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Androgenic morality? Associations of sex, oral contraceptive use and basal testosterone levels with moral decision making

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Abstract

Aside from cultural, psychological, or situational factors, differences in moral judgements might also be influenced by biological variables. Since previous studies have reported stronger utilitarian tendencies in men, the relationship between testosterone and moral judgments has gained interest. Utilitarian judgements focus on the consequences of an action in terms of a cost-benefit analysis while deontological judgements are based on rules that are independent of an action's outcome or of situational features. We investigated decisions in moral dilemma situations in N = 157 young adults using a process dissociation approach to allow an independent estimate of underlying utilitarianism and deontology. Significant effects of sex (p = .009) and endocrine status (p = .011) on utilitarianism were found with the highest levels in men and the lowest in free cycling women while oral contraceptive users fell in between. Furthermore, there were correlations of salivary testosterone with utilitarianism in free cycling women (r = .303) and with deontology in men (r = -.263) while no significant associations between testosterone and moral choices were found in oral contraceptive users. However, the duration of contraceptive use correlated negatively with deontology (r = -.316). The findings underscore the role of sex, endocrine status as well as testosterone in moral judgements but also point to specific associations depending on sex and oral contraceptive use.

Key words: moral judgement, utilitarianism, deontology, sex differences, oral contraceptives, testosterone

1 Introduction

Many psychological, cultural, biological, and situational factors as well as their interactions contribute to differences in moral sense and moral judgement. Because (dis-)agreement on what is considered morally 'right' and 'wrong' is vital for societal functioning, these differences and their potential sources have been under investigation for decades [review: 1]. One research focus is the investigation of potential sex differences.

A well-established research approach into moral decision making is the use of moral dilemma situations [cf. 2] in which potential courses for actions violate either *deontic* or *utilitarian* rules. *Deontic* rules are based on situation-independent moral norms and principles of right and wrong. In contrast, *utilitarian* rules are situation-dependent, outcome-based, and favor overall well-being, i.e., the 'greater good' [3]. Some studies have reported differences between men and women with men showing stronger inclinations towards utilitarian decisions [4-8] although the effect depended in some cases on certain dilemma features (e.g., personal vs. impersonal dilemmas). However, others found no differences between the sexes at all [9-11]. Nevertheless, it has been speculated that one key contributing factor to potential differences between men and women in moral decision making might be testosterone.

In a first study of endogenous testosterone levels and decisions in moral dilemmas, Carney and Mason [12] found that harmful actions in the 'trolley dilemma' were more likely to be judged acceptable by individuals with higher testosterone levels. The association was found in women and men although it appeared to be slightly more pronounced in women. In two other studies, associations between endogenous baseline testosterone and moral permissibility judgments in impersonal (but not personal) dilemmas were found in female samples [13, 14]. Contrariwise, others detected no association with endogenous baseline testosterone levels and actual moral decisions [9, 15]. However, the latter study reported an association between baseline

testosterone and lower sensitivity to moral norms [9] as one suggested underlying factor of behavioral moral outcomes according to the multinomial CNI (consequences, norms, inaction) model [16].

In addition to endogenous testosterone, effects of testosterone administration have also been investigated. In women, the effects of exogenous testosterone on moral decisions were reported to depend on the second-to-fourth-digit ratio [2D:4D; 14] which is an indicator of prenatal testosterone exposure and thus of the organizational effects—i.e., permanent early developmental effects—of the steroid [cf. 17]. A similar study in men reported no significant effects [15]. Another study found in young women in addition to a testosterone × 2D:4D interaction also a main effect of testosterone: After testosterone administration more utilitarian responses were observed but only to dilemmas describing evitable harm [13]. In contrast, in a recent study using a mixed male and female sample, testosterone administration led to *decreased* preferences for utilitarian responses (i.e., actions violate deontic principles but serve a greater good) and an *increase* in the estimated sensitivity to moral norms [9].

Further lines of research point to indirect associations between testosterone and moral judgments and highlight the role of additional modulating factors. Testosterone affects numerous biological functions which then might influence physiological and psychological processes related to moral outcomes [18]. Supporting this notion is research linking testosterone to (lower) empathy [19, 20] although this association was not confirmed in all studies [21]. In turn, participants with lower empathic concern have shown preferences for utilitarian decisions [22, 23]. Furthermore, testosterone has been linked to higher levels of trait psychopathy [review: 24] although this relationship might be further modulated by cortisol reactivity [25]. Individuals with increased trait psychopathy also prefer utilitarian options [26-28]. Another link has been proposed between moral judgement and risky choices with the latter showing positive

associations with testosterone and sharing further antecedents with utilitarianism [29]. At the physiological level, testosterone has been linked to decreased activity in the ventromedial prefrontal cortex [vmPFC; 30] while patients with vmPFC lesions again show an utilitarian bias [31]. In sum, these findings suggest an interconnected set of physiological and psychological variables potentially linking testosterone, although not consistently, to processes related to moral decision making.

There are several reasons for inconsistencies in findings on direct or indirect associations between testosterone and moral judgement. At least in some of the studies statistical power was rather low due to small sample size [cf. 32]. Furthermore, associations between testosterone and moral judgement might be modified or even obscured by additional variables. At least in some studies, the 2D:4D ratio proved to be such a key factor [13, 14] pointing to a complex interplay between the organizational and activational effects of testosterone. Another potential regulator is the current endocrine status of an organism [cf. 33], which, among other things, depends on age, sex, menstrual cycle, as well as the use of hormonal treatments such as oral contraceptives. To our knowledge, the potential role of oral contraceptive use vs. free menstrual cycling in sex differences in moral judgements has not been investigated yet.

In addition, dilemmas used in research into moral decision making vary considerably regarding their content features [34]. Thus, depending on the set of dilemmas used, associations between testosterone and moral judgement may vary. For instance, in the study by Chen et al. [13] testosterone administration resulted in more utilitarian responses but only in the sub-set of dilemmas describing *evitable* harm. Another related issue concerns the classification of 'utilitarian' vs. 'deontological' decisions. In standard moral dilemmas, underlying utilitarian and deontological tendencies are impossible to disentangle since responses are usually scored in a single index (=traditional score). Typically, this score reflects the proportion of outcome-

based, i.e. 'utilitarian' decisions (or, alternatively, rule-based, i.e., 'deontological' decisions) in a set of moral dilemmas. Choosing the 'utilitarian' option in moral dilemmas usually comes at the cost of violating certain rules (i.e., deontic principles) in order to achieve the greatest good for the greatest number of individuals. However, a 'utilitarian' decision in a moral dilemma could be due to strong utilitarian tendencies but also be the result of weak deontological inclinations. The two underlying tendencies might not be in a simple inverse relationship, but have their basis in independent functional processes [35]. Nevertheless, in most studies a single index is used. Conway and Gawronski [22] suggested a solution that allows the additional independent quantifications of underlying utilitarian and deontological inclinations. They adapted the process dissociation (PD) procedure [36] to moral decision making. In brief, PD contrasts responses in *incongruent* dilemmas—in which underlying deontological and utilitarian tendencies compete and result in divergent responses—with responses in *congruent* dilemmas—in which both underlying tendencies converge and lead to the same response [22]. Thus, in addition to the traditional scoring of moral decisions (i.e., using a single index representing the proportion of choosing harmful actions to achieve a 'greater good' or outcome-based decisions) their approach provides independent estimates for utilitarianism and deontology. Here, we employed their method and used German versions of dilemmas from their previous work [22].

In sum, in addition to assessing endogenous testosterone we investigated the role of sex, and hormonal contraceptive use vs. free cycling. Using the traditional scoring of moral decisions as well as the independently estimated underlying utilitarianism and deontology [cf. 22], the study had the following aims: (a) investigation of sex differences including potential differences between free cycling women and COC users in moral judgements, and (b) investigation of associations between endogenous testosterone levels and moral judgements. In addition, ancillary analyses were conducted to examine differences between men and women as well as

between free cycling women and COC users in reaction times and reported difficulties when making moral judgements. Furthermore, potential associations with testosterone levels and reaction times and difficulty ratings were investigated.

2 Materials and Methods

We report how we determined our sample size, all data exclusions, all manipulations, and all measures in the study [cf. 37].

2.1 Participants

A total of 158 participants were recruited at the Technische Universität Dresden during classes, via flyers on campus or through online information. The required sample size was estimated using G*Power 3.1 [38]. Previously reported correlations between testosterone levels and moral judgement (traditional score; trolley dilemma) varied between r = .2 and .3 [12]. However, there were no data available on associations between testosterone and independently estimated underlying utilitarianism and deontology tendencies [cf. 22]. Based on the lower of the reported correlation coefficients (r = .2), we achieved a power (1-β) of 0.82 in the whole sample (α = 0.05).

We aimed to include students from different fields. Thus, while psychology students were not excluded, they make up only 17.2% of the sample. A detailed list of the faculty affiliation of our participants can be found in the supplement. Participants were informed before partaking that they had to fulfil the following criteria: German native speaker, normal or corrected to normal vision, non-smoker, no use of recreational drugs, no current psychological problems or past diagnoses of mental disorders, no severe physical impairment or illness. In addition, at the

beginning of the lab session participants completed a demographic questionnaire that inquired about these variables to ensure fulfillment of the criteria. One lab session had to aborted prematurely due to technical problems. Thus, data on moral decisions are available for 157 young adults (men: n = 71, 25.31 ± 4.30 years; women: n = 86, 23.31 ± 3.35 years). Data collection took place from April until December 2019.

2.2 Session scheduling

Since circadian variation in testosterone levels is comparatively small in the afternoon all sessions started between 13:30 and 17:30 h. In addition, we tested whether session time had an effect on testosterone levels which was not the case ($p = .630$). Basal salivary testosterone measured in the afternoon is sufficiently stable [39] and might thus serve as an indicator for general testosterone levels. Furthermore, since data collection took place from April to December, we tested whether testosterone levels varied significantly over the seasons which was not the case either ($p = .606$).

While male participants could choose any afternoon for their session, lab appointments with female participants were scheduled after a brief telephone interview in accordance with their menstrual cycle or hormonal contraceptive use. Free cycling women (n = 47) were scheduled to partake either during the (early) follicular phase (i.e., days 1-7 of the menstrual cycle; n = 24) or the (late) luteal phase (i.e., during the last six days before menses; n = 23). They had to report regular cycles (max ± 2 days variation) to allow reliable scheduling. Women partaking during the follicular phase were asked not to schedule appointments on days when they might experience menstrual complaints and/or need analgesics to avoid confounding factors.

Women using hormonal contraceptives (n = 39) were invited to participate if they used combined oral contraceptives (COC; containing an estrogen, usually ethinyl estradiol, and a

progestin component) and followed a 21/7-days pill regime consisting of 21 days of active pill use followed by a 7-day-break or 7 days of placebo intake. All reported using their respective COC according to intake instructions without skipping pills. Their lab sessions were scheduled during the time of active pill use (days 4-21). Women using other hormonal contraceptives, e.g., progestin-only pills, hormonal implants, or vaginal rings, were not included in this study. Further exclusion criteria were current and recent (within six months prior to participation) pregnancies or breastfeeding, respectively, as well as the use of the morning-after pill within four months prior to study participation.

2.3 Experimental Paradigm

We translated moral dilemmas previously employed by Conway & Gawronski [22] into German. All dilemmas used can be found in the supplement. The set includes 10 dilemmas in two versions: an incongruent and a congruent scenario. In each dilemma, participants are asked to decide whether or not a suggested harmful action to achieve a specific outcome is appropriate. In *incongruent* dilemmas, these outcomes are overall more beneficial than harmful. However, since they require a harmful action to be achieved, they pit utilitarian and deontological principles against each other. Contrariwise, in the parallel *congruent* dilemmas the suggested harmful action prevents an undesired event, but the net outcome is ultimately more harmful than beneficial. Thus, such actions would be unacceptable based on deontological as well as utilitarian principles.

Dilemmas were presented in the same fixed random order as in previous studies [22, 40]. Participants were instructed to read each dilemma and to indicate whether in their opinion the described course of action would be appropriate or inappropriate. To give their answer, participants had to mouse-click a “yes” or “no” button. Following each dilemma, participants

rated the perceived difficulty of their decision on 5-point Likert scales ranging from 1 (very easy) to 5 (very difficult).

2.4 Procedure

Upon arriving, participants were informed in writing about the study's goals and protocol and gave written consent. Subsequently they filled out a short demographic questionnaire and provided a first saliva sample for later hormone analyses. Afterwards, electrodes for assessment of electro-cardiographic (ECG) and electro-dermal activity (EDA) were attached and heart rate and EDA data was recorded during a 5-minutes resting period (data not reported here). After sensors were removed, participants filled out the Positive and Negative Affective Schedule [PANAS; 41] before reading the instructions to the computerized experiment on moral decision making. If they indicated that they had no further questions, the moral decision paradigm was employed as described above. Afterwards, participants filled out the PANAS a second time and completed German versions of three personality questionnaires: the short version of the Rational-Experiential Inventory [REI-S; 42], the Interpersonal Reactivity Index [IRI; 43], and the Self-Report of Psychopathy Short Form [SRP-SF; cf. 44]; data not reported here. Finally, they gave two additional saliva samples for hormone and DNA analyses, respectively. Participants were subsequently debriefed, thanked and reimbursed. Design and protocol were approved by the ethics committee of the Technische Universität Dresden (EK 225052019).

2.5 Hormone Analysis

Saliva samples for hormone analyses were collected with SaliCaps (IBL; Hamburg, Germany) and kept at -20°C until analysis. Samples were obtained to assess the biologically active 'free' fraction of testosterone. They were centrifuged at 3000 rpm for 15 minutes which resulted in a clear supernatant of low viscosity. Afterwards centrifugation, the two samples of each

participant were pooled and testosterone levels were determined using liquid chromatography-tandem mass spectrometry [LC-MS/MS; 45]. Inter-assay coefficients of variations were below 12%. Testosterone levels in the saliva samples of four female participants (three COC users, one free cycling woman) were undetectable, which was confirmed in a second LC-MS/MS analysis.

During data preprocessing steroid data was checked for outliers. One male participant with pooled testosterone levels of 120 pg/ml had to be excluded (mean of the male sub-sample = 56.52 ± 19.07 pg/ml). Furthermore, two free cycling women with pooled testosterone levels of > 9 pg/ml were excluded (follicular sub-sample mean = 2.96 ± 1.45 pg/ml; luteal sub-sample mean = 4.36 ± 1.83 pg/ml). In addition, four outliers were present in the sample of COC users. Pooled salivary testosterone levels in all four cases were found to be > 13 pg/ml (COC sub-sample mean = 2.40 ± 1.25 pg/ml). Outliers were excluded from all statistical analyses assessing associations of testosterone and moral judgement.

2.6 Statistical Analyses

All analyses were performed using SPSS 26.0 for Windows (IBM Corp., New York, USA).

Moral decisions were analysed in line with previous work [22]. We calculated the proportion of decisions for outcome-based options in *incongruent* dilemmas (traditional score). Higher scores indicate stronger utilitarian inclinations while lower scores indicate stronger deontological tendencies. Following, independent estimates of deontology (D) and utilitarianism (U) were calculated using a process dissociation (PD) approach [22]. MANCOVAs were performed with (i) sex and (ii) endocrine status (free cycling women vs. COC users vs. men), respectively, as between-subject factors. Since men and women differed significantly in age ($p = 0.001$) the latter was entered as a covariate. Ancillary MANOVAs were

performed with difficulty ratings and reaction times as dependent variables and (i) sex and (ii) endocrine status (free cycling women vs. COC users vs. men), respectively, as between-subject factors and age as a covariate. Furthermore, we investigated whether endogenous testosterone levels were correlated with moral judgement indices (traditional score, deontology, utilitarianism) in the three endocrine status groups (men vs. free cycling women vs. COC users).

3 Results

3.1 Manipulation check

First, we tested whether participants responded differently to *incongruent* and *congruent* dilemmas. As in previous studies [cf. 22, 40], participants judged harmful actions in incongruent dilemmas more acceptable (mean = 61.3% ± 15.31) than in congruent dilemmas (mean = 17.8% ± 9.96; t_{156} = 34.36, p < 0.001, d = 2.74). Furthermore, reaction times in incongruent trials was significantly longer compared to congruent ones (t_{156} = 8.58, p < 0.001, d = 0.68) and decisions in incongruent trials were rated as more difficult (t_{156} = 18.95, p < 0.001, d = 1.51).

3.2 Differences in moral judgement between men and women

There was a significant effect of sex on the proportion of outcome-based decisions in *incongruent* dilemmas (= traditional score; $F_{1,154}$ = 7.07, p = .009, η_p^2 = 0.044). Women's scores were lower indicating that they less frequently endorsed harmful actions to achieve a 'greater good' in incongruent dilemmas compared to men. Analysis of the two independently estimated underlying tendencies revealed a significant effect of sex on utilitarianism ($F_{1,154}$ = 4.77, p = .031, η_p^2 = 0.030) with higher levels in men. The effect on deontology was however not significant ($F_{1,154}$ = 2.93, p = .089, η_p^2 = 0.019) albeit with descriptively higher levels in women. Detailed results of the analysis can be found in the supplement (supplemental table 1).

Ancillary analyses revealed that men and women also differed in their reported difficulties in responding in *incongruent* ($F_{1,154}$ = 9.11, p = .003, η_p^2 = 0.056) as well as *congruent* trials ($F_{1,154}$ = 6.36, p = .013, η_p^2 = 0.040) with higher scores in women. Nevertheless, women responded faster than men in *incongruent* trials ($F_{1,154}$ = 5.22, p = .024, η_p^2 = 0.033) while in *congruent* trials the effect was not significant ($F_{1,154}$ = 3.54, p = .062, η_p^2 = 0.022) although women showed descriptively faster response times (see also supplemental table 3 for detailed analysis results).

3.3 Differences in moral judgement in dependence of endocrine status

Endocrine status (free cycling women vs. COC users vs. men) had a significant effect on the traditional score ($F_{2,153}$ = 4.60, p = .011, η_p^2 = 0.057; Figure 1 A). Free cycling women had the lowest scores followed by COC users while men had the highest scores. The effect of endocrine status on utilitarianism was also significant ($F_{2,153}$ = 3.1, p = .048, η_p^2 = 0.039; Figure 1B). Again, the lowest levels were observed in free cycling women followed by COC users while men showed the highest scores. While the effect of endocrine status on deontology did not reach significance (p = .166; Figure 1C) the pattern was reversed compared to utilitarianism with free cycling women showing the highest and men the lowest levels of deontology with COC users falling in between. Additional details can be found in the supplement (supplemental table 2; supplemental figure 1).

[Figure 1 about here]

Furthermore, additional correlation analyses revealed a negative association between deontology and duration of COC use (r = -.316, p = .0499). However, duration of COC use was not significantly correlated with utilitarianism (p = .534) or the traditional score (p = .123).

Also, ancillary analyses on reported difficulties in reaching a moral decision revealed a significant effect of endocrine status (see Table 1) in *incongruent* ($F_{2,153}$ = 4.62, p = .011, η_p^2 = 0.057) as well as in *congruent* trials ($F_{2,153}$ = 3.86, p = .023, η_p^2 = 0.048). However, post-hoc contrast analyses revealed that the two female sub-samples did not differ in any of those ratings (all p ≥ .272). Only the differences between men and free-cycling women (p = .021 and p = .047, respectively) as well as men and COC-users (p = .008 and p = .002, respectively) were significant. The effect of endocrine status on reaction time (see Table 2) in *congruent* (p = .176) and *incongruent* trials was not significant ($F_{2,153}$ = 2.76, p = .067, η_p^2 = 0.035) albeit men's response times were descriptively slower in incongruent trials ((see also supplemental table 4).

[Table 1 and Table 2 about here]

3.4 Associations between moral judgement and testosterone

In free cycling women (n = 44), salivary testosterone levels were associated with estimated underlying utilitarianism (r = .303, p = .046, see also supplemental figure 2) but not with deontology (p = .742) or the traditional score; i.e., the proportion of outcome-based decisions (p = .115). Contrariwise, in men (n = 70) testosterone was (negatively) associated with deontology (r = -.236, p = .049, supplemental figure 3) but not with utilitarianism (p = .532). Again, the traditional score and testosterone levels were not correlated (p = .196). In COC users (n = 32), no significant associations between moral judgement indices and testosterone were detected at all (all p ≥ .295). Furthermore, in none of the three sub-samples were any significant correlations found between testosterone and reported difficulties in responding to *congruent* or *incongruent* dilemmas (all p ≥ .117) as well as reaction times (all p ≥ .186).

4 Discussion

Women and men have been found to differ in decisions in moral dilemmas in some [4-8] but not all studies [9-11]. In our sample, we found significant differences between men and women in opting for harmful actions that are meant to serve a 'greater good'. As in other studies, women were less likely to choose such outcome-based options in *incongruent* dilemmas (=traditional score). In addition, a more detailed analysis of our data revealed effects of endocrine status, i.e., COC use vs. free menstrual cycle. The largest difference in moral decisions (traditional score) was observed between free cycling women and men while COC users fell in between.

Furthermore, analyses of the underlying utilitarianism and deontology based on a process dissociation approach [cf. 22] revealed significant effects of sex and endocrine status on utilitarianism with the highest levels in men followed by COC users and the lowest levels in free cycling women. Although our findings require replication, the data suggests that sex and endocrine status might be affecting underlying utilitarian tendencies more strongly than deontological inclinations.

To our knowledge, associations between COC use and moral judgement have not been investigated yet. While our cross-sectional data allow only limited conclusions, the additional finding of a correlation between duration of COC use and decreasing deontology is interesting. Still, it is of course possible that in our sample key differences between COC users and free cycling women were present before the start of COC use that might explain these results. Additional research is needed to corroborate our findings that indicate that women currently using COC differ less in their moral judgments from men than free cycling women. Nevertheless, since particularly in the Western world, the use of oral contraceptives is widespread [46], the lack of sex differences in moral judgments in some previous studies [cf. 9, 10, 11], might be at least partly due to the often considerable proportion of COC users.

There are multiple endocrine changes in COC users and their potential effects on psychological processes like decision making has only begun to be investigated. Generally, COC use leads to a substantial decrease of endogenous estrogens and progesterone while at the same time providing high levels of a synthetic estrogen (usually ethinyl estradiol) and a synthetic progesterone [progestin; 47, 48]. As Lewis et al. [49] pointed out in a recent review, it is currently unknown, how these states of low endogenous and high exogenous hormones interact and how their net-effect on psychological outcomes deviate from those of regularly changing endogenous hormones over the course of the menstrual cycle. In this context, changes in receptor density and sensitivity due to the long-term alteration of hormone levels might also occur and need further investigation [cf. 49].

In addition to changes in estrogens and progesterone, endogenous androgen levels are reduced as well in COC users with testosterone blood levels decreasing by up to 50% [50-52]. Three underlying mechanisms may contribute to this reduction: (a) suppression of androgen synthesis in the ovaries, (b) increased synthesis of sex-hormone-binding globulin (SHBG) in the liver, and (c) suppression of androgen synthesis in the adrenal glands [53]. Furthermore, different COC formulations contain different progestins [48]. While endogenous progesterone does not bind to androgen receptors, many of these synthetic versions bind with varying affinities to androgen receptors in addition to their target progesterone receptor [48, 54]. This binding may result in agonistic, antagonistic, or no clinical effects [48]. Thus, despite low testosterone levels, signaling involving androgen receptors might actually be increased in COC users depending on the specific progestin used. Another complicating factor is the fact that low- or high-binding affinity does not necessarily translate into a corresponding biological effectiveness [48]. Unfortunately, the current sample is too small to investigate potential effects of different progestins.

Sex and COC use also affected the association between endogenous testosterone levels and moral judgement. While the correlation between moral decisions (traditional score) and testosterone were not significant in any of the sub-samples, there was a negative association between testosterone and *deontology* in men and a positive association between testosterone and *utilitarianism* in free cycling women. Contrariwise, no association at all was found in COC users. The latter might be partly due to the generally decreased testosterone levels in COC users which results in reduced variance. Furthermore, as outlined above, androgen signaling due to the different progestin compounds in the various COCs [48] might confound effects of endogenous testosterone.

Our findings on testosterone in men and free cycling women are generally in line with previous results that indicate higher endogenous testosterone levels are associated with a greater tendency to endorse harmful actions that serve a greater good [12]. However, using the process dissociation procedure suggested by Conway & Gawronski [22] our results indicate that testosterone might be selectively associated with lower underlying deontology in men and higher utilitarianism in free cycling women. Deontological and utilitarian tendencies underlying moral judgements have been suggested to be based on functionally independent processes which might be active at the same time [35]. Moral dilemmas produce a conflict between them with the stronger one driving the observable behavioral response [22].

The relationship between testosterone and behavior is multifaceted. Generally, testosterone has been linked to more self-oriented, asocial and antisocial tendencies [reviews: 24, 55] which might in turn affect moral judgement. However, results are not always straight forward. For instance, investigations based on earlier animal studies into the relationship of testosterone and aggression usually produce only weak associations in humans [review: 56]. Additional factors

(e.g., dominance, cortisol levels) modulate both testosterone and aggression and influence their relationship [56]. Furthermore, testosterone can also be associated with *pro-social* behavior depending on context [57]. Testosterone has also been investigated regarding its possible associations to socio-economic decisions and consumer choices [review: 58]. Although findings are not consistent, they seem overall to suggest that testosterone promotes competitive behavior, tougher inter-personal decisions and social status-enhancing behaviors [58].

Furthermore, testosterone has been linked to intermediate variables that might underlie behavioral differences in moral judgement. Higher testosterone levels have been associated with reduced empathy [19, 20] although a recent study with two comparatively large samples could not confirm this association [21]. Furthermore, another recent study [59] reported a decrease of testosterone (and a concurrent increase of oxytocin) in *response* to empathy induction, indicating a complex reciprocal relationship between testosterone and empathy. Higher prenatal testosterone exposure as well as higher circulating testosterone have also been linked to trait psychopathy. However, findings in this research area also point to the crucial importance of other modulating variables, e.g., social factors, developmental period of high testosterone exposure (e.g., adolescence), or reactivity of the hypothalamic-pituitary-adrenal axis to stressors [review: 24].

Thus, the observed links between testosterone and moral decision tendencies in men and free cycling women might be at least partly mediated by empathy which has been linked to lower testosterone [19, 20] as well as to a preference for deontological judgments, i.e., less willingness to endorse harmful actions [23, 40, 60]. Furthermore, trait psychopathy, which is associated with a stronger ‘utilitarian’ preferences, might be modulating the association with testosterone via decreased compassion for unfortunate others [61-63], and reduced aversions to perform

harmful actions [28]. In addition, it has been suggested that utilitarian choices are more risky than deontological ones [29] since the latter are based on moral rules which provide moral certainty [64]. Risk taking of various kinds has been linked to testosterone [reviews: 65, 66]. Testosterone might thus be a common antecedent of both utilitarian choices as well as risky decisions [29]. Alternatively, a testosterone-induced general preference for riskier options might result in moral decisions, which are less grounded in moral certainty but depend on one's own calculations, i.e. utilitarian choices [cf. 29]. Higher confidence, which also has been associated with testosterone [67], might further contribute to a preference for utilitarian options based on individual cost-benefit analyses rather than fixed rules.

Testosterone binds to androgen receptors which are not only present in the reproductive system but also in the brain with the highest concentration in limbic and hypothalamic regions [68]. To a lesser degree, androgen receptors are found in regions like the ventral tegmental area (VTA), the nucleus accumbens (NAc), the medial prefrontal cortex (mPFC) and the orbital frontal cortex [69-71]. These mesocorticolimbic structures are crucial for decision making with dopamine signaling playing a key role for various executive functions [overview: 72, 73]. Congruently, androgens have been shown to modulate structure and neurochemistry of the mesocorticolimbic system including dopamine signaling and thus to influence executive functions [review: 74]. In addition, aromatase – the enzyme that converts testosterone to estradiol – is expressed in mesocorticolimbic regions [69] and estrogen receptors have been found in the VTA, NAc and mPFC [75]. Thus, in addition to more direct modulating effects of androgens on decision making, potential downstream effects of estradiol due to testosterone conversion need to be considered as well.

There are several limitations to this study. For one, sub-samples are too small to conduct further analyses, for instance regarding the role of different progestins in the various COC formulations [47, 48]. Similarly, while most COC contain ethinyl estradiol, concentrations vary. Thus, in addition to necessary replications, future studies also need to investigate potential effects of different COC compositions with suitable samples. In addition, in the sub-sample of free-cycling women only participants with regular cycles (± 2 days) were included. However, menstrual cycles have been found to be irregular in between 10-38% of free cycling women [76, 77]. Also, while between-subject designs in research on effects of COC use (vs. free cycling) are of practical advantage, there are also several associated issues [cf. 78] including potentially biased data sampling. Furthermore, since we were interested in the role of COCs vs. free cycling we deliberately focused on a younger sample. However, endocrine changes later in life as well as hormonal treatments during this time might also be of interest. In addition to age, cultural background needs to be considered as well. We found sex differences and effects of endocrine status on moral decision making in a sample of young German university students, which limits generalization. Thus, the study findings should be treated with caution until they have been replicated and extended.

In sum, testosterone is one among several interconnected modulators of decision making including moral judgements. There might be subtle sex differences in its effects on tendencies underlying moral decisions. Here, in men, testosterone was primarily associated with decreased deontology, while in (free cycling) women it was linked to increased utilitarianism. Both ultimately result on the behavioral level in an increased endorsement of harmful actions that nevertheless result a positive net outcome. Furthermore, endogenous testosterone's potential influence on moral decisions might be outweighed by the net-effects of COC use. Also, the finding that men tend to endorse harmful actions in moral dilemmas more frequently compared

to women might be particularly due to differences in underlying utilitarian tendencies. Furthermore, COC use might reduce the differences between men and women in moral judgments, highlighting the importance of including endocrine status (e.g., COC use) when investigating sex differences.

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Declaration of interest

None.

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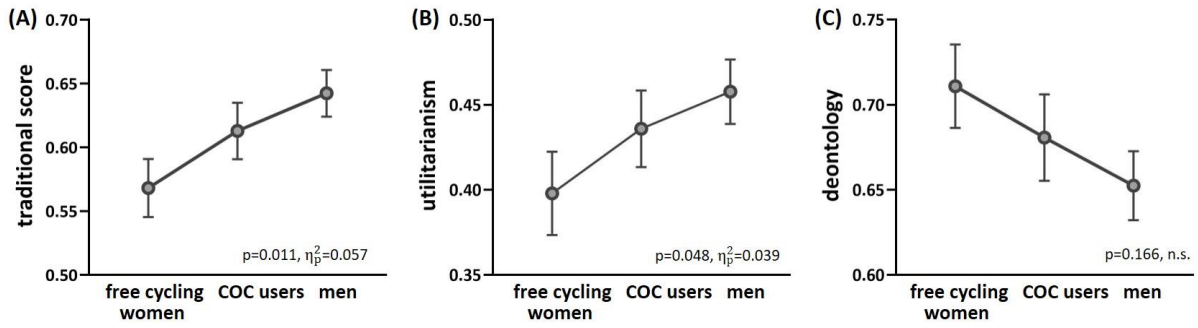

Figure 1: Responses to moral dilemmas (mean ± SEM) in free cycling women, COC users and men. (A) traditional score, (B) estimated utilitarianism, (C) estimated deontology.

Table 1: Rated difficulties (SEM) in responding to incongruent and congruent dilemmas

	free cycling women	**COC users**	**men**
incongruent dilemmas	3.01 (0.08)	3.05 (0.06)	2.79 (0.06)
congruent dilemmas	2.14 (0.06)	2.24 (0.07)	1.98 (0.05)

Table 2: Reaction times (SEM) in seconds in incongruent and congruent dilemmas

	free cycling women	**COC users**	**men**
incongruent dilemmas	37.87 (1.83)	36.51 (1.46)	42.37 (1.53)
congruent dilemmas	33.20 (1.38)	33.26 (1.14)	36.54 (1.13)