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ABHANDLUNGEN

Behavioural Endocrinology in the Social Sciences

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Abstract Hormones are the endocrine system's messengers and an important coordinating mechanism of the body's growth, development, and functioning, with often simultaneous effects throughout the body and brain. Echoing calls for more interdisciplinary research bridging the gap between endocrinology and social sciences, we review evidence for hormones influencing human psychology (behaviour, cognition, and sociality), with a focus on health, sexuality, and further outcomes. We focus on four steroid hormones: testosterone (T), cortisol (C), estrogen (E), and progesterone (P). Embedded into life history theory as a prominent evolutionary framework, effects of T are conceptualised as modulating trade-offs between mating and parenting effort, especially when exposed to potential mates, interacting with offspring, and during competition. The challenge hypothesis suggests acute increases in T when facing challenges, with high T being linked to more competitive

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behaviour. The dual-hormone hypothesis postulates that C, as a measure of stress, inhibits the effects of T on status-seeking behaviour. The allostatic load framework suggests that chronic stress as indicated by high C levels could have detrimental health consequences. Various measurements of C are negatively related to socioeconomic status. The female steroid hormones E and P coordinate female reproduction by regulating the development and function of the uterus. They affect women's sexual desire as well as self-perceived attractiveness and are influenced by endogenous (e.g. pregnancy) as well as exogenous (e.g. hormonal contraceptives) factors. We address misinterpretations of biological determinism, highlight potential challenges in measuring hormones, and discuss ways in which social scientists can continue to incorporate hormones into their research.

Keywords Steroid hormones · Life history theory · Competition · Health · Sexuality

Verhaltensendokrinologie in den Sozialwissenschaften

Zusammenfassung Hormone sind die Botenstoffe des endokrinen Systems und ein wichtiger Koordinationsmechanismus für das Wachstum, die Entwicklung und die Funktionalität des Körpers mit häufig simultanen Effekten auf den gesamten Körper und das Gehirn. Entsprechend den Forderungen nach mehr interdisziplinärer Forschung, welche die Kluft zwischen Endokrinologie und Sozialwissenschaften überbrückt, geben wir einen Überblick über Evidenz, die zeigt, dass Hormone die menschliche Psychologie (Verhalten, Kognition und Sozialität) beeinflussen. Dabei legen wir Schwerpunkte auf Gesundheit, Sexualität und weitere beeinflusste Aspekte. Wir konzentrieren uns auf vier Steroidhormone: Testosteron (T), Cortisol (C), Östrogen (E) und Progesteron (P).

Eingebettet in die „life history theory“, die einen wichtigen evolutionären Rahmen darstellt, werden die Auswirkungen von T als Modulation von Kompromissen zwischen Partnersuche und elterlichen Anstrengungen konzeptualisiert. Diese Kompromisse sind besonders relevant, wenn man potenziellen Partnerinnen ausgesetzt ist, mit dem Nachwuchs interagiert sowie während sozialen Wettbewerbs. Die „challenge hypothesis“ besagt, dass der T-Spiegel bei akuten Herausforderungen ansteigt, wobei ein hoher T-Wert mit einem stärkeren Wettbewerbsverhalten verbunden ist. Die „dual hormone hypothesis“ postuliert, dass C als Maß für Stress die Effekte von T auf statusorientiertes Verhalten hemmt. Das Konzept der allostatischen Belastung legt nahe, dass chronischer Stress, der durch hohe C-Werte gekennzeichnet ist, gesundheitsschädliche Folgen haben kann. Verschiedene Maße von C stehen zudem in einem negativen Zusammenhang mit dem sozioökonomischen Status. Die weiblichen Steroidhormone E und P regulieren die Entwicklung und Funktion des Uterus und koordinieren dadurch die weibliche Reproduktion. E und P wirken sich aber auch auf das sexuelle Verlangen von Frauen sowie auf die selbstempfundene Attraktivität aus und werden sowohl durch endogene (z. B. Schwangerschaft) als auch durch exogene Faktoren (z. B. hormonelle Verhütungsmittel) beeinflusst.

Wir gehen auf Fehlinterpretationen im Sinne eines biologischen Determinismus ein, zeigen mögliche Herausforderungen bei der Messung von Hormonen auf und erörtern Möglichkeiten, wie die Sozialwissenschaften Hormone in zukünftige Forschung weiter einbinden können.

Schlüsselwörter Steroidhormone · Life history theory · Wettbewerb · Gesundheit · Sexualität

1 Introduction

Human behaviour has myriad determinants at societal, social and biological levels. To shed light on the complex interrelationship of biological and social influences, interdisciplinary work is needed (Freese et al. 2003). For this purpose, behavioural endocrinology can inform sociological research about mechanisms underlying behaviour. As a bridge between endocrinology and sociology, psychology can help to fill gaps in the literature in both fields. With this review on hormones and their interaction with social environments, we aim to provide a foundation for more interdisciplinary exchange[1] between endocrinology, psychology and sociology, as has been called for by various authors (e.g. Floyd 2011; Hardy 2019; Weitekamp and Hofmann 2021). Our review focuses on the links between hormones and social behaviour and consequences, where the social environment of an individual is highly relevant.

As one biological variable in humans, hormones are biomarkers that are accessible to study and enable environmental effects on the physical constitution, behaviour, and cognition of individuals, and vice versa, to be uncovered (Taylor 2012). We focus on theories and empirical evidence concerning four steroid hormones that are especially relevant for the social sciences: testosterone (T), cortisol (C), estrogen (E), and progesterone (P). We have chosen to focus on these four steroid hormones not only because they play a key role in modulating social behaviour but also because their behaviourally relevant levels can be measured in attainable human samples (blood, urine, hair, and most often saliva), which is not unambiguously the case for other socially relevant hormones, such as the neuropeptides oxytocin and vasopressin (Quintana 2022). We outline how these hormones are influenced by social roles and contexts (e.g. parenthood, mating, competitive situations) and how they in turn influence key social outcomes (e.g. social status, health, reproduction, outcomes related to romantic relationships, sexuality).

Hormones are the main messengers of the endocrinological system, analogous to the role of neurotransmitters in the nervous system. Although neurotransmitters are single-purpose messengers, hormones have an orchestrating function throughout the body. Beach (1974) defined the endocrinological system as “an integrated, finely tuned coordinating mechanism sensitive to changes in both the internal and external

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[1] We note that interdisciplinary work between these disciplines is also relevant from different perspectives, for example, science and technology studies (see von Scheve 2011); however, this is beyond the scope of this review.

environment and adapted to promotion of the physiological and behavioural effectiveness of the organism" (Beach 1974, p. 15). Crucial to understanding the function of hormones is that their relationship with behaviour is not biologically deterministic. Instead, hormonal effects interact with situational and contextual factors (Roney 2016). The discussion of our review provides a more detailed view of the limitations of behavioural endocrinology, particularly biological determinism and the challenges of measuring hormones. Hormones are mainly released in the body by the endocrine glands and directly by the brain. They circulate through the bloodstream and thus elicit short- and long-distance effects (Carré and Moreau 2014).

There are two main axes that regulate the production of steroid hormones, specifically the hypothalamic–pituitary–gonadal (HPG) axis and the hypothalamic–pituitary–adrenal (HPA) axis. T and E are end products of the HPG axis and their production and release in the gonads (T more in the testes, E more in the ovaries) are stimulated by the follicle-stimulating hormone from the pituitary glands and the gonadotropin-releasing hormone from the hypothalamus (Knight and Mehta 2014). C is the end product of the HPA axis, with its production and release in the adrenal glands being stimulated by further hormones in the HPA axis. This includes the adrenocorticotropic hormone secreted by the pituitary and the corticotropin-releasing hormone released by the hypothalamus. Both are released in response to stress. C also inhibits HPA activity, creating a negative feedback loop inhibiting further C release. In women[2], E, P, and T are mainly produced and released in the ovaries. In men, E and P are produced locally in testes and by brain, skin, bone, and adipose tissue (Cooke et al. 2017). Both sexes also produce smaller amounts of T in the adrenal glands.

In this review, we summarise evidence on behavioural associations of steroid hormones from a psychological perspective. We discuss effects of T over the lifetime in different social contexts, where *life history theory* offers a perspective on how T levels associated with differences in socio-demographic variables like age and relationship status are a response to, but can also drive, trade-offs in effort investments. The *challenge hypothesis* and the *biosocial model of status* describe how T influences social behaviour. The relationship of T with behaviour is not deterministic and depends on personal, contextual, and other physiological variables such as C levels. Further, we review evidence on the measurements of C and their relation to social status and health according to the *allostatic load framework*. Last, we describe the effects of E and P (also called "female" steroid hormones) on behaviour and how they are influenced by different environmental factors.

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[2] Throughout this article, we will refer to individuals with developed ovaries as women or female and individuals with developed testes as men or male, as these biological characteristics are central to their endocrine functioning. We recognize, however, that not all people who identify as "women" or "men" have these organs, and conversely, not all individuals with these organs identify as "women" or "men".

2 Testosterone

One main focus of this review is the steroid hormone T. In humans, men have a greater reproductive variance and show more intense intrasexual competition than women (Wade 1979). In evolutionary biology, the sex difference in the level of intrasexual competition is explained by sex differences in reproductive variance (higher in males) and minimal parental investment (lower in males, *parental investment theory*, Trivers 1972). Owing to internal fertilisation and the concealed ovulation of women, men have a paternity certainty below 100%, and owing to anisogamy (female ova are the largest and male sperm are the smallest cells in the human body) the production of male gametes is less costly and much more abundant. Hence, the theoretically adaptive minimal parental investment of men is lower than that of women, leading to more intersexual competition for mating partners in men. Therefore T, as a steroid hormone effective in the context of social competitions, is assumed to be more relevant in men (Labrie et al. 2009; Puts et al. 2015). Although T is present in men and women, the lower range of blood levels of T in men is still about four to five times higher than the upper levels in women (Clark et al. 2019). T has organisational as well as activational effects, its most important organisational effect being the determination of the male morphological formation (for further details see Breedlove 1994). For a more detailed overview of the organisational effects throughout development, see Sánchez Guerrero et al. (2023, this issue). Activational effects on behaviour, cognition, and physiology are more short-term. For example, acute rises in T lead to more competitive behaviour and risk-taking as an adaptive response in mating situations (Eisenegger et al. 2017; Ronay and von Hippel 2010). The production of T is costly; according to a recent meta-analysis by Foo et al. (2016), the secretion of T had a medium-sized suppressive effect on immune system functioning. Similarly, immune responses to infections are associated with decreases in men's T levels (e.g. respiratory tract infection, Muehlenbein et al. 2010; COVID-19 infection, Salonia et al. 2021).

Most findings reported here are based on correlational and/or cross-sectional studies, allowing no insights on the causal effects of T on behaviour or vice versa. Causal insights can be gained from studies using an experimental design, such as designs with exogenous T administration (e.g. Bos et al. 2010, 2021). However, these designs often face problems with regard to physiologically plausible dosage, timing, and duration, individual differences in androgen receptivity, and ecological validity (e.g. as yet dosages and administration procedures have been validated in men only, Eisenegger et al. 2013).

2.1 Testosterone and Life History Theory

Based on simultaneous, orchestrated effects throughout the body as the defining feature of hormones, Roney (2016) emphasises that hormones need to be synthesised within theoretical frameworks that integrate all their various eliciting conditions and coordinated output effects. He suggests that evolutionary life history theory provides a broader theoretical framework in which trade-offs regulated by hormones can be understood. Life history theory is aimed at explaining the allocation of effort of organisms to fitness-relevant domains across the lifespan (Stearns 1992). According to life history theory, an individual faces different trade-offs of allocating limited resources such as time and energy to diverse behaviours and the development of characteristics in the pursuit of maximising evolutionary fitness (Kaplan and Gangestad 2015). The overall effects of T can be understood as modulating trade-offs between mating and parenting effort. Zilioli and Bird (2017) identified three evolutionarily relevant contexts in which such trade-offs modulated by T are especially implicated: exposure to potential mates, interaction with offspring, and competitive interactions. In these contexts, there is a major trade-off between mating (acquiring new mates, e.g. via status acquisition through intrasexual competition) and parental effort behaviours (nurturing offspring and pair bonding, Gettler et al. 2020). This trade-off can also be framed in terms of competitive versus nurturing behaviour (van Anders et al. 2011), and high versus low T levels are associated with behavioural tendencies towards competitive mating and nurturant parenting respectively. For example, baseline T levels (i.e. stable interindividual differences) are positively related to interpersonal avoidance, dominance, and disconnectedness in men (Turan et al. 2014).

Besides associations on an interindividual baseline level, acute increases in T (i.e. reactively on an intraindividual state level) are relevant for behaviour implicated in mating and reproduction (Wingfield 2017). According to the challenge hypothesis (Archer 2006; Wingfield 2017), T levels rise in individuals facing reproductive challenges and opportunities, such as interactions with potential mates or intrasexual competition (for reviews see Carré and Archer 2018; Geniole and Carré 2018). For example, men's acute T reactivity in a competitive situation with exposure to an attractive woman was positively associated with their self-reported competitiveness and observer-perceived self-assurance (Kordsmeyer and Penke 2019). In contrast, parental effort such as nurturing offspring or relationship maintenance behaviours is related to T decreases (Edelstein 2022), as outlined below. Additionally, it has been argued that some parenting behaviours involving competitive aspects, such as offspring defence, can be related to high T levels (van Anders 2013; van Anders et al. 2011). Thus, life history theory is a useful framework for understanding T's associations with human behavioural tendencies, both stable and situational, especially concerning trade-offs of mating versus parenting. These associations have been studied in research examining a range of relevant demographic, behavioural, and hormonal variables (e.g. Rosenbaum et al. 2018), of which some studies are outlined in the following.

2.1.1 Testosterone and Parental Status

The life history trade-off between mating and parenting effort suggests that romantic relationship status should be related to T levels (Edelstein 2022; Gettler et al. 2020). A recent meta-analysis focusing on heterosexual men showed robust associations between T levels and relationship status (Grebe et al. 2019). Higher T levels were shown for single men compared with men in committed relationships ($r=0.15$, 95% CI [0.12, 0.18], overall $N=11{,}038$, $k=60$ effects). A longitudinal study showed that the T levels of men who got married during a time period of 10 years decreased (above and beyond the typical age-related decline), whereas T of men who got divorced showed an attenuated age-related decline (relative to men who were either married or unmarried at both time points, Holmboe et al. 2017; see also Mazur and Michalek 1998). For women, only a few studies are available to date. One study showed that T levels were higher in unpartnered than in partnered homosexual women[3], with no such difference in heterosexual women (van Anders and Watson 2006). Another study found higher T levels in both single women and women in casual, uncommitted relationships relative to those in long-term relationships (van Anders and Goldey 2010). For men, two studies revealed that the association between relationship status and T levels was qualified by their extra-pair sexual interests (McIntyre et al. 2006). T levels of partnered men were lower especially when their extra-pair sexual interest was restricted. For both men and women, the association between T levels and relationship status was moderated by different facets of their self-reported sociosexuality (sociosexual desire for men, sociosexual behaviour for women, Edelstein et al. 2011). Sociosexuality captures personality differences in the tendency to engage in uncommitted sexuality, qualifying it as a measure of extra-pair sexual interest in couples (Penke and Asendorpf 2008). Hence, for both men and women the link of T with relationship status may be influenced by their degree of commitment to a relationship and their openness to extra-pair sexual encounters.

Similar to relationship status, parental status can be expected to affect T levels as a result of T's mediating role in mating–parenting trade-offs. This has been studied primarily in men as well (Edelstein 2022). The aforementioned meta-analysis on T and relationship status also found that, on average, fathers had lower T levels than non-fathers ($r = 0.19$, 95% CI [0.11, 0.27], overall $N = 6314$, $k = 28$ effects, Grebe et al. 2019; Kuzawa et al. 2009 showed that primarily fatherhood, rather than relationship status, accounted for differences in men's T level; Gettler et al. 2011b, provided longitudinal evidence). Further analyses indicated that especially the degree of fathering behaviours may be driving the effect of lower T in fathers, as fathering behaviours were negatively related to T levels ($r = 0.33$, 95% CI [0.24, 0.42], overall $N = 504$, $k = 11$ effects; but see Gettler et al. 2011a, for a null-result on short-term changes in fathers' T levels after father–child play). One study showed that the decrease in fathers' T levels from before to after childbirth (relative to the T change in non-fathers) was strongest in fathers with lower self-reported sensation-seeking (a personality trait implicated in mating-parenting trade-offs, Perini et al. 2012). Similarly, a study revealed that T levels were not only negatively related to fatherhood but also positively related to fathers' number of children (Pollet et al. 2013). In contrast, in women T levels were unrelated to either motherhood or number of children (Pollet et al. 2013; but see Kuzawa et al. 2010, who found lower T levels in mothers, especially those of children younger than 2 years, than in non-mothers; for a similar finding in men see Rosenbaum et al. 2018). A more recent study in small-scale forager and fisher–farmer communities demonstrated that amongst fathers, especially those showing more prosocial and cooperative be-

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[3] Although a focused review of hormonal influences on sexual orientation is beyond the scope of this review, we direct the interested reader to a recent review and meta-analysis on associations between prenatal gonadal hormones and sexual orientation (Swift-Gallant et al. 2023).

haviours, had lower T levels than less prosocial and cooperative men (Gettler et al. 2020). Thus, overall it seems that men who are more oriented towards investing in committed relationships and offspring have lower T levels than men who are more invested in pursuing new mates and casual, uncommitted relationships, stressing T's role of modulating life-history trade-offs between mating and bonding/parenting behaviours.

On a short-term, situational level, studies showed associations between parental behaviours and T levels. For example, men with lower T levels were more responsive when exposed to infant cries (i.e. reported stronger sympathy and a stronger need to respond, Fleming et al. 2002). Further studies investigated neural responses in relation to their T levels when interacting with infants or exposed to child stimuli. T levels measured after infant interactions were positively associated with stronger responses when interacting with their own infants than when interacting with other infants, whereas these relative neural responses were linked to paternal sensitivity and reciprocal behaviour (Kuo et al. 2012). Studies exogenously increasing T levels via sublingual administration in women found stronger neural responses to stimuli showing crying infants or distressed children, which were also related to indices of parental care (relative to a placebo condition in which women received no T, Bos et al. 2010, 2021). These positive associations of neural responses with both T levels and parental behaviours seem contradictory to the negative relationships between T and fathering behaviours mentioned earlier. Future research needs to investigate how exactly diverse kinds of parenting behaviours are related to such neural responses and associated T levels in both fathers and mothers. This could clarify the extent to which T can positively facilitate acute parental care.

2.1.2 Testosterone and the Young Male Syndrome

According to life-history theory and the challenge hypothesis, higher T levels should also be associated with risk-taking and aggressiveness as facets of competitive behaviour. In a seminal study, Wilson and Daly (1985) reviewed homicidal conflicts in the USA in the 1970s. They observed that among both offenders and victims, young unemployed and unmarried men were strongly overrepresented. They termed this peak of male-to-male aggression *young male syndrome*. Adolescence and young adulthood are ontogenetic periods of intense competition for status and sexual mates going hand-in-hand with the highest T levels throughout development (McAndrew 2009). A meta-analysis between T and aggression found a weak positive association overall (Book et al. 2001; see Archer et al. 2005 for a re-analysis showing a slightly smaller, but still significant positive association). The association was moderated by age in men (but not in women), in that it was strongest in adolescents and young adults, compared with older adults (see Archer et al. 1998). Mazur and Michalek (1998) suggested that changes in baseline T levels might explain lower rates of criminality in married men and increased spousal abuse around the time of divorce. Looking more closely at different facets of aggression, it was argued that T may not be strongly related to physical aggression, but rather to aggression linked to dominant behaviour (Booth et al. 2006; Mazur 2009). For example, in young adolescent boys, T levels were positively related to social dominance, but negatively related to physical aggression (Schaal et al. 1996). Moreover, studies have shown that in particular, reactive aggression (e.g. retaliating against the opponent in a dyadic competition) is related to acute fluctuations in T (e.g. Carré et al. 2009; for an overview see Carré and Olmstead 2015). These life-history trade-offs modulated by T, alongside purported associations of T with certain forms of aggression, suggest that T might play a central role in competitive behaviour.

2.2 Testosterone and Competition

According to the challenge hypothesis, competition between individuals is linked to an increase in T, which may in turn augment mating prospects (Wingfield et al. 1990). Subsequent studies found that heterosexual men had a larger T increase after interacting with an (above-average attractive) woman than after interacting with other men or waiting in a room alone (Roney et al. 2003, 2007; van der Meij et al. 2008). The effect of T on competitive behaviour is also evident in sports, where T levels of men increase in anticipation of, during, and after engaging in sports such as soccer (Edwards et al. 2006), Japanese chess (Hasegawa et al. 2008), or wrestling (Elias 1981). Sports-related increases in T do not seem to depend on the level of physical exertion. Instead, T levels after competition are even negatively related to blood markers of physical exertion and are unrelated to the number of minutes played in a match (Casto and Edwards 2016; Suay et al. 1999). Also, there is evidence that sports fans who watch their favourite team play experience increases in T (Bernhardt et al. 1998). Although increases in T during sports competition do not seem to be linked to levels of physical exertion, they do predict stronger competitive endurance (Casto et al. 2020). Generally, competitive settings seem to be associated with rising T levels. In addition to the competitiveness of a situation, a multitude of other factors in the social environment (like peer groups) play a key role in understanding the situational dependency of T effects, as reviewed by Booth et al. (2006).

2.3 Testosterone and Individual Differences

The relationship between competition and T is bidirectional, with interindividual differences in T level also being associated with stable competition-related individual differences, including personality differences like dominance (Archer 2006), aggressiveness (Archer et al. 2005), and competitiveness (Eisenegger et al. 2017). Baseline levels of T are positively linked to implicit power motives (Schultheiss 2007). Power-motivated people achieve emotional satisfaction from having an impact on others. Specifically, T levels after competition correlate positively with personalised power (i.e. dominance and assertiveness), but only in individuals with low interest in prosocially influencing others (Schultheiss et al. 1999). Furthermore, a rise in T also increases risk-taking behaviours, in line with T promoting success in mating-related competition. Ronay and von Hippel (2010) showed that in the presence of an above-average attractive female confederate, men in a skateboard park demonstrated more successful skateboard tricks but also had more crash landings, moderated by higher T. These studies show that factors on the level of the individual, like dominance-related personality traits, are linked to baseline T levels as well as to a rise in T in competitive situations.

In individuals with certain personalities, the link between T and behaviour is more prominent. In a large study, Geniole et al. (2019) showed that higher T levels were associated with higher levels of aggression in individuals with high trait dominance, high impulsivity and a more independent self-construal (for an article on independent versus interdependent self-construal see Kühnen and Kitayama 2024, this issue). Also, the personality trait narcissism seems to be a moderator for the effect of T on resource allocation strategies. Czarna et al. (2022) found that individuals high in both T and narcissism showed a more prosocial value orientation, whereas individuals high in T but low in narcissism showed a more competitive value orientation. Thus, although both T and narcissism influence status-seeking behaviours and more competitive resource allocation strategies separately, their interaction was related to a prosocial value orientation.

2.4 Testosterone and Status Seeking

The apparently contradictory result that T sometimes influences competitive behaviour and is in other cases associated with a more prosocial value orientation is explained by the biosocial model of status, which suggests that T generally promotes status-seeking behaviour rather than competitiveness per se (Mazur 1985). Status can in some scenarios be gained through more dominant and in others through more prosocial behaviour. The biosocial model of status also makes a prediction for differences in post-competition T levels. T levels rise in winners of competitions to help them to face additional challenges to their social status, whereas T levels do not change after a competition in losers. This is called the winner–loser effect (Booth et al. 1989). A meta-analysis by Geniole et al. (2017) showed a medium-sized positive effect of winning compared with losing on post-competition T levels ($d = 0.20$, 95% CI [0.10, 0.31], overall $N = 2515$, $k = 60$ effects). That effect was due to a rise of T in winners after the competition and mainly present in field studies, possibly because of a higher salience of the outcome. However, although there is agreement that T drives status-seeking behaviours and studies reported positive associations of T with status-related traits, there is also a range of null-findings, for example for aggression in women (Denson et al. 2013), status with teammates in women (Edwards and Casto 2013), and popularity in male rugby players (Ponzi et al. 2016). In a longitudinal study, Cheng et al. (2018) reported an effect of gaining social status through prestige on a rise in T months later in men but not in women. Mazur et al. (2015) also found some evidence for the relevance of speech as a form of status seeking in group conversations, where T measurements were related to ratings of having a leading role in a casual videotaped conversation. Analogous to effects of territoriality in animal studies, in sport competitions the "home advantage" effect (better results in sport competitions at home than away) is a well-documented phenomenon, pre-game T levels are higher in home than in away games (Neave and Wolfson 2003). A study by Jiménez Sánchez and Lavín (2020) during the COVID-19 pandemic even demonstrated that the "home advantage" effect of higher pre-game T levels is independent of the presence of a crowd.

Interestingly, a reverse winner–loser effect (higher post-competition T levels in losers than in winners) can be found in social contexts involving unstable social hierarchies. In a study by Wu et al. (2017), female participants contested in a rigged number tracking task against an experimental confederate and either barely lost or barely won. Losers showed a T increase and winners a T decrease. In the same study, this reverse effect also emerged in the case of uncertain competition outcomes. Additionally, Mehta and Josephs (2006) found that participants who lost a competition but experienced a rise in T during the competition, were more willing to compete again against the same opponent in comparison with those who won the competition (Mehta and Josephs 2006). Thus, within unstable hierarchies T promotes status-seeking behaviour.

However, the effect of T on status-seeking behaviour is less clear for broader life outcomes than for individual competitions. Van der Meij et al. (2016) found no relationship of T levels with leadership as a proxy measure of social status ($r = 0.01$, 95% CI [–0.08, 0.09], overall $N = 1103$, $k = 13$ effects). Also, in a large UK cohort study, there was no clear evidence of a correlation between repeated blood measurements of T and socioeconomic status (Hughes and Kumari 2018). Yet, there are some findings demonstrating a relationship between T and economic risk taking, which in turn is directly influenced by social status (Fisk et al. 2017).

The perspective that T influences status-seeking behaviour in general can also explain certain T effects in the absence of direct challenges. For example, Boksem et al. (2013) studied a trust game, where individuals played once as investors (they made a money investment that was tripled and potentially shared by a receiver, a position including threat to social status, as trust could be exploited) and then as a trustee (they could return a part of a given investment, a position that did not include a threat to social status). The experiment was rigged in that the participants always received a high investment when they played as trustees. Participants high in T donated less when they played as investors, but they returned more when they played as trustees. Such generous, prosocial behaviour may promote status when no threats to social status are present, and the finding that T predicted this kind of behaviour as well underlines the general role of T in status-seeking behaviours. Prosocial behaviour promoted by T may also be influenced by ingroup/outgroup biases (Reimers and Diekhof 2015). In two economic games, football fans with elevated T showed increased cooperation towards individuals supporting their own favourite team but also increased competition towards individuals supporting other teams. More studies exploring the effects of T in diverse social situations will help to solidify the relevance of T effects for status-seeking, competitive behaviour, and group dynamics.

2.5 Testosterone and Cortisol

Besides contexts and personality traits, another moderator of effects of T on social behaviour has been proposed. According to the *dual hormone hypothesis,* introduced by Mehta and Josephs (2010), C moderates the association of T with status-relevant behaviour, in that C inhibits the behavioural effects of T. Biologically, this approach is grounded in the co-regulation of the HPG axis and the HPA axis (Viau 2002).

In two studies, Mehta and Josephs (2010) showed that T and dominance are only positively correlated when C is low and that this correlation disappears or even reverses when C is high.

Supporting initial findings, the interaction between T and C has subsequently been found for social status, measured as popularity within a group (in female athletes, Casto et al. 2019; Edwards and Casto 2013; in male athletes, Ponzi et al. 2016) and leadership positions (number of subordinates, Sherman et al. 2016), as well as with status-related behaviour such as aggression (Popma et al. 2007) and risk-taking (Mehta et al. 2015; van den Bos et al. 2013; for a review see Mehta and Prasad 2015). A recent meta-analysis by Dekkers et al. (2019) reported a small but robust interaction effect in support of the dual-hormone hypothesis ($r = –0.06$, 95% Ci [–0.11, –0.01], overall $N = 8538$, $k = 49$ effects).

3 Cortisol

The moderating role of C for effects of T on status-related behaviour is linked to the glucocorticoid hormone C being understood as an index of the body's stress response. The relevance of cortisol for sociological research is exemplified by Roberts and McWade (2021), who even propose a "cortisol sociology" subfield. Even earlier, Taylor (2012) highlights C as a way of measuring reactions to social stressors and environments. In general, C increases in response to physical and psychological stress, especially in response to uncontrollable or social-evaluative stressors (Dickerson and Kemeny 2004). In addition to these situational C increases, C follows a diurnal release rhythm. Healthy individuals show the highest concentrations in the early morning after awakening, also referred to as the C awakening response. C then declines over the course of the day, with lowest concentrations around midnight (Kirschbaum and Hellhammer 1989). A flattened diurnal C slope suggests a dysregulation of the C release cycle (e.g. Knight and Mehta 2014).

3.1 Hair Cortisol Concentration

Most commonly in human studies, C is measured from saliva, blood serum, or urine (Nicolson 2008). These samples provide a momentary insight into participants' current C levels. They are affected by acutely stressful situations (Dickerson and Kemeny 2004), certain behaviour (e.g. intense exercise, alcohol, food intake, and smoking, Schultheiss and Stanton 2009), or the time of the day (Kirschbaum and Hellhammer 1989). Thus, these samples are able to capture diurnal fluctuations or acute changes in C. However, questions regarding the long-term effects of C require additional methodological effort and would entail multiple (e.g. daily) saliva samples to aggregate over situational variability, which make them difficult to implement in large samples (Russell et al. 2012).

As a more feasible alternative, Cirimèle et al. (2000) analysed C from human scalp hair. This novel method was validated as a measure of long-term stress in analyses of the hair of wild live rock hyrax (Koren et al. 2002). Hair cortisol concentrations (HCCs) capture aggregated long-term cortisol exposure retrospectively and are less susceptible to daily fluctuations (Stalder and Kirschbaum 2012). Validation studies revealed moderate to strong correlations of HCC with daily salivary samples over a 30-day period (Short et al. 2016; Sugaya et al. 2020) but only small correlations over shorter time periods (Stalder et al. 2017) or less dense sampling (Stern et al. 2022). Generally, HCC declines with increased distance from the scalp, indicating that the most accurate results of HCC will be obtained from samples taken closest to the scalp and that within-sample comparisons should be avoided (overall $N = 1320$, $k = 9$ studies, Stalder et al. 2017).

Female humans show lower levels of HCC, in both adults and children, whereas younger age and higher hair washing frequency is associated with lower HCC in adults (Gray et al. 2018; Stalder et al. 2017). Similar to traditional measures of C, correlations of HCC with subjective, self-reported stress are inconsistent. However, HCC is higher in groups experiencing chronic stressors such as caregiving stress, especially when stress is ongoing while the sample was taken (Stalder et al. 2017). Hence, especially on a group level evidence indicates that HCC is a viable biological marker of chronic stress.

3.2 Acute and Long-Term Stressors

Acute changes in C in response to social stressors are considered adaptive. C mobilises the energy resources necessary to handle the demands of highly stressful situations (Dickerson and Zoccola 2013). Accordingly, C is higher after experiencing status threats (Taylor 2014) and social exclusion (in adults, Helpman et al. 2017; Peterson et al. 2020; in children, Simmons et al. 2019). However, especially for associations of C and social exclusion, evidence is inconsistent with regard to gender (reviewed in Helpman et al. 2017), emphasising the need for more research.

Only if the individual is exposed to extended periods of stress is C considered potentially harmful. For example, individuals with low socioeconomic status tend to experience constant stressors such as (risk of) unemployment and financial insecurity (Lennon and Limonic 2009). Indeed, socioeconomic status correlates negatively with basal salivary C in human studies (reviewed in Knight and Mehta 2014) and C correlates negatively with social rank in primates (e.g. Abbott et al. 2003), indicating that an individual's societal standing is related to C. Furthermore, individuals with lower socioeconomic status show a flattened diurnal C slope in salivary measures, indicating a dysregulation in the C release cycle (Knight and Mehta 2014; Sherman and Mehta 2020). In a study by Zilioli et al. (2017), the flattened diurnal C slope mediated the relationship of socioeconomic status and health, in that individuals with a lower socioeconomic status reported a greater severity of physical symptoms. In addition, HCCs are also higher in children of families with low socioeconomic status (Cantave et al. 2023; Vliegenthart et al. 2016) and Black ethnicity compared with other ethnic groups (Abell et al. 2016). However, HCC is positively associated with employment grades, though no longer significantly after adjusting for confounding factors (Abell et al. 2016).

In sum, the association of socioeconomic status with C can be found using various measures of C. The reviewed evidence shows that the social environment an individual is exposed to can impact C release momentarily via acute social stressors and chronically via long-term stressors, with far-reaching implications for the individual.

3.3 Implications: Cortisol and Health

A dysregulation of the HPA axis in response to chronic stress is consistent with the allostatic load framework. Allostasis describes adaptive responses of in- or overactivity of the neural, neuroendocrine, and immune systems (McEwen 1998). If these adaptive responses occur chronically or are dysregulated (Dowd et al. 2009), they inflict costs termed "allostatic load". High allostatic load predisposes an individual to diseases such as viral infections, coronary heart disease, obesity or hypertension (McEwen and Stellar 1993). Allostatic load offers a theoretical framework that explains how social experiences can impact health. For example, high allostatic load, sustained over a prolonged period of time (e.g. due to repeated experiences of discrimination) can have long-term negative effects and may contribute to an explanation of the health- and mortality-gradient between subpopulations (Goosby and Cheadle 2024, this issue).

Empirical evidence is consistent with this notion of C's link to health outcomes. A meta-analysis on C and severity of COVID-19 infections indicates that higher serum C is a risk factor for a more severe COVID-19 infection ($SMD = 1.48$ µg/dL, 95% CI [0.51 µg/dL, 2.46 µg/dL], overall $N = 476$, $k = 11$ effects, Amiri-Dashatan et al. 2022). According to another meta-analysis, a flattened diurnal C slope is associated with a wide range of negative health outcomes ($r = 0.15$, 95% CI [0.11, 0.18], overall $N = 26{,}167$, $k = 179$ effects, Adam et al. 2017). In particular, HCC, as a biomarker for allostatic load and chronic stress, was higher in individuals with diabetes or obesity in a large cohort study ($n = 4460$, Abell et al. 2016), indicative of dysregulation of the metabolic system. HCCs were also higher in individuals with cardiovascular disease, but findings are inconsistent for C measured via saliva, blood serum, or urine (reviewed by Iob and Steptoe 2019). Although Abell et al. (2016) did not report any significant direct associations of HCC with cardiovascular diseases, they suggest HCC as a marker of cardiovascular disease risks instead, as both diabetes and obesity are known risk factors. The authors further reported higher HCCs in depressed individuals. Seemingly contradictory, but consistent with other work in the clinical context, Stalder et al. (2017) reported lower HCCs in individuals with diagnosed anxiety disorder, although this finding needs replication as the sample size was small ($b = -0.18$, 95% CI [–0.36, –0.01], overall $N = 50$, $k =$ 3 effects).

Allostatic load as a framework was introduced to sociological research by Massey (2004). In the following years, C was incorporated in studies, mainly on sociology of health (e.g. Karb et al. 2012; Li et al. 2021; Robinette et al. 2016). This empirical evidence reflects a perspective in sociology that has already implemented hormonal measures and highlights the wide-ranging consequences of physiological processes that in turn might be affected by or affect an individual's social environment.

4 Female Steroid Hormones

The steroid hormones E and P are mainly produced in the ovaries and are thus considered “female” steroid hormones, even though men produce both hormones as well in the testes and adrenal glands. However, their main biological role is to coordinate female reproduction by regulating the development and function of the uterus. E and P show specific patterns over the ovulatory cycle in naturally cycling women. Although E peaks at the end of the follicular phase (before ovulation) and shows a second, smaller peak during the luteal phase (after ovulation), levels of P are highest during the luteal phase, between ovulation and menstruation. Patterns observed in pregnant women or women using hormonal contraceptives differ considerably (Fleischman et al. 2010). Besides coordinating the reproductive system, E and P are hypothesised to affect further aspects of the body and brain (Del Río et al. 2018). In the following, we highlight findings on the psychological effects of E and P between and within women, as well as on endogenous and exogenous factors influencing levels of E and P. By putting an exemplary focus on hormonal contraception we discuss how female steroid hormones may be relevant for the social sciences.

4.1 Effects of Female Steroid Hormones

Although there are a few empirical studies showing between-women effects of E and P on facial attractiveness (Law Smith et al. 2006), physical attractiveness (Jasieńska et al. 2004), and attractiveness of body odour (Lobmaier et al. 2018), a long list of null-replications (e.g. Grillot et al. 2014; Jones et al. 2018; Puts et al. 2013) as well as methodological criticism (e.g. Arslan et al. 2021b; Jones et al. 2018) cast doubt on these results. The most robust evidence for effects of E and P on women’s cognition and behaviour is based on within-women analyses across the ovulatory cycle. Around ovulation, heterosexual women show an increase in sexual desire (Arslan et al. 2021b), self-perceived attractiveness (Schleifenbaum et al. 2021), attraction to male bodies (Jünger et al. 2018a; Stern et al. 2021), and attraction to male voices (Jünger et al. 2018b). Evolutionary psychology has investigated the idea that during non-fertile times women would prefer partners who invest in offspring and during the fertile phase they would prefer partners with outstanding genetically heritable characteristics (Pillsworth and Haselton 2006). However, to date no compelling empirical evidence for robust and substantial effects exists (see Arslan et al. 2021a and Gangestad and Dinh 2021 for an ongoing debate).

4.2 Endogenous Factors: Menarche, Pregnancy, and Menopause

Different factors influence the levels of E and P in women, some of which are endogenous and connected to specific developmental life stages. Girls experience an increase in E and P shortly before menarche (Gray et al. 2010) or preceding it (Zhang et al. 2008). These changes in the endocrine system are hypothesised to be connected to an increased development of negative affect during puberty in girls (Steiner 2003) and might be one explanation for the increased prevalence of depression in adolescent girls compared with boys (Kessler and Walters 1998).

During pregnancy, levels of E and P drastically increase in comparison with non-gestational levels (e.g. O'Leary et al. 1991; Tulchinsky and Hobel 1973), inducing physiological adjustments to facilitate adequate foetal development (Noyola-Martínez et al. 2019). After birth, declining levels of E have been associated with postnatal depression (Ahokas et al. 2001) and postpartum psychosis (Wieck et al. 1991). Later in life, levels of E and P decrease during menopausal transition. Higher levels of E during menopausal transition were associated with an increased risk of breast cancer (Missmer et al. 2004). In addition, greater E variability and lower levels of P across the cycle during menopausal transition were linked to higher levels of depressive symptoms (Joffe et al. 2020).

In sum, endogenous factors play an important role in altering the levels of E and P over women's life span. The main functions of these changing levels are organising aspects concerning female reproduction. Nevertheless, the literature suggests that the levels of E and P during different life stages might influence women's experience and behaviour.

4.3 Exogenous Factors: Malnutrition and Exercise

Following Roney's (2016) theoretical framework, levels of E and P are not only influenced by life stages but also by eliciting conditions. In the following, we focus on energy availability, as there is strong evidence for its effects on women's ovarian function (for a review see Ellison 2003).

Reduced energy intake in the form of malnutrition leads to lower levels of E and P (Panter-Brick et al. 1993), especially during the luteal phase after ovulation (Schweiger et al. 1988). Possibly related to malnutrition is the effect of socioeconomic conditions on levels of E and P. The age of menarche has decreased significantly during the twentieth century in industrialised countries because of improved socioeconomic conditions (Papadimitriou 2016), marking one example of a strong environmental influence on the endocrine system across whole populations. An opposing but potentially complementary effect, proposed based on life-history theory, suggests that adverse circumstances (e.g. absence of biological fathers) might lead to an earlier age of menarche on an individual level (Belsky et al. 1991). A meta-analysis by Webster et al. (2014) found empirical support for a small relationship between father absence and daughter menarcheal age ($r = 0.14$, 95% CI [0.09, 0.38], overall $N = 70{,}400$, $k = 33$ effects), but effect sizes across studies were heterogeneous. Furthermore, genetically controlled studies suggest that heritable individual differences might confound this association (Mendle et al. 2006; Rowe 2002).

Besides effects on the age of menarche, mean levels of E and P are significantly lower in populations of women who experience regular seasons of reduced caloric intake than in populations of women in industrialised countries with more consistent caloric intake (e.g. Ellison et al. 1989). Moreover, in a non-industrialised country, levels of P were significantly lower in poorer women (presumably with lower caloric intake) than in better-off women (presumably with more consistent caloric intake, Vitzthum et al. 2002).

Aside from energy intake, energy availability is influenced by energy expenditure, for example, through exercise. In an early study, Bullen et al. (1985) found evidence that periods of very intense training led to lower levels of E and most women experienced more intermenstrual bleeding and delayed menstruation, especially when experiencing weight loss as well. Ellison et al. (1985) provided converging evidence that even moderate exercise led to lower levels of P. Further, athletes showed reduced levels of E and P during the luteal phase compared with a control group (Schweiger et al. 1988). One possible explanation for these effects of energy availability on the endocrine system are evolved adaptive mechanisms. One proposed mechanism is that during poor environmental conditions with low energy availability, reproductive functions are suppressed. This mechanism would allow women to survive during periods of limited energy availability, when pregnancy would incur a severe additional burden, and to increase their mating efforts during periods of sufficient energy availability, overall improving their lifetime reproductive success (Jasienska 2001).

Further exogenous factors are proposed to influence the endocrine system, including, for example, acute psychological stress (Roney and Simmons 2015) and stressful environmental conditions during childhood (Núñez-de la Mora et al. 2007). Empirical findings for these eliciting factors are mixed and further research on this topic is needed.

4.4 Hormonal Contraception

Another important exogenous factor is hormonal contraception, like oral contraceptives (also known as the pill), as its use reduces variation in E and P across the ovulatory cycle. They are used by more than 25% of women worldwide (United Nations 2019). Evidence concerning effects of hormonal contraceptives on sexuality and well-being is mixed. On the one hand, empirical evidence suggests that hormonal contraceptives might have negative side effects on heterosexual women's sexuality (e.g. sexual desire, frequency, and functioning, see Lundin et al. 2018; Zethraeus et al. 2016) and their well-being (e.g. depression, suicide, and general well-being, see Skovlund et al. 2016, 2018; Zethraeus et al. 2017). On the other hand, there is research suggesting positive or no effects of hormonal contraceptives on heterosexual women's sexuality (e.g. sexual arousal, desire, and frequency, see Blumenstock and Barber 2022; Caruso et al. 2005) and their well-being (e.g. depression, general well-being, and mental health, see Lundin et al. 2022; Toffol et al. 2011).

Overall, the question of how hormonal contraceptives affect the endocrine system and thereby influence women's sexuality and well-being remains unanswered. The conflicting evidence could be partly due to the use of different research designs (e.g. randomised controlled trials compared with cross-sectional correlative studies). It is therefore unclear whether or not these effects are causal (Botzet et al. 2021) and whether or not they are homogenous across women (Hill and Mengelkoch 2022). To improve our ability to distinguish causal effects of hormonal contraceptives from other sources of association and estimate individual treatment effects in real life settings, future research should explicitly state assumptions necessary to draw causal inference and apply appropriate methods based on longitudinal datasets with large sample sizes (for an example see Botzet et al. 2023).

5 Discussion

In this review, we focused on evidence regarding steroid hormones' associations with socially relevant human behaviour, contexts, and environmental factors, mainly from a psychological perspective. Our review covered acute behavioural changes in response to situations, changes along the human lifetime, and changes elicited by an individual's (social) environment. Although we focused mainly on interindividual differences, factors influenced by society (e.g. parental roles and associated norms) and socioeconomic factors were considered in accordance with relevant theoretical frameworks. In addition, we outlined potential effects of steroid hormones on a whole range of outcomes, including sociality, health, and sexuality. When considering the available empirical evidence on steroid hormones and outcomes relevant to the social sciences, it is important to keep in mind that the vast proportion of knowledge is based on correlational, often cross-sectional, studies. Therefore, causal inference based on these studies is limited. To estimate the causal effect experiments are considered the gold standard. Some of the studies presented in this review used an experimental approach to estimate causal effects of steroid hormones on socially relevant variables, for example, studies exogenously increasing T levels via sublingual administration (Bos et al. 2010, 2021) or randomised controlled trials investigating effects of hormonal contraceptive methods (Skovlund et al. 2016; Zethraeus et al. 2016). Other studies estimated causal effects of socially relevant variables on steroid hormones based on experiments manipulating the variable supposedly associated with the hormone, such as men interacting with their own infant compared with interacting with other infants (Kuo et al. 2012), men interacting with a woman compared with a man (Roney et al. 2007), or participants interacting with same-sex or other-sex confederates when performing a problem-solving task (Taylor 2014). Our review provides a fairly broad overview of a selection of research questions related to the interplay between steroid hormones and socially relevant variables (for more detailed reviews of specific research questions see, for example, Booth et al. 2006; Carré and Archer 2018; Dreber and Johannesson 2018; Ellison 2003; Geniole and Carré 2018; Knight and Mehta 2014; Mehta and Prasad 2015; Sherman and Mehta 2020). We focussed on questions that may be particularly relevant for the intersection of endocrinology, psychology, and sociology, while striving for an account of a representative set of questions for which there is currently active and progressing research.

5.1 Research Concerning Other Hormones: Oxytocin

Besides steroid hormones, other hormones like the neuropeptide oxytocin affect social behaviour (Nitschke et al. 2019). Peripherally, oxytocin is involved in childbirth and lactation (Lee et al. 2009), and acts as a de-stressor (Windle et al. 2004). In animals, oxytocin centrally promotes affiliative behaviour (reviewed in Schiller and

Heinrichs 2019), whereas studies in humans show more inconsistent findings (reviewed in Nitschke et al. 2019). Human studies face methodological challenges regarding the reliability and validity of oxytocin measurement (Quintana 2022; Tabak et al. 2022). Behaviourally relevant levels of oxytocin in the brain are not readily measurable from blood, saliva, or urine since the large neuropeptide molecules do not cross the blood–brain barrier; thus, administration studies are a more common methodological approach in this area than steroid hormone studies. However, the effectiveness of nasally administering oxytocin to the central nervous system is under scrutiny, with the scarce available evidence suggesting that only a negligible portion (0.005%) crosses the blood–brain barrier (Leng and Ludwig 2016). Results from human studies on the behavioural effects of oxytocin and the closely related, yet far less studied hormone vasopressin should thus not be taken at face value and need to be read with a keen eye on methodological issues.

5.2 Biological Determinism

When investigating the effects of hormones on human behaviour and cognition, it is important to note that the findings described in this review do not imply biological determinism. Biological behavioural determinism can be defined as the belief "that the behaviour in question is fundamentally caused by biological processes, and that social and other environmental causes and interactions are trivial or nonexistent" (Udry 2001). As Booth et al. (2006) argue, we need to consider hormones as one component to understand behaviour, next to other influences including further physiological, psychological, and sociological variables, as well as their interactions. Research therefore needs to move away from simplistic biological determinism to biosocial models that include social environments as a key player in understanding associations between hormones and behaviour (Booth et al. 2006) and allow discussions of the resulting complexity that go beyond the focus of any single field (Roberts and McWade 2021). Unfortunately, the line between biological determinism and biosocial models is often hard to define, as exemplified by the role of biological determinism in gender construction (for discussions see Miller and Costello 2001; Udry 2000, 2001).

5.3 Challenges with Measuring Hormones

There are several methods of assessing hormones in humans, most of them on serum, urine, hair, or saliva samples. Most psychological research investigating the role of steroid hormones is based on saliva samples, because it is non-invasive, the cheapest and most convenient method (Schultheiss and Stanton 2009). There are a few important aspects that need to be considered when implementing hormonal assessments based on saliva in studies or representative surveys. As some steroid hormones vary on a daily, monthly, or seasonal scale, it is important to keep the time of the measurement consistent (e.g. time of day or phase of the ovulatory cycle) or control for the time of measurement in robustness analyses (Schultheiss and Stanton 2009; for T see also Idris et al. 2017; for C see also Kirschbaum and Hellhammer 1989). Furthermore, contamination of samples can severely bias hormone measures and thus needs to be prevented. For example, to prevent saliva samples from blood contamination, participants should abstain from eating, drinking (except plain water), smoking, chewing gum, or brushing teeth before the sample collection. Participants should also abstain from activities that can influence hormone production on the day of sample collection, including ingesting caffeine, drinking alcohol, exercising, and taking recreational or non-prescribed clinical drugs. The adherence to these restrictions can be assessed by a screening questionnaire before the hormone sample collection (Schultheiss and Stanton 2009).

In specific cases, for example, when measuring C in adults or T in young men, salivary hormone assessments can be very precise. In other cases, the reliability and validity of salivary hormone assessments need to be considered critically. This is especially the case when it comes to measurement of hormones at lower concentrations, for example, T in women (Schultheiss et al. 2018). This does not only apply to the measurement of T between and within women, but also plays an important role when assessing E and P within women over the ovulatory cycle (Arslan et al. 2023). When assessing hormones in saliva, we recommend using liquid chromatography tandem mass spectrometry instead of the widely available enzyme-linked immunosorbent assays, owing to the former's superior reliability (Schultheiss et al. 2018) and validity (Arslan et al. 2023). When researchers are interested in aggregated hormone levels over a longer period of time instead of the situational context, a convenient method is to measure steroid hormones based on hair (Stern et al. 2022).

6 Conclusion

With this review we illustrate the crucial role hormones play in human behaviour and cognition, ranging from immediate interplay between physiology and situations to long-term developmental processes across the lifespan. The first hormone secretin was discovered in 1902, but even more than 120 years later our understanding of social and behavioural endocrinology is far from complete (Henriksen and de Muckadell 2000). However, it has become evident by now that there are transactions between hormonal and social factors, opening up a multitude of research questions of relevance for social sciences. To facilitate approaching such questions, we have summarised research through a psychological lens in the current review, contributing to the process of building a bridge between endocrinological and sociological viewpoints.

Research on the four different steroid hormones discussed in this review has already started to fill the gap between endocrinology and sociology. T studies have demonstrated a role of this androgen hormone in regulating mating versus parental effort, for example, as evidenced by an association between T levels and involvement in the mating market depending on fatherhood and marital status (e.g. Holmboe et al. 2017; Grebe et al. 2019). Specifically, T increases may trigger mating-oriented behaviours not focussed on the current partner (McIntyre et al. 2006), which may further enhance the odds of separation. Future research could investigate in more detail the mechanisms and socio-contextual qualifiers of these effects. Among the hormones we reviewed, C is most widely discussed within sociology (Roberts and McWade 2021; Taylor 2012) and our review highlights sociological research that has implemented C assessments. Methodological advancements such as C assessments from hair samples facilitate a broad application of endocrinological measures to sociological research. The sociological perspectives allow the identification of relevant stressors that affect experience and behaviour on a broader level than psychology does. Minority status or the experience of micro-aggressions, among many other social stressors, are understudied in psychological research on behavioural endocrinology. With respect to the female steroid hormones E and P, the question of how hormonal contraception affects the experiences and behaviours of women around the world, is an area of research that would greatly benefit from a sociological perspective. Although there is growing evidence that hormonal contraception affects sexuality and well-being (e.g. Blumenstock and Barber 2022; Lundin et al. 2022; Zethraeus et al. 2016, 2017), the decision on which contraceptive method to use is not made in a vacuum. The interplay between historical feminist narratives and contemporary perceptions potentially shapes women's reproductive health choices. By taking a sociological approach, researchers can explore these complex processes and understand the impact of historical influences and societal assumptions. This would help to provide valuable insights into the nuanced dynamics that shape women's decisions about contraceptive methods.

An important avenue for future research is the integration of endocrinological measurements into large-scale panel datasets, as are standard in sociology. By incorporating hormonal assays alongside traditional sociological data collection methods, such as surveys and interviews, researchers can acquire a comprehensive understanding of how hormonal fluctuations influence and are influenced by social behaviours, attitudes, and other sociologically relevant outcomes. This integration also allows for the exploration of the relationships between hormone levels and variables like stress, mating effort, and social status within diverse populations. Moreover, by tracking hormonal changes longitudinally within these datasets, sociologists can discern patterns, identify causal relationships, and unravel the complexities underlying individual and societal dynamics.

Hormones may not interact directly with all sociological phenomena, but they have an effect on our perceptions and behavioural dispositions, which in turn lead to sociologically relevant phenomena. Psychology, as the science of perception, cognition, and behaviour, can shed light on mechanisms relevant to the interplay of hormones and sociological variables. In this review, we summarised research from a psychological perspective as an effort to build a bridge between sociological and behavioural endocrinological research.

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