section.

2.1.2 Relationship Quality

The term relationship or partnership quality is based on marriage quality, as most research on romantic relationships has dealt with married couples. The first empirical studies on marital quality emerged in the 1930s. They explored the impact of several factors, such as role compatibility, age differences, education, socioeconomic status, personality, and expectations and attitudes towards marriage. Mostly, the focus was on the question of whether similarity or complementarity was best for marital quality (e.g. Posavac, 1971; Klohnen & Mendelsohn, 1998; Dryer & Horowitz, 1997; Markey, 2007). However, most results revealed that these factors did not significantly predict marital quality. Eysenck and Wakefield (1981) used questionnaires to explore 566 married couples with regard to their similarity in several factors. They found the following ranking for the factors influencing variability in marital quality: Most important was sexual behavior (58% of variability), followed by sexual attitudes (41%), data of individual life history (25%), personality (18%), and social attitudes (3%).

According to Spanier and Lewis (1980), high quality of marriage is defined by a high adjustment, an adequate communication, a strong commitment, and an intensive satisfaction

with the relationship. Bierhoff and Grau (1997, 1999) considered the duration of the partnership as another important issue for the quality of partnership. After all, there is evidence that the duration of the partnership is a better predictor of the stability and continuation of the relationship than relationship satisfaction or other psychological variables.

Taken together, there are three different, but highly related, approaches to relationship quality. First, relationship *satisfaction* is a subjective estimation of their relationship by both partners. Second, relationship *quality* is related to more structural issues of the couple, and to a more objective estimation by indicating issues on a continuum from good to bad (Spanier, 1976). The third approach focuses on the duration of the partnership and is named relationship *stability* (Dinkel, 2006).

Recent literature and research suggest the term of relationship *quality* as a subordinate concept concluding relationship *satisfaction* and relationship *stability*. For this reason, the term of relationship quality is used in the same way in this work.

So far, the explanation and predictability of relationship satisfaction and relationship stability have been the main focuses of research on romantic relationships (Gottman, 1998). Therefore, interpersonal conflicts and conflict behavior of couples have been well explored (Cahn, 1994; Spitzberg & Cupach, 1998). In addition, the quality and satisfaction of romantic relationships show variations over time. Mostly, a decline in the quality of romantic relationships over time, and especially during the first year, were reported in many studies (Glenn, 1990; Rollins & Feldman, 1970, Tucker & Aron, 1993).

2.1.3 Measurement of Relationship Quality

In this work, relationship quality is assessed using the validated German version of the Partnership Questionnaire (Partnerschaftsfragebogen: PFB, Hahlweg, 1996). This questionnaire contains 30 items and reflects three aspects of relationship quality: *Quarrelling*, which means a destructive way of coping with conflicts, *Togetherness/Communication*, including different aspects of bonding aspects such as shared activities, verbal exchange and openness and interest in the opinion of the partner, and *Tenderness*, encompassing positive sexuality, both physically and verbally.

2.2 Transition to Fatherhood

2.2.1 Definition

Transition to fatherhood means the period including pregnancy, birth, childbed and some weeks afterwards. Multiple changes and a great deal of energy are required of parents in this period. The main challenge for men is the adaptation to the paternal role, which requires a new definition and enlargement of the actual partnership as well as adaptation to new social roles and adjusting individual career plans. Even though the transition to parenthood is no longer seen as a critical life event but rather as a normative event, changes and adaptations demand considerable resources from both mother and father (Petzold, 1998). Besides the motherhood and the mother-child relationship, research on fatherhood and the role of fathers has been well established for the last two decades (Bronstein & Cowan, 1988; Cath, Gurwitt & Gunsbers, 1989; Fhenakis, 1985; Pedersen, 1989).

As for research methods, there is a trend towards longitudinal studies in order to compare stage-specific characteristics, challenges, and needs of resources. As yet, the majority of studies have been based on questionnaires. The first longitudinal study was conducted by Russell (1974). Results of this study were unable to corroborate the hypothesis that the reason for dyadic crisis was the new baby, but instead found economic reasons, such as tiredness, financial charges, and the relationship to friends and family. To sum up, the transition to parenthood creates a mix of consequences that require a great amount of adjustments and adaptations, but not all of them lead to distress (Cowan & Cowan, 1989; Huston & Vangelisti, 1995).

Gloger-Tippelt (1988) generated a description with eight phases regarding the transition to parenthood (see Table 1).

Table 1: Description of 8 phases for the transition period of first-time fathers-to-be by Gloger-Tippelt (1988)

Phases	Issues	Duration of Phases
<i>Pregnancy</i>		<i>Weeks of pregnancy</i>
1	Uncertainty	up to the 11th
2	Adaptation	12th - 20th
3	Concretization	21st - 32nd
4	Anticipation and preparation	32nd - 40th
<i>Birth</i>		
5	Phase of birth	Birth
<i>After birth</i>		<i>Months after birth</i>
6	Overwhelmed and exhausted	up to the 2nd
7	Challenge and adjustment	3rd - 6th
8	Adaptation	7th – 12th

The model starts with a first phase of uncertainty and ambivalent feelings about the pregnancy depending on expectations and planning of a child. This is followed by a second phase with processes of cognitive and emotional adaptations and concretizations. Also in this phase, first movements of the baby are perceived, encouraging the parents to realize the baby as an individual. Pregnancy culminates in a fourth phase of anticipation and concrete preparations for the birth. In this phase, parents-to-be are ready to end the pregnancy and are looking forward to the living with a baby, and most couples participate in prenatal classes. The fifth phase is defined by the birth as a culmination and a turn in the development of family and it means the first contact of the parents with their baby.

After the birth of their baby, parents experience three more phases demanding great challenges and adaptations from both mother and father. The first phase after the birth is characterized by overwhelming emotions and also exhaustion, often followed by great happiness and gratitude. For this reason, this phase is sometimes called “baby honeymoon” in the literature. In the second phase after the birth, mother and father experience great

challenges of adaptation to their new role as parents and the couple dynamics undergo great changes. This is often associated with decreasing relationship satisfaction and quality. The last phase of this model (up to one year after the birth) reflects the habituation to being a family with all its implications. Sometimes, parents experience a kind of disillusionment with parenthood in this phase.

This model is mainly based on experiences of the pregnant woman and new mother, but fathers might experience similar phases, in particular nowadays, because it is quite common for fathers to support and care for the female partner intensively, even during birth.

2.2.2 Transition to Parenthood and Relationship Quality

The transition to parenthood is an outstanding event and challenge, associated with new experiences, new duties, and new roles. It requires huge efforts of adaptation to the new situation from both mother and father. Many studies pointed out that transition to parenthood is associated with big changes within the relationship of the parents, whereas some might affect relationship satisfaction. In general, there is less time for couple activities and more conflicts are reported, so that relationship quality rather decreases (Belsky & Pensky, 1988; Huston & Vangelisti, 1995, Bodenmann, 2000). However, there are also couples who even report an improvement in relationship quality (Belsky & Rovine, 1990; Terry, McHugh & Noller, 1991). Other studies found that relationship quality after the birth depends on the couple satisfaction before the birth of the first child (Cowan, Cowan, Heming & Miller, 1991).

According to Reichle (1994), the above-mentioned change in subjective relationship quality seems to differ with respect to gender. Fathers complain rather about restrictions of sexuality after the birth and a reduction in affectionate care by their female partner. A reduction of togetherness and communication in the couple seems to be less important for fathers as compared to mothers. Mothers see a reduction in subjective relationship quality in all couple-specific aspects but sexuality.

Entwistle and Doerig (1981) distinguished between two different crises: on the one hand, there is a physiological crisis brought about by the physiological stress of the birth in mothers, and on the other hand, there is a social crisis due to the psychosocial stress of adaptation processes, and all couples having to restrain from sexuality for a period of time.

In a longitudinal study, Fthenakis, Kalicki, Peitz (2002) compared the relationship quality of couples having their first child with couples having their second child. With regard to Quarrelling, they revealed a continuous increase from last trimester up to three years after the birth of the first child, whereas couples with the second child stayed constant over the same time. However, it was not the absolute amount of conflicts that rose, but rather the coping with conflicts changed in couples after the birth of their first child. More destructive conflicts (including impertinence, insults, and ignoring the partner) occurred at the expense of constructive conflicts (including discussions and reasoning) (Crohan, 1996). In addition, the results for Togetherness/Communication and tenderness revealed a continuous decrease in couples with the first child, whereas couples with the second child generally showed lower but constant levels of Togetherness/Communication and Tenderness than couples with the first child (Fthenakis et al., 2002).

In conclusion, the transition to parenthood is associated with a decrease in relationship quality, which is stronger than the erosion effect over time which can be observed in couples without children. However, it is important to mention that couples after the birth of their first child are not unhappy, merely that there is a decrease from the status quo before the birth, meaning that on the whole, they can still be happy couples (Fthenakis et al., 2002). In summary, first parenthood does not bring partners closer to each other, but it does intensify variations between partners that already existed (cf. Cowan & Cowan, 1985).



In the field of research about parenthood, only a few studies have focused on fathers and fatherhood. Therefore, in this work, the focus is on fathers and how they cope with the transition to fatherhood, taking into account endocrinological processes and effects of personality traits, such as sensation seeking (SS). In this context, the challenge hypothesis of Wingfield et al. (1990) plays an important role.

2.3 Sensation Seeking

2.3.1 Definition

The theory of SS is based on the assumption of the existence of an optimal level of stimulation and activation (Holt & Goldberger, 1960; Berlyne, 1960; both as cited in Möller & Huber, 2003). The construct of “sensation seeking” was developed by Zuckerman (1964), who created the first sensation-seeking scale in order to measure individual differences in optimal levels of stimulation and arousal with a questionnaire. Therefore, the first publication on SS was a chapter on the optimal level of stimulation and arousal by Zuckerman (1969). He described several factors that might determine this individual optimal level, such as constitutional factors (especially of the individual sensitivity and reactivity of the central nervous system), age (the peak of SS is in adolescence and decreases with age), learning experiences (so that the optimal level might be adapted), recent levels of stimulation (after a period of over- or under-stimulation, individuals try to return to the optimal level by either seeking or avoiding exciting stimuli), task demands (complexity versus simplicity of a task demands different levels of stimulation and arousal for optimal achievement), diurnal cycles (periods of full wakefulness need little stimulation and periods of tiredness need more stimulation). Referring to this, the most current definition of SS by Zuckerman (1994) is as follows:

“Sensation seeking is a trait defined by the seeking for varied, novel, complex, and intensive sensations and experiences, and the willingness to take physical, social, legal and financial risks for the sake of such experiences” (p. 27).

As there is evidence that SS is based on physiological constitution and as mentioned above, there are individual thresholds of arousal, it should be qualified that persons try to regulate arousal by exploring or avoiding excitatory stimuli according to their individual threshold of arousal.

2.3.2 Sensation Seeking and Behavior

SS correlates significantly and positively with particular unhealthy or risky behavior. Zuckerman (1994) pointed out that young high Sensation Seekers are more likely to try multiple drugs because they are looking for intense experiences. There is also empirical evidence that SS and consumption of nicotine are positively correlated (e.g. Kraft & Rise, 1994; Zuckerman, Ball & Black, 1990). Zuckerman et al. (1990) reported that 20% of high sensation seekers, 12% of moderate sensation seekers, and 9% of low sensation seekers are smokers. Zuckerman (1994) suggests that high sensation seekers are more sensitive to the effects of nicotine.

There is also evidence for a positive association between SS and alcohol consumption (e.g. Comeau, Steward, Loba, 2001; Kraft & Rise, 1994). SS seems to be a relevant predictor of alcohol consumption, especially in adolescence. Positive associations with SS were also found for the consumption of marijuana and other illegal drugs (Roth & Petermann, 2003).

In addition, there is evidence that SS is a predictor of interest and performance in high-risk sports, such as skydiving, rock climbing or car racing (Zuckerman, 1983; Breivik, 1996; Mehr & Valkanover, 2001). Furthermore, high sensation seekers are often very interested in gambling, more because of the thrill than the financial gain (Zuckerman, 1994). High sensation seekers show more risky car-driving as well as more frequent drunk-driving than low sensation seekers, especially in adolescence (Zuckerman, 1994; Herzberg & Schlag, 2003).

Furthermore, SS is related to particular sexual behaviors. According to Zuckerman (1994), sexuality is “a primary form of sensation seeking for many people” (p. 187). High sensation seekers have more sexual partners, more frequent unprotected sex, higher sexual motivation, and more variability in sexual practices as compared to low sensation seekers

(e.g. Arnold, Fletcher & Farrow, 2002; Beatty, 1997; Zuckerman, Bone, Neary, Mangelsdorff, Brustman, 1972).

There are also studies relating to deviant and pathological behavior in association with SS (for an overview see Schmidt, 2003). These relations are not described any further at this point, because subjects with mental problems or disorders were excluded in the studies of this work, and therefore descriptions of these relationships would be beyond the scope of the studies.

2.3.3 Measurement of Sensation Seeking

The first instrument for measuring the personality trait of SS was the Sensation Seeking Scale (SSS), which was developed by Zuckerman (1964). Since then, this questionnaire has been developed and adapted many times. Nowadays, the most common and widely used form is the SSS-V, which was developed by Zuckerman, Eysenck, and Eysenck (1978), based on a large sample and analyses. Compared with the SSS-IV, the number of items was reduced from 72 to 40 items. By means of factorial analysis, Zuckerman et al. (1994) selected only items loading highest on one of the four factors and lowest on the other three factors, in order to reduce intercorrelation (Zuckerman et al., 1978). Finally, the SSS-V contains 10 items for each of the four subscales Thrill and Adventure Seeking (TAS), Experience Seeking (ES), Disinhibition (Dis), and Boredom Susceptibility (BS). In this work, the German adaptation of SSS-V by Beauducel, Strobel and Brocke (2003) is used.

Nevertheless, there are critics of the SSS-V. Jackson and Maraun (1996) criticized that the items are formulated as wishes and preferences instead of real experiences. In addition, Arnett (1994) found fault with the “forced-choice” format of the items and also criticized that most of the contents of the questions are associated with physical achievements, which could be a problem, especially in elderly subjects.

2.4 Testosterone

2.4.1 Biological Fundamentals

Testosterone is the most important androgen in the human male. Over 95% of T is produced by the Leydig cells in the testes of men, which produce approximately 6-7 mg per day (Coffey, 1988). Although Leydig cells produce the major part of circulating T, the adrenal cortex also contributes to this production. The release of T results from the hypothalamic–pituitary-gonadal axis (HPGA) (see Figure 1). The pathway begins with a secretion of gonadotropin-releasing hormone (GnRH) in parvocellular neurons of the arcuate nucleus. Through the hypophyseal portal system, GnRH reaches the anterior pituitary, where luteinizing hormone (LH) and follicle-stimulating hormone (FSH) are released. Both LH and FSH act on the gonads (in men testes with the Leydig cells), where among other things, sex hormones are released. In the HPGA, release of hormones is regulated by a negative feedback mechanism, which inhibits the release of both LH and GnRH (Behre & Keck, 2002; Kamischke & Nieschlag, 1997).

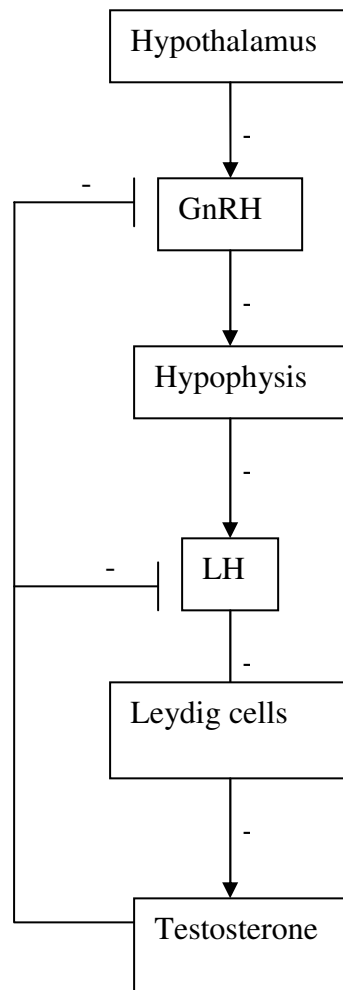


Figure 1: Schematic diagram of T-cascade

The primary functions of T are the spermatogenesis and the development and sustaining of male secondary sex characteristics, such as deepening voice, pubic and facial hairs, muscular build. In adults, T affects libido, and mental and physical energy.

There are endogenous and exogenous factors that impact the variation of T levels. Endogenous factors are age, weight, sleep, season, and diurnal rhythms. Exogenous factors are personality traits, socioeconomic status, relationship status, fatherhood, sex, stress, sport, and lifestyle (consumption of alcohol, nicotine, and caffeine). The associations are positive or negative or may alter depending on different circumstances when a factor occurs.

In childhood and especially in puberty, T increases continuously and reaches its peak at the age of 29 to 34 years. It then decreases continuously but slightly until, at the age of approximately 50 years, it reaches a level similar to that in puberty (Booth, Johnson, Granger, Crouter & McHale, 2003). Last but not least, there are seasonal effects in T. T levels are highest in spring and lowest in autumn (Van Anders, Hampson & Watson, 2006).

T is also one of the best investigated hormones in behavioral endocrinology, with empirical evidence of relationships with some important behaviors. These primarily include behavior associated with the aim of reproduction, such as sexual stimulation and performance or male-male aggression followed, for example, by a rise in status.

In general, hormones and behavior underlie a bidirectional interaction: hormones can affect behavior, and behavior can alter hormone levels. The effect of hormones on behavior cannot be deliberately controlled. Hormones facilitate a disposition or a probability that a particular behavior or reaction to a particular stimulus may occur. However, a person is able to directly control a part of hormone variation by executing particular behavior. As regards T, this may, for example, be physical exercise, stress, sexual behavior, alcohol consumption, and nutrition.

2.4.2 Measurement of Testosterone

In order to avoid invasive methods, T was assessed by saliva instead of serum. Only 2% of T is in free form, i.e. not plasma-bound and therefore measurable in saliva. The norm secretion over the course of a day averages 200-500 pmol/l. T in saliva underlies the circadian rhythm, with high levels in the morning and decreased but more stable levels in the evening (Ahokoski, Virtanen, Huupponen, Scheinin, Kairisto & Irjala, 1998).

Nevertheless, it is a fact that salivary T reacts very sensitively to situational stimuli, meaning that many confounding external variables exist (Dabbs, 1993; Granger, Shirtcliff, Booth,

Kivlighan, Schwartz, 2004). For instance, there can be an interference effect caused by leakage of blood into saliva brought about by micro-injury to the oral mucosa (Kivlighan, Granger, Schwartz, Nelson, Curran, 2004) There is evidence that T levels rise proportionally to the amount of blood contamination in the saliva (Schwartz & Granger, 2004). Furthermore, there can be effects of storage conditions.

Besides these difficulties, there are great advantages to measuring T by saliva. Saliva sampling is easy to handle and can therefore be collected by the subjects themselves. This allows the assessment of saliva samples in the field, i.e. in the very situation in which the behavior to be measured occurs, for example, in our study, when fathers are at home together with their wife and baby. In conclusion, external validity can be optimized. Furthermore, subjects are able to collect several samples over the day or during a particular period of time, in order to measure individual hormonal changes over a specific period, without being obliged to show up at the laboratory for each assessment of T. Taking into consideration the fact that the association between T and behavior is dynamic and reciprocal, i.e. an association between intrinsic characteristics and features of the social environment is suggested, multiple measures of T are essential (Brooks-Gunn, Graber, Paikoff, 1994; Susman, 1997; Granger & Kivlighan, 2003) .

2.4.3 Testosterone – State or Trait

In recent research, there have been contradictory findings about the state or trait character of T level. Nisbett and Cohen (1996) and Bernhardt, Dabbs, Fielden and Lutter (1998) suggested an effect of short-term social interactions in T. However, Mazur and Michalek (1998) and Gray et al. (2004) found no within-subject differences in male T levels depending on social interactions with wives and children. On the other hand, they did find between-subject differences in T levels depending on relationship status and on whether or not the subject was a father; T level may act as a state variable over longer periods of months or years.

Taken together, most authors who reported a state character of T cited the challenge hypothesis of Wingfield et al. (1990). The challenge hypothesis describes a trade-off between mating and parenting effort. On the one hand, there are increasing T levels during periods of mating effort, facilitating competitive behavior between males and sexual stimulation and activities. On the other hand, T levels are decreased during the period of fatherhood, facilitating pair bonding and paternal care.

More evidence for a state character of T was found by Roney, Mahler, Maestriperi (2003), who reported temporary and relatively fast (10 to 30 minutes) increasing T levels by exposing males to specific social stimuli such as females. This is a reactive increase in T level, also called the “mating response”.

However, empirical evidence for a trait character of T is mainly based on the longitudinal study of T and relationship status by Van Anders & Watson (2006). The most interesting result of this study was that men who changed from unpaired at baseline to paired at the follow-up already had significantly lower T levels at baseline compared with men who stayed single. Since the authors explored heterosexual and homosexual men and women, they found another interesting relation. The aforementioned effect was found in heterosexual men and homosexual women, but not in homosexual men and heterosexual women. In conclusion, decreased T levels are only found in subjects oriented towards females. It might be suggested that reduced T levels relating to facilitating paternal care only make sense in subjects with a female partner, who might give birth to offspring.

2.5 Testosterone and Psychological Factors

In the following sections, the two psychological constructs of relationship quality and SS, which are associated with T levels focusing on the period of transition to parenthood, will be explained and empirical evidence gathered to date will be summarized.

2.5.1 Partnership and Testosterone

Evidence has been found that testosterone is associated with relationship status. Most recent studies revealed that men with lower T levels are more likely to live in a committed, romantic relationship compared with men with higher T levels.

To conclude, baseline T levels are suggested to be a state over months or years, close to a trait. This baseline T level describes how a disposition facilitating specific behaviors, which for its part is influenced by psychosocial and cultural factors, i.e. an interaction between genetic factors and constant situational factors such as living in a relationship, might best explain the stability of baseline T levels.

Booth and Dabbs (1993) examined the relation of T with tendencies to marry or divorce as well as with relationship quality. They found a negative association of T production with marriage, but a positive association with divorce and a negative association with relationship quality. Although they broadly examined a large sample of men, they did not assess paternal status, so the possible relationship between mating and parenting effect on T production remains unclear.

Gray et al. (2002) analyzed paternal status and T in a sample of 58 US-men and found lower evening T levels in married men compared with unmarried men and lowest T levels in married fathers. Furthermore, Burnham et al. (2003) hypothesized that T levels may reflect and affect specific behavior in relation to mating and parenting effort. 122 male Harvard

Business School students, aged 23-24 years, collected one saliva sample each and filled in a questionnaire. In line with Gray et al. (2002), results revealed that students in committed, romantic relationships showed 21% lower T levels compared with single students. Fathers among paired men even had 42% lower T levels than unpaired men and 28% lower T levels than paired men without children. Therefore, the authors showed that low T levels depend on living in a committed, romantic bond with a mate and not on marital status.

Finally, Van Anders and Watson (2006) explored T concentrations in both longitudinal and cross-sectional analyses. They examined 258 subjects including heterosexual and non-heterosexual men and women. They found lower baseline T levels in partnered heterosexual men and non-heterosexual women than in unpartnered subjects. Longitudinal analyses revealed no changes in baseline T levels after changes in partnered status. Interestingly this effect was only observed in individuals who were attracted by female partners.

These results appear to be in line with the challenge hypothesis of Wingfield et al. (1990), (see also the section on challenge hypothesis). From the point of view of evolutionary biology, the aim of mating effort is reproduction. In mammals, only females can give birth to offspring, which is why the competitive behavior associated with increased T levels is limited to male-male interaction. However, there is no significant decrease in T level in subjects becoming partnered in a longitudinal exploration (van Anders & Watson, 2006), which might support the assumption of a genetic disposition in reproductive strategy. This suggestion corroborates the findings of Storey et al. (2000) that lower T level is associated with greater parental effort.

2.5.2 Sensation Seeking and Testosterone

There are also other biological influences on SS, for example the neurotransmitter dopamine and serotonin, but due to our interest in T variation across the transition to fatherhood, we will only focus on T in the current work.

Hormone levels, especially T and cortisol, have been suggested to contribute to the variability of individual scores on SS. In addition, there is evidence of existing gender differences, i.e. females usually have lower SS scores than males. Furthermore, SS decreases with age; thus, an association between T level and SS score has been hypothesized.

Nevertheless, the results of past research on the association between T and SS are inconclusive. In some studies, no relationship was found between T and SS (Wang, Mason, Charney, Yehuda, Sherry, and Southwick, 1997; Rosenblitt, Soler, Johnson, Quadagno, 2001), while other studies revealed positive associations between T and SS (Bogaert and Fisher, 1995; Gerra, Zaimovic, Timpano, Zambelli, Delsignore, and Brambilla, 2000; Daitzman, Zuckerman, Sammelwitz, and Ganjam, 1978; Daitzman & Zuckerman, 1980). In addition, Dabbs and Morris (1990) and Mazur (1995) revealed in their studies positive relations between T and risky behavior, such as gambling, alcohol use, and multiple sexual partners. Thus, a comparison of these inconsistent results is difficult, since there are many methodologically confounding variables, such as different sample sizes and, above all, different age ranges.

Certainly, besides the biological influences, there are also other impacts on SS score, such as social context, socially expected behavior, and gendered differences in socialization in relation to norm-breaking or risky behaviors (Rosenblitt et al., 2001).

Typical behavior of SS usually is positively associated with T, such as risky or mating behavior. Aluja and Garcia (2005) found significant relationships between total and free T and curiosity about sex. Although T may have the character of a trait, it may also reflect environmental events in combination with behavior. In particular, free T – measured in saliva – shows specific variation. Stress, for example, has a negative impact on T levels and sexual stimulation has a positive impact.

2.5.3 Sensation Seeking, Paternal Investment and Testosterone

Paternal investment implies not only direct care and support for offspring by fathers, but also assuming responsibility and thoughtful handling in general. Because the survival of the baby depends on its care givers, primarily on its own parents, it is also necessary for fathers to prevent the baby from any harm of physical or mental integrity. If a father endangers his own health, e.g. by excessive drinking, risky driving or other risky adventures, he would also endanger his baby and its healthy development.

In this context, the personality trait of SS is suggested to be an important construct that is negatively associated with paternal care. On the one hand, SS is related to T and on the other hand, SS is associated with above-mentioned behavior, such as risky and mating behavior that is incompatible with paternal care and social responsibility. Therefore, from an evolutionary point of view, it would be best if the amount of SS was rather low in new fathers.

Sakaguchi et al. (2006) hypothesized an association between SS and reproductive strategies. The aim of their study was to examine a possible association between variable affective response styles with different reproductive strategies. Subjects were 26 paired and 54 non-paired Japanese male students. In contrast to the large survey by Zuckerman and Neeb (1980), they did not find a significant difference in SS between paired and non-paired men. They speculate that subjects were too young and the paired men in their study had only been in a relationship for a short time. However, analyses with T revealed that SS is a

significant predictor of evening T, as well as a borderline significant predictor of the diurnal fluctuation of T, with sharper diurnal rhythms in high sensation seekers compared with low sensation seekers. Although this finding is inconsistent with other studies, which reported positive associations between SS and T levels in the morning (Aluja & Turrubia, 2004; Daitzman & Zuckerman, 1980). In conclusion, high sensation seekers seem to have an extraordinarily high endogenous T secretion, which is detected in high morning T levels, instead of accumulating high T levels in response to social stimuli, which have long been hypothesized.

To our knowledge, in the field of research on associations between T and pair bonding as well as reproductive strategies, the study by Sakaguchi et al. (2006) is the first that took into account personality traits, such as SS, self-monitoring, and Type A behavior pattern. However, to our knowledge, there are no studies on T and the transition to fatherhood that examine the potential effect of personality trait.



2.6 Endocrinology of Transition to Fatherhood

2.6.1 Paternal Endocrinology in Animals

In vertebrates, paternal care is widespread. Fish and birds in particular often share parental care, such as nest building, breeding, and feeding. However, in mammals, as the name already implies, paternal investment is rare. Lactation is the role of the mother and fathers usually pursue a quantitative strategy of reproduction by mating as many females as possible in order to father a great quantity of offspring.

Only in about 6% of mammals do fathers stay with the mother and offspring and show paternal care. Numan and Insel (2003) associate paternal care with monogamous social organization. Direct paternal care is found in some species, including, for example: callitrichid primates that bear twin offspring (*Callithrix* and *Saguinus* spp.), and rodents, including prairie voles (*Microtus ochrogaster*), California mice (*Peromyscus californicus*), Mongolian gerbils (*Meriones unguiculatus*) and Djungarian hamsters (*Phodopus campbelli*) (Wynne-Edwards & Reburn, 2000). A possible explanation for paternal care is an enhancement of the survival of the offspring. Therefore, paternal care is a specific and important behavior that concurs with mating behavior.

Due to the fact that only 4% of mammals live monogamously, there are only few animal studies regarding paternal endocrinology. These studies confirmed the hypothesis that paternal care is associated with increasing prolactin levels, for example in common marmosets (*Callithrix jacchus*) (Schradin & Anzenberger, 2004; Mota, Franci & Sousa, 2006), and in New World monkeys (*Platyrrhini*) (Mota & Sousa, 2000). Other hormones, such as prolactin, estradiol, progesterone and testosterone are found to be important in the context of parental and also paternal care. In particular, prolactin and testosterone are assumed to be important physiological factors in parental care.

Wingfield, Hegner, Dufty, and Ball (1990) established the challenge hypothesis based on studies on monogamous bird species. The challenge hypothesis describes a physiological mechanism between mating and parenting effort, which is principally controlled by T. It suggests that T encourages males to carry out mating efforts, i.e. mate attraction, aggressive and competitive behavior against other males, mainly during reproductive phases. In contrast, T is reduced in phases of paternal care in order to down-regulate mating, aggressive and competitive behavior, and to be able to spend time and energy on caring for their offspring. Conversely, male T levels remain constant in polygynous bird species, and they lack paternal care (Wingfield et al., 1990).

2.6.2 Human Paternal Investment and Testosterone

As described above, animals show specific hormonal variations depending on reproductive strategies, social interactions and environmental influences. The same can be observed in humans. From animal research, many explanations may be adapted for humans. As in animals, humans' paternal endocrinology depends on biological development, i.e. reproductive strategy, chemical and neurological processes and environmental stimuli. In the studies of this work, T was explored, as it is the most important sexual hormone in men. Therefore, the following chapters focus on T.

With respect to reproductive strategy, in humans, cultural differences exist that need to be taken into account. Ethnographic research has reported paternal care in at least 40% of human cultures. The degree of paternal care seems to be influenced by social organization, with fathers more involved in predominantly monogamous societies (Numan & Insel, 2003). As it would be beyond the scope of the studies in this work to describe different cultural influences, we focus on predominantly monogamous societies, according to most recent studies (Booth & Dabbs, 1993; Gray, Campbell, Marlowe, Lipson, & Ellison, 2004; Gray, Kahlenberg, Barrett, Lipson, & Ellison, 2002; Gray, Yang, & Pope, 2006; Mazur & Michalek, 1998; Burnham et al., 2003; Gray, Chapman, et al., 2004; Van Anders & Watson, 2004). The

human reproductive strategy is based on the potential trade-off between mating and parenting effort. They form long-term bonds with a mate and provide paternal care. This trade-off is modulated by male T and is described in detail in chapter 2.6.1, which addresses the “challenge hypothesis” (Wingfield et al., 1990; Hirschenhauser, K., Frigerio, D., Grammer, K. & Magnusson, M.S., 2002).

To our knowledge, Storey et al. (2000) provided the first survey of hormonal changes in fathers during transition to fatherhood. In this study, 35 couples collected blood samples during pregnancy and after the birth of their child. Results revealed about 33% lower T levels after the birth compared with T levels during pregnancy. In addition, fathers attended an experiment with exposure to infant cues, and fathers with low T levels showed a significant increase in T directly after this experiment. This study was mostly cross-sectional, and the researchers failed to assess any psychosocial variables.

In order to explore this effect longitudinally, Berg & Wynne-Edwards (2001) recruited twenty-three men, who were to become fathers for the first time, from first-trimester prenatal classes. In addition, they recruited 14 men who were not fathers as controls. Subjects provided frequent samples, i.e. fathers during pregnancy until 3 months after the birth. T levels in fathers were lower compared to controls, and decreased from before to after the birth. No psychosocial variables were assessed.

These results gave rise to the hypothesis that change in male T may be directly induced by chemical signals such as pheromones from the female partner, besides others exogenous cues (e.g. cues from the infant, sleep disruption, altered coital activity, time off work, etc.; cf. Place, 2001). For this reason, Berg and Wynne-Edwards (2002) explored nine couples before and after the birth of their first child in order to assess whether hormonal changes, such as T changes, correlate between father and mother. Results obtained by Pearson correlations indicated no significant association of hormonal changes between mothers and

fathers. A possible explanation could be that each sex has to cope with different specific challenges over the same interval. Duties and responsibilities of fathers might include reduced aggression as well as reduced mating effort in order to provide paternal care or social bonding to the infant (Clark and Galef, 1999, 2000).

In conclusion, these results suggest that hormones, especially T, facilitate specific behavior relating to mating behavior, and therefore T decreases in order to reduce such behavior that is not compatible with pair bonding and paternal care. Furthermore, there is also an interaction with other hormones, such as prolactin or estradiol, which increases facilitating behavior that is needed in the same situation. Such changes in hormones may be induced by the aforementioned exogenous cues. After birth, the most important exogenous factors are surely infant cues.

Fleming, Corter, Stallings and Steiner (2002) examined the responsiveness of new fathers compared with non-fathers toward infant cues. The subjects were exposed to infant cries and to control stimuli in order to measure endocrine responses (i.e. salivary T and cortisol and plasma prolactin) before and after exposure. Focusing on T, they found a greater increase in T in fathers hearing the cries compared with fathers not hearing the cries. With regard to differences with controls in terms of T levels, they only reported a main effect, i.e. fathers had significantly lower T levels than control men.

Gray, Parkin and Samms-Vaughan (2007) recruited 43 men aged 18-38 years with different relationship status (singles, "coresidential" fathers, and "visiting" fathers – living apart from their female partner and their child). Among other things, they collected salivary T. Results revealed significantly lower T levels in visiting fathers comparing with single men. Gray et al. took advantage of the cultural background with dynamic family structures including variable paternal role, i.e. many fathers (about 50%) lived apart from their family (visiting fathers). They found the lowest baseline T levels in visiting fathers compared with coresidential

fathers and single men. Furthermore, both groups of fathers had lower T levels than single men. Therefore, Gray et al. concluded that T levels are a common marker of fatherhood.

2.7 Integrating Model and Conclusions for the Experimental Design

In this chapter, an integrating model is described, which summarizes the reviewed state of research with regard to the transition to parenthood and the transition to fatherhood, respectively. Based on this model, hypotheses for the empirical studies of this work were generated and conclusions for the study design were drawn.

2.7.1 Integrating Model of Biopsychological Factors of Transition to Fatherhood

The transition to fatherhood has been found to have many different effects on both mother and father, as well as on the couple dynamics. To sum these up, we created a model of transition to fatherhood including psychological and endocrinological effects and interactions, based on the review of recent research on transition to fatherhood.

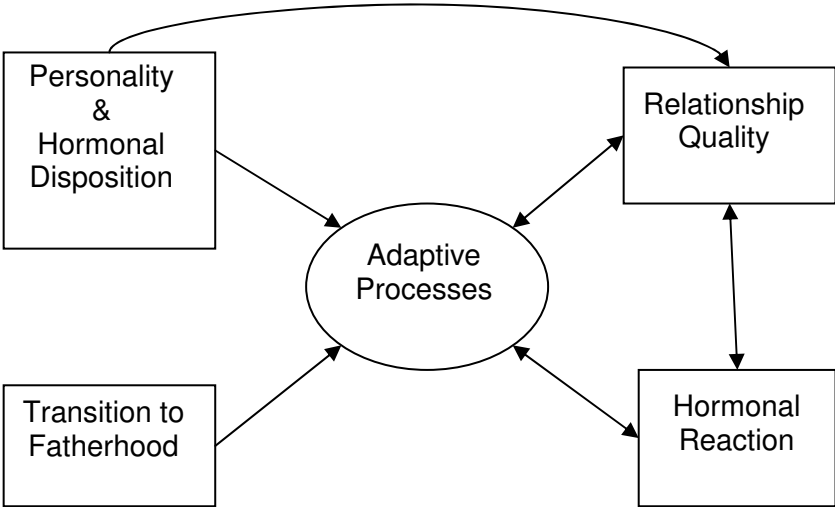


Figure 2: Integrating model of transition to fatherhood (modified according to the vulnerability-stress-adaptation model of marriage by Karney and Bradbury (1995))

As mentioned above, there is empirical evidence of an interdependence between personality traits and hormonal disposition, e.g. between T and SS (Bogaert & Fisher, 1995; Gerra et al., 2000; Daitzman et al., 1978; Daitzman & Zuckerman, 1980). According to Van Anders et al. (2006), T level reflects a disposition to a specific reproductive strategy. Men with lower T levels are more likely to live in a committed romantic relationship and are therefore more likely to live monogamously and invest in paternal care than men with higher T levels (Burnham et al., 2003; Gray et al., 2002). These findings suggest that this combination of personality traits and hormonal disposition is associated with the experience of transition to fatherhood. Another association was found between hormonal disposition and relationship quality, i.e. the lower the T level of the male partner, the better the relationship quality (Booth & Dabbs, 1993). Further, the transition to fatherhood, as a normative life event, challenges new fathers and demands several adaptive processes (Gloger-Tippelt, 1988; Petzold, 1998; Cowan & Cowan, 1989; Huston & Vangelisti, 1995). In turn, these adaptive processes affect hormonal reactions (Storey et al., 2000; Berg & Wynne-Edwards, 2001) as well as relationship quality (Belsky & Pensky, 1988; Huston & Vangelisti, 1995, Bodenmann, 2000; Belsky & Rovine, 1990; Terry et al., 1991; Cowan et al., 1991). In contrast to personality traits and hormonal disposition, as well as to the transition to fatherhood, hormonal reaction and relationship quality interact with the adaptive processes (Clark & Galef, 1999, 2000; Fleming et al., 2002). For example, a good relationship quality enables the couple to succeed in adaptive processes, and hormonal reaction might facilitate specific adaptive processes, and both of these factors act as a feedback process (Gray et al., 2002).

2.7.2 Conclusions for the Experimental Design

Given the inconsistencies in the empirical evidence in research on the transition to fatherhood and the potential importance for understanding paternal behavior, with its correlatives of endocrinological aspects, in our studies, we combined psychological and

endocrinological aspects in a longitudinal design and compared potential changes and associations with a matched sample of men without any children as controls.

In designing the empirical studies of this work, it was important to reduce effects of confounding external variables and also to take into consideration the diurnal rhythm of T for the assessment of T in saliva. All subjects collected saliva samples three times a day. Furthermore, subjects were instructed about several confounding variables, such as sexual activities, physical exercise and consumption of alcohol, nicotine or caffeine, and they were therefore requested to abstain from these activities and consumption for 24 hours before assessment of saliva samples. In addition, all subjects were asked to fill in a protocol of activities during these 24 hours, to enable confounding external variables to be controlled for or subjects reporting such activities or consumption to be excluded.

3 Empirical Studies

This section will describe the two empirical studies within the scope of investigating biopsychological aspects of the transition to fatherhood. The first study focused on associations between T and relationship quality and the second study examined the association between the personality trait SS and T, both across the transition to fatherhood.

3.1 The Paternity Effect or how Testosterone affects Relationship Quality

3.1.1 Introduction

There is an increasing interest in the biological mechanisms of fathers-to-be, and strikingly, recent research has found not only changes in mothers' hormonal levels, but also a significant effect of fatherhood on neuroendocrine systems in men (Storey et al., 2000; Berg and Wynne-Edwards, 2001 and 2002; Gray et al., 2002).

In animal research, there is clear evidence that differences in specific reproductive strategies are strongly associated with either monogamous or non-monogamous living species (Wynne-Edwards and Reburn, 2000). Basically, a distinction is made between the reproductive strategies of species with few offspring (qualitative reproductive strategy) and species with many offspring (quantitative reproductive strategy). Especially from the male perspective, there are large differences in the specific behavior depending on reproductive strategy. For example, in mammals, which have few offspring, paternal investment is sometimes very intense in order to enhance the survival rate of the offspring. Consequently, monogamy is the ideal reproductive strategy and pair bonding in these species is considered to be of particular importance.

There are specific hormones that are assumed to affect pair bonding and paternal investment. In males, androgens and particularly testosterone (T) are assumed to reflect specific reproductive behavior (Wingfield et al., 1990). In behavioral endocrinology, T is one of the best investigated hormones, with empirical evidence linking T with behavior associated with reproduction and aggression, such as sexual stimulation and performance or male-male aggression followed by a rise in status (Archer, 2006; Wingfield et al., 1990). In humans, T levels were also positively linked to mate-seeking effort and negatively linked to paternal behavior (Archer, 2006). In line with these studies, recent research revealed that men with lower T levels are more likely to live in a committed romantic relationship than men with higher T levels (c.f. Burnham et al., 2003; Gray et al., 2004; Mazur and Michalek, 1998; van Anders and Watson, 2006). This association might be caused either by the relationship status (partnered vs. non-partnered) or by T. However, longitudinal data from van Anders and Watson (2006) suggest that baseline T acts as a trait in order to modulate relationship status in men. From an evolutionary biology perspective, both long-term relationships and paternal care might be related to reduced mate-seeking effort and increased couple intimacy and parenting effort.

Burnham et al. (2003) reported that fatherhood was associated with even lower T levels than in non-fathers living in a committed romantic relationship alone. In this context, and with regard to the interpretation of T as a trait marker, not only the comparison between fathers and non-fathers but the *transition* to fatherhood might be of particular importance. Indeed, previous research found decreasing T levels from pre to post birth in fathers expecting the birth of their (first) child. Storey et al. (2000) found 33% lower T levels three weeks after the birth of the child in comparison to three weeks before, while Gray et al. (2002) detected a significant decrease in T levels one week after versus one week before the birth.

Based on these results, it would be particularly interesting to investigate psychological factors that might in turn be associated with T levels during the transition to fatherhood.

Indeed, in an independent strand of research, the transition to fatherhood has been associated with decreases in relationship quality in several studies (e.g. Belsky et al., 1983; Bodenmann, 2000; Gloger-Tippelt et al., 1995). In line with this, a positive relationship between couple intimacy and paternal care has been shown in psychological studies (c.f., Whiting and Whiting, 1975; Broude, 1983; Belsky et al., 1991).

Based on this research, it is tempting to assume that endocrinological changes, and particularly T levels, might modulate the psychobiological adaptation in fathers to a life as a family. We consider the transition to fatherhood as being particularly suitable for testing the dynamic influences of T on relationship quality, because this phase represents an important challenge in the context of paternal investment. We therefore sought to investigate the relationship between changes in T levels during the transition to fatherhood and their association with relationship quality before and following birth. In a long-term prospective design, we investigated first-time fathers-to-be and control subjects who were living in committed relationships.

3.1.2 Methods

3.1.2.1 Subjects

For this study, 94 healthy men (aged 23-54 years) were recruited by advertisements in newspapers, posters and flyers as well as by presentations of the study in prenatal classes in hospitals from the Zurich area. Forty-six were expectant fathers and 48 were controls, i.e. men in a committed romantic relationship without children. Criteria for expectant fathers were that the female partner was in the third trimester of pregnancy with the first child, with no history of in-vitro fertilization or any pregnancy disturbances. Criteria for controls were that they had been together with their partner for at least six months. Exclusion criteria for all participants were physical or psychiatric illness, substance abuse, medication, smoking, and shift work.

In the group of expectant fathers, nine participants were dropped from the analysis because five became fathers before the first assessment day, three did not provide the second (t2) set of saliva samples and one did not fill out the second set of questionnaires, resulting in thirty-seven subjects. In the group of controls, ten participants dropped out of the analysis because one couple separated, one female partner became pregnant, two did not fill out the second set of questionnaires and six were not available for the second part of the study. There were no significant differences in baseline characteristics in those subjects who completed the study and those who dropped out of the analyses or were excluded.

Finally, 75 healthy men were included in the analysis. 37 were expectant fathers (age mean=34 years, SD=5 years; duration of relationship mean=6 years) and 38 were controls (age mean=32 years, age SD=7 years; duration of relationship mean=5.5 years).

For their participation, subjects were paid CHF 50.00 following the first interview. The study was approved by the Ethics Committee of the Canton of Zurich, Zurich, Switzerland.

3.1.2.2 Study procedures

Potential participants were selected by a telephone screening in order to check the exclusion criteria. During t1, after giving informed consent, all subjects were invited to answer questions in a semi-standardized interview protocol regarding sociodemographic data, duration of partnership, personal living situation and the desire to have a child. On this occasion, it was explained to them how to collect the saliva samples and they were given the Salicaps, in order to collect the saliva samples at home. On two work-free days, they collected a set of three saliva samples (7am; 5pm; 9pm) and filled in a protocol about activities during the day. All subjects were asked to refrain from sexual activities and consumption of alcohol during the 24 hours of assessment days. In the group of expectant fathers, the first assessment day of saliva samples took place one month before due day (t1) and the second assessment day two months after the birth of their child (t2). The two assessment days of controls were arranged with a latency of three months between t1 and

t2. All subjects completed an online questionnaire on relationship quality within the same week of each day of saliva collection. Around the time of the second assessment day, subjects were contacted by telephone in order to assess changes or events over the last three months, besides the birth and birth-related issues.

3.1.2.3 Questionnaires

The questionnaires were presented online and were completed at home. They were password-protected and could only be accessed by the subject and the study administrators.

Relationship quality

Partnership Questionnaire [PFB; Partnerschaftsfragebogen]. The PFB (Hahlweg, 1996) assesses partnership quality as an interactional construct with 3 scales (Quarreling, Tenderness, and Togetherness/Communication), each with 10 items, to be combined into a total score. This total score has excellent psychometric properties, with a Cronbach's α of approximately .95 and high correlations with the Dyadic Adjustment Scale ($r=.85$, Hahlweg et al., 1992). In addition to the three subscales "Communication", "Tenderness", and "Conflict", the overall satisfaction with the relationship is assessed with one question, answered on a 6-point scale from 0 (very unhappy) to 5 (very happy) ("Terman item", Terman et al., 1938).

Protocol of Activities

Since T is influenced by environmental factors, and as such a variation in T may last for several hours, all subjects were asked to fill out a protocol about their activities during the day of saliva sampling. They were requested to indicate whether their partner, the baby or any other people were present on that day and the amount of time they had spent together, Furthermore subjects were asked to give information about paternal care, how long they had slept, whether they had woken up during the night and about their sexual activities.

3.1.2.4 Endocrine measures

The physiological part of this study contains measures of salivary free T. Measuring the free T in saliva is a convenient method, due to the easier sample collection without repeated venipunctures, as would be necessary by measuring in blood.

Participants collected saliva at home by means of a commercially available sampling device (Salicaps© from Sarstedt in Selevon, Switzerland). To minimize the effects of diurnal fluctuations (T shows a circadian rhythm with an increase during sleep and decrease during the day) and the influence of activities or external stimuli, participants were requested to collect saliva three times a day (7 am, 5 pm and 9 pm) at home. They sent them back to our laboratory, where the saliva samples were stored at -20°C until they were biochemically analyzed in a laboratory of the Technical University of Dresden. Test Principle: Luminescence Immunoassay for the quantitative determination of free T in saliva.

3.1.2.5 A Priori Power Analyses

The statistical power was calculated a priori using the software G-Power (Buchner, Faul, Erdfelder, 1998), and suggested an optimal total sample size of N=68 (f= .35, power= .80, level of significance, alpha= .05).

3.1.2.6 Data analysis

All calculations were performed using the SPSS (version 15.0) statistical software package (SPSS Inc., Chicago, Illinois, USA). Data are presented as mean \pm SEM (standard error of the mean).

Before statistical procedures were applied, data were tested for normal distribution and homogeneity of variance using Kolmogorov-Smirnov and Levene's test. Results were considered statistically significant at the $p \leq 0.05$ level and borderline significant at the $p \leq 0.1$ levels. All tests were two-tailed. Cases were excluded listwise if there were missing values.

For each of the two assessment days (t1 and t2), T was computed as area under the total response curve, expressed as area under the measured time points with respect to ground (AUCg) for circadian T secretion (AUCg-T), using the trapezoid formula, according to Pruessner et al. (2003).

Across the two groups of fathers and controls, t-tests for independent samples were applied to analyze group characteristics as well as for confounding variables, such as sleep duration, activities, time spent together as a couple and with significant others.

To assess both changes in relationship quality and changes in T levels from t1 to t2, we calculated ANOVA with repeated measures, with group as the independent variable and the repeated factor as the dependent variable. Results were corrected by the Greenhouse-Geisser procedure where appropriate (violation of sphericity assumption). For post-hoc testing, T-tests for independent samples were calculated for group characteristics as well as for relationship quality and T at t1 (AUCg-T1) and at t2 (AUCg-T2). To assess changes within each group, we conducted paired T-tests.

To estimate the impact of T on relationship quality, we calculated moderator analyses by linear regression modeling following Baron and Kenny (1986) with AUCg-T1 and the AUCg-T-change (AUCg-T-changes = AUCg-T1 subtracted from AUCg-T2) and the interaction thereof as independent variables and as dependent variable changes in each relationship quality parameter in a separate regression analysis.

3.1.3 Results

3.1.3.1 Group characteristics

Fathers and controls did not differ in any of the control variables, such as age, BMI, relationship duration, and consumption of caffeine.

Table 2: Group characteristics of fathers and controls

Characteristic (mean/S.D.)	Fathers (N=37)	Controls (N=38)	p-value (Student's t-test)
Age male partner (years)	33.9 (5.3)	31.6 (7.2)	0.11
Age female partner (years)	32.0 (3.7)	30.1 (8.2)	0.21
BMI	24.1 (3.2)	23.76 (2.5)	0.63
Relationship duration	6.0 (3.1)	5.4 (5.6)	0.57
Caffeine (cups)	2.3 (1.0)	2.3 (1.1)	0.92

3.1.3.2 Testosterone

Two-way ANOVA with repeated measures indicated lower repeated T levels in fathers as compared to controls (main effect of group: $F(1/64)=6.627$, $p=.012$). There was neither a main effect of time ($p=.557$) nor an interaction effect of time and group ($p=.542$).

Post-hoc, the significant group effect was tested by calculating T-tests separately for t1 and t2. AUCg-T levels were lower in fathers than in controls at t1 ($T=-1.952$, $df=73$, $p=.055$, significant at the trend level) and at t2 ($T=-2.226$, $df=65$, $p=.030$, significant).

3.1.3.3 Relationship quality

Total Score

ANOVA with repeated measures revealed a significant decrease in total score of PFB over time (main effect of time: $F(1/61)=4.481$, $p=.038$) and a significant interaction between group and time ($F(1/61)=14.154$, $p=.000$).

Post-hoc tests of the significant interaction effect revealed that the groups did not differ at t1 ($p=.825$). However, at t2, fathers had a significantly lower PFB-total score as compared to controls ($T=-2.352$, $df=61$, $p=.022$). Moreover, fathers decreased in PFB-total score over time

($T=3.988$, $df=33$, $p=.000$), whereas there was no significant change in PFB-total score in controls ($p=.217$).

Subscales

To avoid multiple comparisons, subscale analyses were only conducted in fathers and not in controls. Paired T-tests (for t1 and t2) revealed significant decreases for the subscale Tenderness ($T=4.986$, $df=33$, $p=.000$) and the subscale Togetherness/Communication ($T=2.727$, $df=33$, $p=.010$); however, no significant change was obtained for Quarreling ($T=-0.190$, $df=33$, $p=.850$).

3.1.3.4 Testosterone and relationship quality

As relationship quality changed in fathers but not in controls over time, in the following analyses we focused on fathers only.

Regression analyses

In fathers, we tested the influence of T on relationship quality by calculating regression analyses. The aim was to establish whether T level at t1 (AUCg-T1) and the change in T level (AUCg-T1 subtracted from AUCg-T2) predicted the change in relationship quality (total score) and the subscales with significant decreases over time: Tenderness and Togetherness/Communication. First, we entered AUCg-T1 and the change in AUCg-T from t1 to t2 (AUCg-T-change) simultaneously as independent variables. Changes in the PFB total score, and changes in Tenderness, or Togetherness/Communication, respectively (t1 subtracted from t2), were entered as dependent variables in separate analyses. Second, we added the interaction term of AUCg-T1 x AUCg-T change (see Figure 3) as a third independent variable in each of the two regression analyses (Baron and Kenny, 1986).

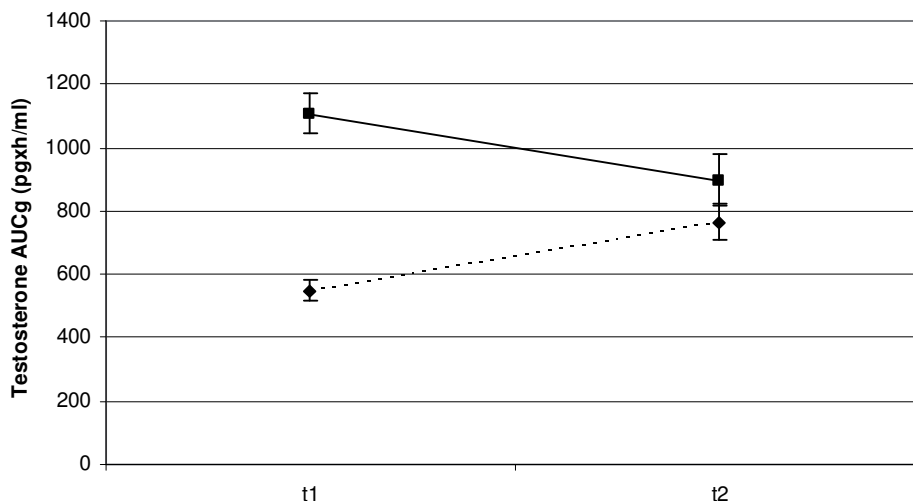


Figure 3: Change in T associated with low baseline T (dashed line) or high baseline T (solid line) in fathers across transition to fatherhood

Neither AUCg-T1 ($p=.423$) nor change in AUCg-T from t1 to t2 ($p=.156$) predicted change in total score of relationship quality. Only the interaction term thereof predicted change in total score of relationship quality by changing R^2 with significance at a trend level ($\Delta R^2=0.091$, $p=.080$).

With regard to decreases in Tenderness from t1 to t2, AUCg-T1 had no significant impact, but change in AUCg-T from t1 to t2 was associated with decreases in Tenderness. This effect was significant at a trend level ($\beta=0.390$, $p=.074$, $R^2=0.234$). In line with our hypotheses, the interaction term significantly predicted decreases in Tenderness ($\Delta R^2=0.098$, $p=.044$), suggesting that men with high T levels at t1 and a strong change in T levels over time show the strongest decrease in Tenderness, whereas men with low T levels at t1 and a weak change in T levels over time show the weakest decrease in Tenderness (see Figure 4).

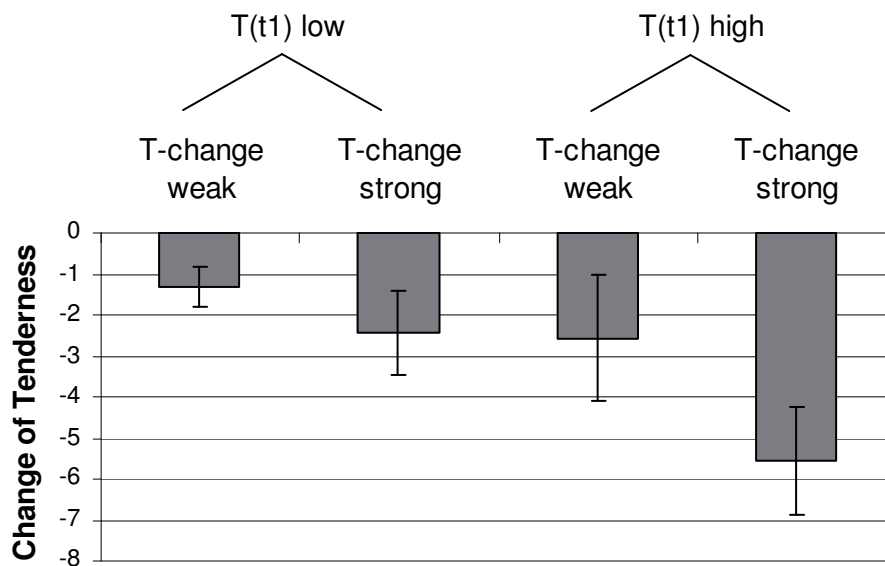


Figure 4: Change in Tenderness in association with high versus low change in T in fathers across transition to fatherhood

The decreases in Togetherness/Communication in fathers, however, were not significantly predicted, either by AUCg-T1 ($p=.613$), by change in AUCg-T from t1 to t2 ($p=.303$), or by the interaction thereof ($p=.273$).

3.1.4 Discussion

The purpose of this study was to investigate adaptation processes across the transition to fatherhood with respect to both psychological and endocrinological aspects. To our knowledge, this is the first study to investigate both endocrine and psychological markers and their interaction across the transition to fatherhood. The focus was on the effect of hormonal disposition and hormonal response on adaptation processes, which might have an impact on relationship quality.

T levels and transition to fatherhood

In line with recent studies, our results showed lower T levels in fathers in comparison with controls at both t1 and t2 (Berg and Wynne-Edwards, 2001; Burnham et al. 2003; Gray et al., 2002; Gray et al., 2006; Mazur and Michalek, 1998; van Anders and Watson, 2006).

Surprisingly, and in contrast to earlier studies investigating fathers (Storey et al., 2000; Berg and Wynne-Edwards, 2002; Gray et al., 2002), we did not find a significant decrease in T levels in fathers from t1 to t2. In our data, we even identified 22 fathers (out of 37) with rising T levels from t1 to t2, which is at odds with our expectations and the available studies in this area. One might speculate that a major life change, such as the transition to fatherhood, might even raise T levels temporarily in some individuals. This would be in line with Mazur and Michalek (1998), who found higher T levels surrounding a divorce, which is also a major life change. In particular, fathers with lower T levels at t1 showed rising T levels from t1 to t2 (see fig. 1). It might be suggested that fathers with lower T levels at t1 are more sensitive about changes within the couple relationship and might therefore experience the adaptation to fatherhood as a stronger challenge and as a stronger life change, meaning that T levels would rather rise, whereas fathers with higher T levels at t1 might rather change from mating to paternal effort with reducing T levels. Another interpretation of our findings is that T levels might have already been reduced in comparison with controls, as the first saliva samples were collected one month before birth only. Perhaps the proximity to the birth is of relevance for lower T, and t1 in our study was only one month before the birth, while t2 was two months after the birth.

Relationship quality and transition to fatherhood

We investigated the difference in relationship quality between fathers and controls. Fathers showed significantly lower overall relationship quality compared with controls at t2 but not at t1. In line with recent research (Belsky et al., 1983; Bodenmann, 2000; Gloger-Tippelt et al., 1995), this difference was due to a significant decrease in relationship quality in fathers, whereas total scores of relationship quality in controls did not change meaningfully over time.

In-depth analyses revealed a significant reduction in Tenderness and also in Togetherness/Communication over time in fathers. Both of these results corroborate findings of Belsky et al. (1983), who reported a change from a romantic to a more functional relationship from the last trimester of pregnancy up to about 9 months after the birth of the first child. With regard to Quarreling, we surprisingly did not find changes in fathers or in controls. This result is not in accordance with earlier studies, which suggested that the coping with conflicts deteriorates in parents after the birth of their first child (Belsky and Rovine, 1990; Cowan and Cowan, 1989). With respect to our study, we can conclude that the decrease in relationship quality through transition to fatherhood is due to decreases in Tenderness and Togetherness/Communication, but the new parents seem to adapt without increasing Quarreling.

Although we found decreases in some aspects of relationship quality, parents were still genuinely satisfied with the relationship in relation to the norm sample. As mentioned above, t1 took place in the third trimester. Therefore, we do not know whether relationship quality even temporarily rose during pregnancy and returned to normal after the birth. In addition, data in the mothers/ female partners, which may differ from the satisfaction of fathers, might be of interest in future studies (c.f., Kashy and Snyder, 1995).

Testosterone and relationship quality across transition to fatherhood

Strikingly, in fathers, we found that T levels moderated a decrease in relationship quality and particularly in self-reported tenderness between partners across the transition to fatherhood. More precisely, lower T levels at t1 are associated with stronger changes in T over time and this interaction explains 10% of the decrease in total scores of relationship quality. These data are in line with findings by Gray et al. (2002), who showed that men with lower T levels were more committed in the relationship than men with higher T levels. Consequently,

fathers with lower T levels at t1 seem more satisfied in relation to Tenderness and show less decreasing Tenderness scores from t1 to t2 (see fig. 2).

More specific analyses showed that the interaction of T level at t1 with change in T level from t1 to t2 was related to decreases in Tenderness in fathers. Again, lower T levels at t1 were associated with stronger changes in T levels over time. This interaction explains 10% of variance in decrease in Tenderness. These data might be interpreted with regard to the “Challenge Hypothesis” by Wingfield et al. (1990), and it could be concluded that T levels decreased in fathers with high baseline T levels in order to reduce mating effort in favor of paternal effort. In addition, these fathers reported a steeper decrease in subjective satisfaction with Tenderness in their relationship. As high T levels are associated with higher mating effort (Burnham et al. 2003, Gray et al., 2002; van Anders and Watson, 2006), one might speculate that these fathers were more sexually active prior to the birth of their child, meaning that a restriction of sexual intercourse during the first weeks after parturition might be associated with greater dissatisfaction in these fathers compared to fathers with lower baseline T levels. However, future research should investigate possible mediating factors of the rising T levels in fathers with low baseline T levels across the transition to fatherhood, which we surprisingly detected in our data.

Limitations

Our investigation is limited to men. The inclusion of the female partner in future studies might add important information to the data on relationship quality in interaction with endocrine measures in parents-to-be.

Conclusion

The association between T levels and relationship quality is an outstanding finding of this study. This association is very important, since the two factors influence each other to a significant degree, thus playing an important role for coping and adaptation of the transition to fatherhood as a major life change. This might also provide some hints for therapeutic interventions. The finding was only possible with a longitudinally designed study with a large sample size; both of these criteria were met in this study. In addition, the inclusion of a control group with paired men without children and the fact that all fathers were having their first child makes this study particularly reliable.

3.2 Sensation Seeking in Fathers: The Impact on Testosterone and Paternal Investment

3.2.1 Introduction

Parenting effort and personal father-child interactions have significantly increased in fathers in Western societies and more recently, research has turned towards the biological correlates of reproductive strategies in men (Storey et al., 2000; Berg and Wynne-Edwards, 2001; Alvergne et al., 2009; reviewed in Kentner et al., 2009). In animal research, biological determinants of fathering have been well established during recent years. As early as 1990, Wingfield et al. described the challenge hypothesis in their study on monogamous bird species, which stands for a trade-off between mating effort and parenting effort. Mating effort includes mate attraction, male to male competition and aggression during reproductive phases, whereas paternal effort means the time and energy males spend on caring for their offspring. There are large differences in reproductive strategies between species. For example, in mammals, which have few offspring, paternal investment is sometimes very intense in order to enhance the survival rate of offspring. Most species with intense paternal investment are monogamous. There is evidence that natural variation in T is associated with individual variation in the trade-off between mating and parenting efforts (McGlothlin et al., 2007), since T levels are negatively associated with paternal care and bond maintenance (Wynne-Edwards and Reburn, 2000; Numan and Insel 2003) and positively associated with mating effort (McGlothlin et al, 2007; Muller et al. 2009). An analogous endocrine regulation of male reproductive trade-off through T is suggested as a common feature of human populations (Geary, 2000; Alvergne et al., 2009). Several studies revealed lower T levels in partnered males than in non-partnered men (Booth and Dabbs, 1993; Mazur and Michalek, 1998; Gray et al., 2002). Furthermore, based on their results of a longitudinal study, van Anders and Watson (2006) found that men with lower baseline T levels are more likely to become partnered than men with higher baseline T levels. This is in line with studies reporting greater paternal responsiveness in men with lower T levels as compared to men

with higher T levels (Storey et al., 2000; Berg and Wynne-Edwards, 2001). Besides the baseline T level, T level responses occur, triggered by specific stimuli such as infant cries (Fleming et al., 2002).

There is some evidence that inter-individual variability in reproductive strategy is reflected by T levels (Alvergne et al., 2009), but T levels might also be influenced by different characteristics of personality traits. To our knowledge, the influence of personality traits underlying endocrinological variability across the transition to fatherhood has not been investigated so far. However, Storey et al. (2000) suggested that individual social experiences of men might interact with hormonal variances. Generally, T levels decline across the day, with the largest declines early in the day (Dabbs, 1990). Several studies on behavioral variations found stronger correlations with afternoon and evening T levels than with morning T levels (reviewed in Muller et al, 2009). Recent research suggests that morning T levels reflect an endogenous physiology (Gray et al., 2007), whereas afternoon and evening T levels might be influenced by male behavioral profile and social contacts during the day. Recently, Sakaguchi et al. (2006) revealed that several personality factors correlate with the T diurnal fluctuation. In the same study, the authors found sharper diurnal rhythms in high sensation seekers and blunted diurnal rhythms in high self-monitors, Type A men, and those who obtained less sleep.

The personality trait “sensation seeking” (SS) has been associated with differences in reproductive strategies (Sakaguchi et al., 2006). SS was shown to be associated with low paternal investment, risky behavior in terms of courtship behavior, and seeking sexual contacts. Thus, most types of characteristic behavior of SS represent mating effort rather than paternal care. This corroborates the findings of Zuckerman and Neeb (1980), who discovered in a large-scale survey that married men and women tended to be lower sensation seekers than singles. More recent studies investigated the association of SS and T in men in general, but reported inconsistent findings. In some studies, there was no

relationship between T and SS (Wang et al., 1997; Rosenblitt et al., 2001), while other studies revealed positive associations between T and SS (Bogaert and Fisher, 1995; Gerra et al., 1999; Daitzman et al., 1978; Daitzman and Zuckerman, 1980). In addition, Dabbs and Morris (1990) and Mazur (1995) revealed in their studies positive relations between T and risky behavior, such as gambling, alcohol use, and multiple sexual partners. Research in both areas is faced with the challenge of possible confounding influences on SS and T levels, such as age, relationship status, relationship duration, and environmental influences.

Taken together, there is convincing empirical evidence for associations between a) SS and mating effort, b) SS and T, and c) T and mating effort. In addition, some studies have found decreasing T levels during the period of transition to fatherhood, which might hint at reduced mating behavior in young fathers (Storey et al., 2000; Berg and Wynne-Edwards, 2001; Gray et al., 2002).

In line with Wingfield et al. (2001) and Archer (2006), we therefore assume that decreasing T levels are linked with a reduction in incompatible engagements in competitive or mating behavior, consequently resulting in more time and energy left for paternal behavior. Moreover, we assume that individual characteristics, such as different personality traits, are likely to be associated with different endocrinological responses to the transition to fatherhood. The purpose of this study was to examine the role of SS in expectant fathers in comparison to men without any children, who live in a committed romantic relationship with non-pregnant female partners. Therefore, the specific question is whether SS moderates T levels of expectant fathers during the transition to fatherhood. A further question is whether the diurnal fluctuation of T changes due to the transition to fatherhood depending on the individual characteristic of SS. To our knowledge, this is the first study to investigate the personality trait SS in concert with repeatedly measured T levels across the transition to fatherhood in a longitudinal approach.

3.2.2 Methods

3.2.2.1 Subjects

Ninety-four healthy men (aged 23-54 years) participated in this study (46 expectant fathers, and 48 men in a committed romantic relationship as controls). They were recruited from the Zurich area through prenatal classes in different hospitals, through advertisements in newspapers, and through posters and flyers. Inclusion criteria for expectant fathers were that the female partner was nulliparous pregnant in the third trimester with no history of in-vitro fertilization or any pregnancy disturbances. Controls had been in committed exclusive dating relationships for at least six months. Exclusion criteria for all participants were physical or psychiatric illness, substance abuse, medication, smoking, and shift work.

In the group of expectant fathers, five subjects became fathers before the first measurement point, three did not provide the second (t2) set of saliva samples and one did not fill out the second set of questionnaires, resulting in thirty-seven subjects. In the group of controls, ten participants dropped out of the analysis because one couple separated, one female partner became pregnant, two did not fill out the second set of questionnaires and six were not available for the second part of the study.

At the end of the study, seventy-five healthy men were included in the analysis. Thirty-seven participants were expectant fathers (mean age=34 years, SD=5 years; mean duration of relationship=6 years, SD=3.1) and 38 were control participants (mean age=32 years, SD=7 years; mean duration of relationship=5.5 years, SD=5.6).

There were no significant differences in baseline characteristics in those subjects who completed the study and those who dropped out of the analyses or were excluded.

Following the first interview, each subject received CHF 50.00 for their participation. The study was approved by the Ethics Committee of the Canton of Zurich, Zurich, Switzerland.

3.2.2.2 Study procedures

First, a telephone screening was conducted to clarify the exclusion criteria. Following this, a meeting took place. After signing the informed consent document, all subjects were requested to answer questions in a half-standardized interview protocol about sociodemographic data, duration of partnership, personal living situation and the desire to have a child.

On this occasion, all subjects received an explanation of how to collect saliva samples and were handed out the SaliCaps, in order to provide the saliva sample by themselves at home. They were asked to refrain from sexual activities and consumption of alcohol the evening before and during the assessment days. On two work-free days, they were required to collect a set of 3 saliva samples (7am, 5pm, 9pm) and fill out a protocol about activities during the day. In the group of expectant fathers, the first day of saliva collection had to take place one month before due day (t1). The second measurement day took place two months after the birth of the child (t2). With regard to the control group, the criterion was that there was a time period of three months between the two days of saliva collection. In addition, subjects completed several online questionnaires (for the personality trait of SS and for control variables) within the same week of the measurement days. Around the time of the second measurement day, a telephone interview was conducted to assess special changes or occurrences over the last three months.

3.2.2.3 Questionnaires

All questionnaires were presented online and were completed at home. All questionnaires were password-protected and could only be accessed by the subject and the study administrators.

Sensation Seeking

The SS personality trait was measured with the German version of Zuckerman's Sensation Seeking Scale SSS-V (Beauducel et al., 1999), which is an inventory with 40 forced-choice items. The reliability and construct validity is well established. After performing a factor analysis, four subscales were extracted with 10 items each: Thrill and Adventure Seeking (TAS, Cronbach's $\alpha=0.80$), Experience Seeking (ES, $\alpha=0.61$), Disinhibition (DIS, Cronbach's $\alpha=0.69$) and Boredom Susceptibility (BS, Cronbach's $\alpha=0.46$). The Total Score (TS, Cronbach's $\alpha=0.82$) ranges between 0 and 40.

Protocol of Activities

Since T is influenced by environmental factors, and variation in T may last for several hours, all subjects were asked to fill out a protocol about their activities during the days of saliva sampling. They were requested to indicate whether their partner, the baby or any other person was present on the day in question and the amount of time they had spent together. Furthermore, subjects were asked to provide information about paternal care, sleep duration, sleep interruption during the night, and about their sexual activities. Even though they were asked to restrain from sexual activities for about 24 hours, we controlled for it again, because there is a strong effect on T level.

3.2.2.4 Endocrine measures

T was assessed in saliva. Measuring free T in saliva is a convenient method without repeated venipunctures, as would be necessary when measuring T in blood.

Participants collected saliva at home by means of a commercially available sampling device (SaliCaps®, Sarstedt, Selevon, Switzerland). To minimize the effects of diurnal fluctuations (T shows a circadian rhythm with an increase during sleep and decrease during the day) and the influence of activities or external stimuli, participants were requested to collect saliva three times per day at standard times (7 am, 5 pm and 9 pm). All subjects received

envelopes in which to send the samples back to our lab, where they were stored at -20°C until biochemical analyses in a laboratory of the Technical University of Dresden. Analyses were conducted using a standard luminescence immunoassay. Intra- and interassay coefficients were below 10% for all assays.

3.2.2.5 A Priori Power Analyses

The statistical power was calculated a priori using the software G-Power (Buchner et al., 1998). To reach a large effect size of $f=0.35$ with a power of .80 and $\alpha=0.05$, an optimal total sample size of $N=68$ was calculated.

3.2.2.6 Data analysis

All calculations were performed using the SPSS statistical software package (SPSS Inc., Chicago, Illinois, USA), version 15.0. Data are presented as mean \pm S.E.M. (standard error of the mean).

Before statistical procedures were applied, data were tested for normal distribution and homogeneity of variance using Kolmogorov-Smirnov and Levene's test. Results were considered statistically significant at the $p \leq 0.05$ level and borderline significant at the $p \leq 0.1$ level. All tests were two-tailed. In the case of missing values, data were excluded listwise.

For each of the two assessment days (t_1 and t_2), circadian T secretion was computed as area under the total response curve, expressed as area under the measured time points with respect to ground (AUC_g), using the trapezoid formula according to Pruessner et al. (2003).

Across the two groups of fathers and controls, t-tests for independent samples were applied in order to analyze group characteristics.

To assess changes in circadian T secretion between the two groups at t1 in comparison to t2, ANOVAs with repeated measures were calculated with group as the independent variable and the repeated factor (AUCg-T1 and AUCg-T2) as the dependent variable. Results were corrected using the Greenhouse-Geisser procedure where appropriate (violation of sphericity assumption). For post-hoc testing, T-tests for independent samples were calculated for group characteristics and T levels at t1 (AUCg-T1) and at t2 (AUCg-T2). In order to assess changes within each group, paired T-tests were conducted.

In order to test for differences in SS between fathers and controls, T-tests for independent samples were applied for the total score and for each of the four subscales.

To estimate the impact of SS on T in association with the transition to fatherhood, moderator analyses were performed using linear regression modeling following Baron and Kenny (1986) with group variable (fathers vs. controls) and the total SS score (SSSV-TS) as independent variables in a first step and the interaction thereof in a second step. AUCg-T1 and AUCg-T2 were entered separately as dependent variables. SS was considered to be a significant moderator of T if the interaction term (group x SSSV-TS) turned out to be a significant predictor of either AUCg-T1 or AUCg-T2.

Since AUCs are aggregated measures, a reduction of information ensues. To validate the results of the regression analysis for all measurement points, general linear models were conducted with repeated measures for T as repeated factor (for both the two days and the three measurement points on these days), the group (fathers and controls) and SSSV-TS and the interaction thereof as independent variables.

In order to visualize the significant results, although they were not used for modeling and testing, four groups of men were computed, i.e. fathers with low and high SSSV-TS and controls with low and high SSSV-TS.

3.2.3 Results

3.2.3.1 Group characteristics

Fathers and controls did not differ with regard to any of the control variables, such as age, BMI, relationship duration, and consumption of caffeine (see Table 3).

Table 3: Group characteristics of fathers and controls. Data are expressed as mean (S.D.)

Characteristic (mean/S.D.)	Fathers (<i>N</i> =37)	Controls (<i>N</i> =38)	<i>p</i> -value (Student's <i>t</i> -test)
Age male partner (years)	33.9 (5.3)	31.6 (7.2)	0.11
Age female partner (years)	32.0 (3.7)	30.1 (8.2)	0.21
BMI	24.1 (3.2)	23.76 (2.5)	0.63
Relationship duration	6.0 (3.1)	5.4 (5.6)	0.57
Caffeine (cups)	2.3 (1.0)	2.3 (1.1)	0.92

Moreover, during the second assessment, fathers with low SS and fathers with high SS did not differ with regard to any confounding variables, such as age, BMI, relationship duration, sleep quality and subjective fatigue, and the amount of time spent together with the partner or the baby (see Table 4).

Table 4: Group characteristics after the birth in the two groups of fathers with low SS versus high SS. Data are expressed as mean (S.D.)

Characteristic (mean/S.D.)	low SS (N=14)	high SS (N=20)	p-value (Student's t-test)
Age (years)	33.3 (3.4)	34.7 (6.5)	0.42
BMI	25.2 (2.3)	23.6 (3.4)	0.1
Relationship duration	6.7 (3.7)	5.4 (2.6)	0.26
Sleep duration (hours)	7.6 (0.9)	7.9 (1.2)	0.42
Sleep interruptions (frequency)	1.7 (1.3)	1.2 (0.9)	0.18
Subjective fatigue	2.8 (1.3)	3.0 (1.4)	0.73
Time spent with partner (hours)	12.4 (8.3)	13.4 (7.7)	0.42
Time spent with baby (hours)	5.6 (4.2)	4.4 (2.4)	0.36

3.2.3.2 Testosterone

Two-way ANOVAs with repeated measures (AUCg-T1 and AUCg-T2) indicated lower repeated T levels in fathers compared to controls (main effect of group: $F(1/64)=6.627$, $p=.012$). There was neither a main effect of time ($p=.557$) nor an interaction effect of time and group ($p=.542$).

Post-hoc tests indicated that AUCg-T was lower in fathers than in controls at t1 ($T=-1.952$, $df=73$, $p=.055$; significant at the trend level) and at t2 ($T=-2.226$, $df=65$, $p=.030$, significant). In addition, T-tests for paired samples were computed within each group separately for T levels at t1 in comparison to T levels at t2. Neither within the group of fathers ($p=0.984$) nor within the group of controls ($p=0.486$) did the changes in T levels reach statistical significance.

3.2.3.3 Sensation Seeking

Total Score

Fathers showed significantly lower levels in sensation seeking than controls ($T=-2.26$, $df=67$, $p=.027$).

3.2.3.4 Testosterone and Sensation Seeking

Regression analyses

In order to test our main hypothesis that SS might modulate T levels, we calculated moderation analyses on the influence of SS on AUCg-T.

In a first step, the group variable (fathers and controls) and the SSSV-TS variable were entered as independent variables simultaneously and AUCg-T1 or AUCg-T2, respectively, as dependent variables in separate equations. In a second step, the interaction term of group and SSSV-TS was added as a third independent variable into each of the regression analyses.

Sensation Seeking Total Score (SSSV-TS)

For AUCg-T1, the linear regression analysis neither revealed SSSV-TS ($p=.109$) as a significant predictor of AUCg-T1 nor the group variable ($p=.130$). However, when adding the interaction term of SSSV-TS x group into the equation, R^2 changed with borderline significance ($\beta=0.912$, $p=.060$, $\Delta R^2=0.051$). For AUCg-T2, all three variables, SSSV-TS ($\beta=.245$, $p=.043$), group ($\beta=-1.081$, $p=.021$) and the interaction term thereof ($\beta=1.328$, $p=.005$, $\Delta R^2=0.113$) were significant predictors.

In order to validate the results of the regression analysis, general linear models with repeated measures of T (with both of the two assessment days and the three measurement points on these days) were conducted with the four groups of fathers and controls with high and low

SSSV-TS as a between group variable. There was a significant main effect of group ($F(1/59)=5.64, p=0.021$) and of SSSV-TS ($F(1/59)=4.50, p=0.038$) and also a significant interaction effect of group x SSSV-TS ($F(1/59)=9.20, p=0.004$) on repeated T measures. Within subjects, there was a significant interaction of SSSV-TS and the variation of T over the day ($F(1.68/58)=9.27, p=0.00$).

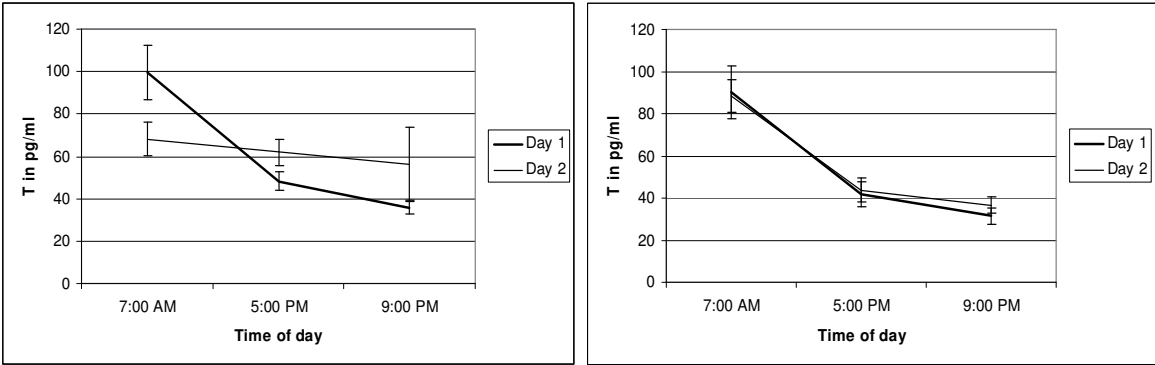


Figure 5: Change in diurnal T-fluctuation from t1 to t2. On the left: fathers with low SS; on the right: fathers with high SS. Data are expressed as mean±S.E.M.

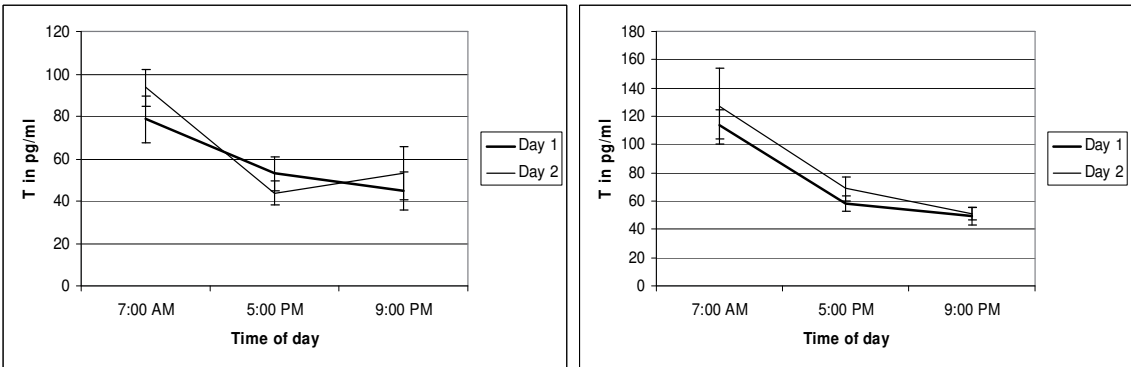


Figure 6: Change in diurnal T-fluctuation from t1 to t2. On the left: controls with low SS; on the right: controls with high SS. Data are expressed as mean±S.E.M.

3.2.4 Discussion

In this study, we investigated the potential effect of SS on male T levels across the transition to fatherhood. Up to now, most studies in the field of paternal endocrinology have not taken into account the impact of psychological factors, such as personality traits. To our knowledge, this is the first study to examine the changes in male T levels through the

transition to fatherhood that includes SS as an important personality trait in connection with paternal investment.

Our results revealed that fathers showed lower T levels and also lower values of SS than controls. Furthermore, our findings verified the hypothesis of moderating effects of SS on the T levels of fathers after the birth of their child. The key finding shows a significant change in diurnal fluctuation of T levels in fathers with low SS values, whereas the diurnal fluctuation of T levels in fathers with high SS values remained unchanged from before to after the birth of their first child.

Our finding of lower T levels in fathers compared to controls is in line with recent studies (Mazur and Michalek, 1998; Burnham et al., 2003; Gray et al., 2004; van Anders and Watson, 2006). However, in our study, T levels of fathers did not decrease significantly after the birth of their first child, which was in contrast to our hypothesis and the results reported by Storey et al. (2000) and Gray et al. (2002). One possible factor to explain the lack of decrease in T levels of fathers from before to after the birth of their first child may be the fact that personality traits, such as SS, might influence adaptation processes of the transition to fatherhood and its endocrinological reaction. For this reason, the transition to fatherhood might be experienced and adapted to in very different ways, depending on individual characteristics of personality traits of fathers. Although there is empirical evidence that endocrinological processes, such as changes in T levels, are associated with both adaptation processes and personality traits, so far, human research into endocrinological aspects in the transition to fatherhood has mainly failed to assess psychosocial variables such as personality traits (Sakaguchi et al., 2006).

SS has shown an association with reproductive strategy, especially with mating effort (Zuckerman and Neeb, 1980; Sakaguchi et al., 2006). The higher a man's SS scores, the higher the disposition to promiscuous sexual behavior. As expected, we found lower SS

levels in fathers compared to controls. This is in line with the challenge hypothesis of Wingfield et al. (1990), confirming the suggestion that specific SS behavior is incompatible with parenting effort. Additionally, we should take into account the potentially confounding variable of T responses. Besides a low baseline T level of fathers, T levels could rise temporarily through exposure to infant stimuli, such as a baby's cries (Storey et al., 2000; Fleming et al., 2002). Nevertheless, it is important to note that fathers who felt concerned or wanted to comfort the baby while hearing the baby's cries showed significantly different patterns of T levels than fathers who did not report such concerns (Storey et al., 2000). Again, the degree of concern felt might be associated with individual characteristics of personality traits. Thus, we assumed that the same event and challenge, such as becoming a father for the first time, could have a differing impact on T levels in fathers, depending on their individual SS value. In conclusion, we may assume that fathers with low SS values might be more caring and concerned about their baby, which might be reflected in stronger T responses (Storey et al., 2000). However, it should be noted that studies to date have revealed inconsistent results on correlations between T and SS (Daitzman and Zuckerman, 1980; Gerra et al., 1999; Rosenblitt et al., 2001; Aluja and Torrubia, 2004; Aluja and Garcia, 2005; Sakaguchi et al., 2006). According to Zuckerman et al. (1962), each father has an individual optimal balance between calmness and stimulation. Becoming a father, and especially coping with the challenges after the birth, may be associated with arousal for some fathers and for others with a slowdown in relation to their normal individual threshold of arousal. Consequently, this may have an impact on the variation of T levels in the transition to fatherhood.

As mentioned above, our analyses revealed a significant moderation effect of SS on T levels before and after the birth, with a significant group difference between fathers and controls. Only in fathers do T levels change differently over time depending on SS. This proves the impact of the challenge of becoming a father on the variation of T levels, depending on the individual characteristic of SS, or in other words, T levels are moderated by the SS value.

The validation of the results of the moderation analyses across all measurement points revealed a significant difference in the diurnal fluctuations of T between high SS compared to low SS for the second assessment day, but only in fathers and not in controls. In low SS fathers, the diurnal fluctuation of T changed significantly, but in high SS fathers, the diurnal fluctuation did not change meaningfully from t1 to t2. At t1, low SS fathers showed about the same diurnal fluctuation as high SS fathers, while at t2, the morning T level was lower, and T levels in the late afternoon and evening were higher than at t1. In general, T levels show strong diurnal fluctuations with differences of up to 20-30% between higher morning and lower evening concentrations (Zitzmann and Nieschlag, 2001). In contrast to baseline T levels, the diurnal fluctuation seems to be related more to the characteristics of individual responses of T due to activities and experiences over the day (Sakaguchi et al., 2006). Therefore, diurnal fluctuation of T is assumed to be also associated with personality traits. Since psychological changes and personality traits have not been sufficiently investigated, it is not surprising that the fluctuation of T has also been disregarded in previous studies. However, there is evidence that T levels of fathers respond to stimuli such as infant cries (Fleming et al., 2002) or the presence of a male competitor (Mazur and Booth, 1998). Therefore, one might assume that fathers with higher evening T levels experienced more of such stimulation over the day. Nonetheless, this would not explain the higher evening T levels in fathers with lower SS as compared to fathers with higher SS. Another factor to mention is a possible negative association between T levels and the amount of time fathers spent together with their female partner or their child during the day (Storey et al., 2000; Gray et al., 2002). In another study, however, Gray et al. (2004) were unable to replicate this association. In the current study, the two groups of fathers with either high or low SS did not show a significant difference in the amount of time they spent together with the partner or the baby (see Table 4). According to Sakaguchi et al. (2006), sleep duration and sleep interruption may also have a negative association with diurnal fluctuation of T. However, fathers with low SS and fathers with high SS did not differ significantly in sleep duration, sleep interruption and subjective fatigue (see Table 4). In line with the challenge response

(Wingfield et al., 1990), increasing T levels, or in our case a stable high T level over the day, may, for example, be caused by a situation that calls for a physiological response in order to mobilize protection of the baby. In an experiment conducted by Storey et al. (2000), new fathers were exposed to infant stimuli (e.g. cries of newborn previously recorded from the neonatal unit) and showed higher T levels following this reactivity test compared to the baseline T. In addition, in fathers with lower baseline T, the rise in T was stronger compared to fathers with higher baseline T.

Taken together, we suggest that for fathers with lower SS, the baby is a greater challenge and they are more engaged in paternal care. For this reason, they might be concerned and alerted by infant stimuli more often over the day, meaning that the physiological responses of T are mobilized easier and more often. To conclude, T levels in fathers with lower SS are constantly higher over the day, whereas T levels of fathers with higher SS decreases during the day. Another explanation could be that fathers with higher SS do not need a special physiological mobilization of T, because their threshold of arousal is not exceeded by the challenge and stimuli of a new baby.

For the first time, we were able to show the impact of individual characteristics of personality trait such as SS on T levels across the transition to fatherhood. This finding is very important, because different coping strategies are needed in fathers depending on their individual characteristics of SS. This might provide hints for parent counseling or therapeutic support for new fathers or parents. This study is particularly reliable since it was longitudinally designed with a large sample size and with the inclusion of a control group with paired men without children.



Limitations

Our investigation is limited to men. The inclusion of the female partner in future studies might add important information to the data on relationship quality in interaction with endocrine measures in parents-to-be.

4 General Discussion

In the following sections of this work, the key findings of the two empirical studies presented will be briefly summarized. In a next step, results will be discussed, based on the theoretical background. Furthermore, methodological issues and limitations of the studies will be explicated, and finally, the clinical relevance of the reported results will be considered and future research needs will be discussed.

4.1 Summary of the Results

4.1.1 Introduction

As we know, the transition to fatherhood is a challenging life event demanding great adaptations from both mother and father. The addition of a newborn infant turns a couple into a family and brings about many profound changes. As we have reported, there are many studies exploring the transition to fatherhood in relation to different associations, such as personality traits, attachment style, role models, relationship status, relationship quality, and endocrinological aspects. However, as described in the chapters above, results have been mostly inconsistent.

Most studies had a cross-sectional design, but a longitudinal exploration of parents would be of absolute necessity, especially because the fact of becoming parents and becoming a father, respectively, is characterized by profound changes. The few longitudinally designed studies addressing the transition to fatherhood lacked a control group in order to verify the effects and to control confounding variables. In addition, most studies referring to the transition to fatherhood were limited to either psychological or endocrinological aspects. Methodological issues make it difficult to draw conclusions about associations between psychological factors and endocrinological aspects from the results of such different studies.

4.1.2 The Paternity Effect or how Testosterone affects Relationship Quality

The aim of this study was to find out more about the effects of the transition to fatherhood on T and variation of T levels over time, on relationship quality and its variation over time as well as an interaction of either T on relationship quality or the variations thereof. Two groups were examined, one group of fathers-to-be and another group of men in a committed romantic relationship without any children as controls. T was assessed by SaliCaps© and relationship quality was assessed with the validated German version of Partnership Questionnaire (*Partnerschaftsfragebogen: PFB*, Hahlweg, 1995). As the study was longitudinal, the saliva samples and the questionnaire were assessed on two days (the first day was one month before the due day, the second day two months after the due day; for controls, the two assessment days took place with three months in-between). Within the group of fathers, we found that baseline T levels interacted with the variation of T levels over time. Furthermore, results revealed an association between the variation of T levels over time and the variation of the subscale Tenderness of the Partnership Questionnaire. More precisely, the decrease in T levels over time was related to decrease in Tenderness over time.

4.1.3 Sensation Seeking in Fathers: The Impact on Testosterone and Paternal Investment

In this study, we explored associations between SS and T within the period of transition to fatherhood by comparing a group of fathers-to-be and new fathers with a group of men in a committed romantic relationship without children. As in the first study, T was assessed by SaliCaps© and SS was assessed with the German version of Zuckerman's Sensation Seeking Scale SSS-V (Beauducel, Brocke, Strobel, 1999). All subjects collected saliva samples on two days (the first day was one month before due day, the second day two month after due day; for controls, the two assessment days took place with three months in-between) and filled in the SSS-V only on the first day, because SS reflects a trait character.

Key results revealed a significant interaction between group and SS on T levels. Further explorations showed a significant change in the diurnal fluctuation of T on the second assessment day, but only in low SS fathers. In conclusion, the transition to fatherhood is associated with a reduction in the extent of diurnal fluctuation of T for fathers with low scores in SS.

4.2 Discussion of the Results

Central to both of the empirical studies in this work was the investigation of the transition to fatherhood as a so-called 'normative life event', related to the strong adaptation processes in both psychological and endocrinological aspects. Following our integrating model of transition to fatherhood (see Figure 2), the two studies are each related to a different part of the model, meaning that only an integration of both studies completes the model. The first study focused mainly on the effect of hormonal disposition on adaptation processes, which are associated with hormonal responses and changes in relationship quality. The second study focused on the effect of personality trait on adaptation processes, which are associated with hormonal responses.

Recent studies reported inconsistent results regarding associations and consequences of adaptation processes with both T and relationship quality. With respect to relationship quality, inconsistent findings in terms of the direction and extent of change in satisfaction following the birth of a child might be caused on the one hand by methodological issues and on the other hand by different focuses on consequences and perspectives. During the adaptation process of new parents (see Figure 2), many different changes, agreements, and adjustments are demanded from new parents, but only some of them lead to distress (e.g. Belsky, 1985; Cowan & Cowan, 1989; Huston & Vangelisti). As mentioned above, methodological issues of different studies do not allow the combination or integration of

existing findings on either hormonal changes or psychological changes; thus, we tried to incorporate these issues in the design of our studies.

To our knowledge, the studies presented in this work are the first to examine longitudinally the transition to fatherhood integrating psychological and endocrinological aspects, by investigating interactions between the variation of relationship quality and the variation of T level with regard to the personality trait of SS.

Our results revealed that the group of fathers showed significantly lower T levels than controls at both t1 and t2, which is in line with recent research on T levels in combination with relationship status (Berg & Wynne-Edwards, 2001; Burnham et al. 2003; Gray et al., 2002; Gray, Yang, Pope, 2006; Mazur & Michalek, 1998; van Anders & Watson, 2006). However, in contrast to other studies (Storey et al., 2000; Berg & Wynne-Edwards, 2002; Gray et al., 2002), T levels of fathers did not decrease meaningfully over time in our study.

Following the model of eight phases of Gloger-Tippelt (1988) (see Table 1), the first assessment day took place in the phase of anticipation and preparation of the birth and the future living together with the baby. This could be a reason why T levels were already reduced at t1, corroborating our findings of borderline significant lower T levels in fathers as compared to controls at t1. As a consequence, the extent of the decrease in T levels was lower than expected. However, the contrast to studies mentioned above (Storey et al., 2000; Berg & Wynne-Edwards, 2002; Gray et al., 2002) persists, as they assessed T levels in the same phases and found significant decreases from before to after the birth.

Most surprising was the finding that in all fathers, evening T levels even rose (see Figure 5). This is in contrast to the expectation of reducing evening T levels, because according to Gray et al. (2002) and Mazur and Booth (1998), T levels in the evening should be influenced by 'short term events', and according to the activity protocol, most fathers spent the second

assessment day together with the partner and the baby and this would usually be associated with lower T levels. In conclusion, there must have been other confounding variables, such as personality trait or relationship quality, that should have been taken into account.

With regard to relationship quality, all subjects completed the partnership questionnaire (PFB, Hahlweg, 1996), which focuses on three aspects of relationship quality: Tenderness, Togetherness/Communication, and Quarreling. The results of our first study revealed a reduction in relationship quality of fathers across the transition to fatherhood, whereas the extent of the reduction differed for each of the three aforementioned aspects. To sum up, the greatest significant decrease was shown in Tenderness, and another significant decrease was found in Togetherness/Communication. Surprisingly, Quarreling did not show a significant change over time, although there are studies reporting an increase in negative conflicts after the birth of the first child (Belsky & Rovine, 1990; Cowan & Cowan, 1988; Crohan, 1996). A probable reason might be the fact that all subjects of the study reported rather high values of relationship quality, and in addition, all babies were planned. However, it should be mentioned that these results were based only on fathers, without considering the level of subjective satisfaction of the female partner, which may differ from the satisfaction of fathers (Kashy & Snyder, 1995). As we focused on variation of T levels associated with relationship quality across the transition to fatherhood, the subjective experience of fathers was the key issue, even though the dynamics of the couple depend on both mother and father. Besides, results are in line with findings of Reichle (1994), who pointed out that fathers complained most about restrictions of sexuality after the birth compared to mothers, who complained more about the other aspects and less about sexuality restrictions.

Moreover, it should be noted that even if women generally have to abstain from sexuality, i.e. penetration, for a couple of weeks after the birth, they would not have to abstain from sexual activities other than penetration. In our study, sexual activities are reflected by the subscale of Tenderness from the PFB. Therefore, it needs to be emphasized that the subscale of

Tenderness contains both behavior with physical contact and verbal expression of tender feelings (Hahlweg 1996). By exploring data of the subscale of Tenderness on an item level, a decrease in satisfaction was revealed mainly in physical contact, whereas other items did not change meaningfully. This finding is in line with Gloger-Tippelt et al. (1995), who reported significantly less affectionate and sexual behavior in parents than in non-parents.

Although we found decreases in some aspects of relationship quality, parents were still rather satisfied with the relationship in relation to the norm sample. Again as mentioned above, the first assessment day took place in the phase of anticipation and preparation of the birth and the future living together with the baby (Gloger-Tippelt, 1988; see also Table 1). Therefore, we do not know whether relationship quality even temporarily rose during pregnancy and returned to normal after the birth.

Thus, the results of our first study revealed an interesting interaction between baseline T levels of fathers with the variation of their T levels from t1 to t2. Furthermore, we found an association between the aforementioned interaction of T levels and the variation of relationship quality, especially for the subscale of Tenderness. Taking together these variations from t1 to t2, fathers with higher baseline T showed a decrease in T levels and also reported a decrease in relationship quality, especially in the subscale of Tenderness, and fathers with lower baseline T showed only a slight decrease or even a rise in T levels but also reported a decrease in relationship quality, especially in the subscale of Tenderness, but to a lower extent than fathers with higher baseline T levels.

In line with the challenge hypothesis of Wingfield et al. (1990), it makes sense that T levels decreased most in fathers with high baseline T levels in order to reduce mating effort in favor of paternal effort. In addition, these fathers reported a greater decrease in subjective satisfaction of Tenderness. As high T levels are associated with higher mating effort (Burnham et al. 2003, Gray et al., 2002; van Anders & Watson, 2006), one might speculate

that these fathers were more sexually active prior to the birth of their child, so that a reduction might be associated with greater dissatisfaction in comparison with the fathers with lower baseline T levels. However, the rising T levels in fathers with rather low baseline T levels across the transition to fatherhood remain to be explained. Clearly, there must be other confounding variables.

According to the integrating model (see Figure 2), in the first study of this work, we explained hormonal influences on adaptive processes as well as hormonal responses to adaptive processes and the association with relationship quality. To complete the model, personality trait should be integrated, investigating its influence on adaptive processes and as consequences on hormonal responses. Therefore, in the second study of this work, the personality trait of SS and the related hormone T were investigated.

Regarding the personality trait, SS was chosen due to the association with both T (Aluja & Garcia, 2005; Aluja & Torrubia, 2004; Gerra et al. 1999; Daitzman & Zuckerman, 1980; Rosenblitt et al., 2001; Sakaguchi et al., 2006) and reproductive strategies, i.e. with specific behavior associated with mating effort, such as male-male competition or sexual activities (Sakaguchi et al., 2006; Zuckerman & Neeb, 1980). However, SS has never been investigated in connection to the transition to fatherhood.

In our second empirical study of this work, we were able to verify the hypothesis of lower SS in fathers than in controls. According to the challenge hypothesis of Wingfield et al. (1990), behavior that is associated with SS, i.e. reflecting mating effort rather than parenting effort, should be reduced in fathers in favor of behavior that is associated with paternal care.

The main finding of the second study was a significant moderation effect of SS on T levels across the transition to fatherhood. Besides the aforementioned significant difference between fathers and controls, there was found another interesting difference between fathers

with low SS in comparison to fathers with high SS, i.e. fathers with high SS showed about the same diurnal fluctuation of T before and after the birth, whereas fathers with low SS showed a significant reduction in the extent of diurnal fluctuation of T following birth compared to before. In concrete terms, on the second assessment day, fathers with low SS showed lower morning T and higher evening T as compared to the first assessment day. Therefore, we assume that low SS in connection with the transition to fatherhood is more challenging for adaptation processes.

Teresaki, Shiomi and Hiraoka (1987) as well as Sakaguchi et al. (2006) found broader diurnal fluctuations of T in high sensation seekers, but in our study, the extent of diurnal fluctuation of T in fathers with low SS occurred only on the second assessment day, when the baby was already born. Therefore, one might assume that in new fathers, sleep was reduced or disrupted due to the baby, and according to Sakaguchi et al. (2006), sleep duration was negatively correlated with the extent of diurnal T fluctuation. However, in our study, we found no significant difference regarding sleep duration, sleep disruption, and subjective fatigue between fathers with high or with low SS, following the activity protocol. Furthermore, Gray et al. (2002) and Mazur and Booth (1998) found a negative correlation between T levels in the evening and the time spent together with their partner or the baby. Thus, again according to the activity protocol, the two groups of fathers with high or low SS did not differ in terms of time spent with their partner or baby. Finally, we refer to the first publication of Zuckerman (1969), who described SS based on the theory of the existence of an optimal level of stimulation and activation (Holt & Goldberger, 1960; Berlyne, 1960; both as cited in Möller & Huber, 2003). Furthermore, Zuckerman (1994) described high sensation seekers as open to new experiences, which might be of advantage during the adaptation process with the new baby. Therefore, we suggest that fathers with low SS feel more challenged and experienced a higher arousal by the baby, as well as by the adaptation processes to being a father, than fathers with high SS. Consequently, this experience might mobilize the T secretion in fathers with low SS during the day.

Since SS reflects mating behavior, low SS should be an indication of reduced mating effort in favor of paternal effort. Therefore, fathers with low SS might be more caring and concerned about the baby, which might cause a stronger secretion of T during the day (Fleming et al., 2002; Storey et al., 2000).

4.3 Methodological Considerations and Limitations

As there are some limitations inherent in cross-sectional studies, we aimed at resolving some of these limitations by employing a longitudinal design in our study. The findings of this work were only possible using a longitudinally designed study with a large sample size; both of these criteria were met in both empirical studies. In addition, the inclusion of a control group with paired men without children and the fact that all fathers were having their first child makes these studies particularly reliable.

Although the data presented in this work were repeatedly measured and we were able to verify some hypotheses, such as existing associations between T and relationship quality and between SS and T across the transition to fatherhood, the methods we used have certain limitations.

The two empirical studies presented in this work were limited to men, and therefore results cannot be generalized to women. Furthermore, in order to take into account the dynamics of the couple and a more objective assessment of relationship quality, data and reports of the female partner would have been necessary.

An important limitation is represented by the homogeneity of the sample. Most subjects were university graduates and had a rather high socioeconomic status. On the one hand, homogeneity in some variables, such as age, BMI, alcohol, nicotine, or drug consumption is

crucial in order to compare samples regarding the hypothesized effects. On the other hand, the findings are limited to the range of persons fulfilling these criteria.

In addition, the sample showed quite homogenous scores in relationship quality, and most subjects showed a rather high relationship quality. Taking into consideration the fact that men in committed romantic relationships were recruited through advertisements, flyers and in prenatal classes, we thus might speculate that rather happy couples decided to participate voluntarily in the study, especially as the title of advertisements already revealed the interest in relationship quality. Furthermore, the sample of the second study was quite homogenous regarding SS, meaning that most of the subjects showed moderate scores, and only few could have been considered as high or low sensation seekers. Similar to the homogeneity of the relationship quality, the main reason might be a recruitment bias, because exclusion criteria for all participants were, for example, smoking, alcohol or substance abuse, which are strongly associated with high SS (Comeau, Steward, Loba, 2001; Kraft & Rise, 1994; Roth & Petermann, 2003; Zuckerman, 1994; Zuckerman, Ball & Black, 1990).

Another limitation of the studies concerns the comparison between fathers and controls. It should be mentioned that most controls were not yet living together with their female partner, whereas all fathers were cohabiting with their female partner. This might constitute a bias regarding relationship quality as well as for T. However, to our knowledge, there is no study that takes into account this comparison.

Besides the aforementioned limitations, some interpretations of our results remain speculative, especially when fathers were compared with controls. There is a lack of baseline values, because even on the first assessment day, the two groups were already at completely different stages of their lives. Following Gloger-Tippelt (1988), fathers were already in the phase of anticipation and preparation (32nd-40th week of pregnancy), when conditions are very different than in couples who are not expecting a child (e.g. pregnancy



might encourage couple to be more gentle and affectionate to each other). For this reason, differences in T and in relationship quality might already be influenced by the different conditions. This has to be considered not only for differences between fathers and controls, but also for changes in T and relationship quality from before to after the birth.

4.4 Clinical Relevance and Outlook

The transition to parenthood is defined as the period of late pregnancy, the birth, the childbed and some weeks after, which is closely connected with mothers. However, the adaptation processes of new parents can only succeed when both mother and father work on them and when they are able to support each other in this challenging period. The findings of the empirical studies in this work presented the complexity and importance of the transition to parenthood also in fathers. Adaptation processes of fathers are associated with psychobiological adjustments, i.e. psychological as well as hormonal changes. Knowledge of such changes, which imply new feelings, experiences, behavior, and responses, enables the couple to cope effectively with the situation.

As psychobiological research on fathers is rare, the presented studies of this work focused on men. Results mainly confirm the integrating model described in Figure 2. Adaptation processes across the transition to fatherhood are associated with personality traits such as SS and hormonal dispositions (baseline T levels) as well as with hormonal responses and relationship quality. As this is the first study to investigate all of these aspects combined, some important dynamics and mechanisms in men becoming fathers for the first time might be better understood by our results.

Thus, there are some outstanding findings of the studies in this work. The association between T levels and relationship quality is very important, since the two factors influence each other to a significant degree. Furthermore, we were able to show for the first time the impact of individual characteristics of personality trait, such as SS on T levels across the transition to fatherhood. All of these findings play an important role for coping and adaptation of the transition to fatherhood as a major life change. There are different coping strategies needed in fathers, depending on their individual personality and relationship characteristics.

These findings might be very helpful for parent counseling or therapeutic support for new fathers or parents.

Although the results show important associations between psychological and endocrinological aspects of fathers, further studies involving female partners are required in order to complete the model by integrating couple aspects. Moreover, it would be important for ongoing research in the field of transition to parenthood to investigate interactions between adaptation processes and other personality traits (e.g. the Big Five) as well as other hormones which are known to be associated with parental behavior, such as estradiol, progesterone, prolactin, and oxytocin. Furthermore, a longer time period with more assessment days might provide more interesting insights into the adaptation processes across the transition to parenthood. Very interesting, but quite difficult, would be a baseline assessment prior to pregnancy. However, assessment after one year of parenthood, i.e. after one year of adaptation, would also be very important. Last but not least, a repeated measure of SS would be useful, because adaptation to meaningful events, such as becoming parents for the first time, might modulate even a personality trait.

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