Adaptive Human Behavior and Physiology (2017) 3:1–13
DOI 10.1007/s40750-016-0046-8

ORIGINAL ARTICLE

The Effects of Exogenous Testosterone on Men's Moral Decision-Making

Steven Arnocky[1] · **Sara M. Taylor**[1] · **Nathan A. Olmstead**[1] · **Justin M. Carré**[1]

Received: 7 February 2016 / Revised: 14 April 2016 / Accepted: 21 April 2016 /
Published online: 26 April 2016

Abstract Correlational research has linked testosterone (T) to moral reasoning, such that individuals high in T respond to moral dilemmas in a more utilitarian manner (Carney and Mason 2010). In the present study, 30 male undergraduates completed baseline measures of T, psychopathic traits, and digit-ratio (2D:4D) and were subsequently administered 150 mg of testosterone or placebo in a double-blind within-subjects experiment meant to explore a potential causal influence of T on moral decision-making. Following drug administration, participants rated their agreement with a set of incidental and instrumental moral dilemmas, the total of which provided an index of the participant's utilitarian decision-making on that testing day. Results revealed a significant drug × type of dilemma interaction. Post-hoc analyses revealed that T administration was associated with increased utilitarian behavior within incidental moral dilemmas, but with decreased utilitarian decision-making in instrumental dilemmas, although neither trend was statistically-significant. The interpersonal/affective facet (i.e., Factor 1) of psychopathy was positively correlated with utilitarian responses. No effects were found for baseline testosterone or digit ratio. Potential reasons underlying the effect of T decreasing utilitarianism in incidental dilemmas, as well as future directions for research in this area, are discussed.

Keywords Testosterone · Moral decision-making · Psychopathic traits

Morality embodies the values and customs that guide individuals in their social conduct (Moll et al. 2008). Morality is universal, yet simultaneously varies across cultural or contextual boundaries (Haidt 2007) and among individuals (Rai and Fiske 2011). Indeed, some view morality as such an innate human characteristic that it constitutes a 'sixth sense' (Pinker 2008) which most likely evolved as an emotional mechanism for

✉ Justin M. Carré
justinca@nipissingu.ca

[1] Nipissing University, North Bay, ON, Canada

regulating social interactions and cooperation in small group living environments. Suhler and Churchland (2011) argued that such adaptationist hypotheses would be expected to be supported by evidence from the study of biological mechanisms underlying moral decision-making. Consistent with this perspective, recent evidence has suggested that testosterone (T) may play an important role in moral reasoning. The present study tested this hypothesis experimentally by examining the influence of exogenous T administration upon men's moral decision making.

Moral decision-making is typically studied in the laboratory by presenting participants with hypothetical moral dilemmas. For instance, one popular way to study moral decision-making is to have participants perform the trolley paradigm (Foot 1978; Thomson 1985). In this hypothetical scenario, participants are told that a runaway trolley is moving down a track en-route to killing five railway workers and they can avert this disaster by pulling a lever and in doing so, killing one individual located on a secondary track, in order to save the five workers. This is considered an *incidental* moral decision because the death of the singular worker occurs as a side effect of one's pursuit of saving the others (by diverting the train) (Manfrinati et al. 2013). A common alteration of this problem, known as the footbridge dilemma, presents the option to once again save five lives, this time by actively pushing an individual off a bridge in order to stop the trolley. This is considered an *instrumental* moral decision, given that the behavior (pushing an individual off of a bridge) occurs as a part of one's means to pursue that end (stopping the train) (Manfrinati et al. 2013). Instrumental dilemmas tend to be more affectively charged relative to incidental dilemmas (Sarlo et al. 2012). Although both scenarios sacrifice one life in order to save five, often, different results are shown between the two scenarios. When given the incidental "lever pull" option, most choose to do so; when faced with the decision of instrumentally pushing an individual off of a footbridge, most choose to do nothing, and let fate run its course (Carney and Mason 2010).

Recent research concerned with identifying the mechanisms underlying individual differences in utilitarian decision-making has highlighted the role of social-emotional functioning. Behavioral evidence suggests that emotionality influences moral reasoning, such that high emotionality and physiological arousal are generally linked to less utilitarian decision making; acutely stressed participants often respond with decreased utilitarian decision making (Starcke et al. 2012; Youssef et al. 2012), whereas individuals made to suppress their emotions increase their utilitarian moral reasoning (Lee and Gino 2015).

Neuroimaging and lesion studies have further supported this relationship. At the neural level, increased utilitarian responding has been linked to damage to the ventromedial prefrontal cortex (vmPFC) –a brain region crucial to the normal generation of social emotions (Koenigs et al. 2007; Moll and de Oliveira-Souza 2007). Reduced emotionality in vmPFC patients (as indicated by lower skin conductance response) mediates the link between damage to this area and utilitarian moral reasoning (Moretto et al. 2010). Moreover, heightened amygdala reactivity to moral dilemmas correlates negatively with ratings of the moral acceptability of utilitarian responses. Specifically, Shenhav and Greene (2014) found that an increase in amygdala reactivity during emotional assessment of a moral dilemma is negatively correlated with ratings of the moral acceptability of said dilemma. The authors also found strong vmPFC-amygdala functional coupling when making emotional assessment of moral dilemmas, suggesting

that the amygdala provides an affective assessment of the course of action, whereas the vmPFC integrates that signal with the anticipated utilitarian outcome, perhaps via reappraisal of the initial emotional meaning of the utilitarian option against the current situation/goal (such that the vmPFC weakens the negative emotional response to the utilitarian option, making it more likely to be adopted; Hu and Jiang 2014). Taken together, converging lines of evidence suggest the heightened emotional reactivity is linked to reduced utilitarian moral decision-making.

The Role of Testosterone

Given the influence of heightened social emotionality upon moral reasoning, it is conceivable T would *reduce* utilitarian decision-making by increasing amygdala reactivity and decreasing amygdala-vmPFC function (e.g., Hermans et al. 2008; Goetz et al. 2014; Radke et al. 2015; van Wingen et al. 2010).

However, indirect and direct evidence conversely suggests that T may actually *increase* utilitarian decision-making. Indirect evidence comes from the study of psychopathy, which has been linked to both heightened T levels (Glenn et al. 2011; Welker et al. 2014; Yildirim and Derksen 2012) as well as increased utilitarian decision-making in moral dilemmas (Koenigs et al. 2012) perhaps stemming from weaker negative emotionality surrounding the prospect of harming others (Patil 2015; see also Schaich Borg et al. 2013). More direct evidence has linked T and moral decision-making. Carney and Mason (2010) measured basal salivary T and responses to trolley problems. As expected, 105 of the 117 participants agreed to divert the trolley, but only 39 of the participants agreed to push the person from the footbridge (Carney and Mason 2010). It was found that "utilitarians", who chose the most practical solution in both instances, were significantly higher in basal T than "fair-weather utilitarians" who endorsed the incidental solution only (Carney and Mason 2010). This suggests that high-T individuals may be more willing to endorse decisions that are costly (and potentially morally reprehensible) yet logical; in this way, they may be divorced from negative affect associated with the utilitarian decision (Carney and Mason 2010). Carney and Mason (2010) suggested that this differential decision-making may be due to a decreased aversion to risk and diminished sensitivity to affective signals, as well as a higher threshold for conflict, fear, stress, and threat among high versus low T individuals (Carney and Mason 2010). Since testosterone is associated with lower sensitivity to affective signals, which can facilitate the pursuit of empathetic behaviours, the individual is more likely to make less affective decisions, and more utilitarian ones (Carney and Mason 2010).

However, the Carney and Mason (2010) study was limited by its cross-sectional design, as well as in using only two dilemmas which were not counterbalanced and therefore were subject to order effects. Moreover, T levels were derived 3 weeks prior to actually engaging in the moral decision task. Because T fluctuates based on a multitude of internal and external factors (e.g., Field et al. 1994; Miller and Maner 2010), it is not certain that participants' T had any influence on moral reasoning at the time of making the decisions. Finally, because men and women were collapsed across gender, it is possible that men may have driven their effect. Indeed, when analyses were split by sex, there is no significant effect in either men or women (p's > .11). If too many

males were among those responding as 'intransient' utilitarian—then higher T levels in this condition relative to others may have been driven by sex differences in T.

Researchers have observed that the T-moral decision-making link may be fundamentally tied to hormonal exposure during development. The 2D:4D ratio (i.e., ratio of the length of the index finger to the ring finger) has been shown to correlate negatively with the ratio of prenatal testosterone to estradiol (Lutchmaya et al. 2004), and is typically lower in men than women (Puts et al. 2004). Some research suggests that the 2D:4D ratio is linked to sociability and empathy (Carré et al. 2015; Knickmeyer et al. 2006; Weisman et al. 2015; van Honk et al. 2011; c.f. Voracek and Dressler 2006); two factors that are presumably complicit in moral reasoning (Carney and Mason 2010). Building upon this hypothesis, Montoya et al. (2013) found that women with higher 2D:4D ratios have a more notable increase in utilitarian judgements following T administration compared to women with lower 2D:4D ratios. The authors suggested that higher prenatal estrogen priming increases the effects of testosterone on moral decision-making in women (Montoya et al. 2013), and that administered T may have facilitated individuals with higher 2D:4D ratios (which indicate higher prenatal estradiol exposure, Zheng and Cohn 2011) to override fearful and emotionally-empathic processes, in turn prompting a utilitarian decision.

Present Study

Given conflicting theoretical information surrounding the potential relationship between T and utilitarian decision-making, as well as the dearth of empirical evidence surrounding it, we examined whether exogenous T administration might influence men's incidental and instrumental moral decision-making. We examined potential moderating effects of psychopathy and 2D:4D ratio.

Method

Participants

Thirty male undergraduates between the ages of 18 and 35 ($M_{age} = 21.21$, $SD = 2.19$; $n = 28$ Caucasian/White, $n = 1$ Hispanic, $n = 1$ First Nations/Aboriginal) were recruited from a small university and college in Ontario. Prior to testing, all participants reported being free of medications affecting hormone concentrations and having no history or diagnosis of a psychiatric illness or drug dependency.

Experimental procedures involved a within-subject design with testing occurring on 3 separate days. On the first day of testing, participants were introduced to the procedures, and provided demographic, psychological (e.g., psychopathic traits) and physiological measures for the calculation of 2D:4D digit ratio. The second and third days of testing began at an off-campus Urology Clinic, where participants provided a blood sample (10 mL) in order to measure baseline testosterone concentrations. Using a counterbalanced double-blind design, participants were administered 150 mg of testosterone (Androgel ®) or placebo to the upper arms and shoulders. Two additional blood samples were collected at 60 and 120 min following gel administration on both testing days in order

to assess changes in testosterone concentrations related to experimental condition. Following the final blood draw, participants performed the Moral Decision Making task as a part of a larger series of cognitive, perceptual, and behavioral tasks. Previous research using the same dose of Androgel® found that serum testosterone concentrations begin rising within 2 h of administration in men, and reach peak levels within 3 h (Eisenegger et al. 2013). Participants performed the Moral Decision Making task approximately 2.5 h after receiving Androgel® or placebo ($M = 157.8$ min, $SD = 6.4$ min). Days two and three of testing occurred 2 weeks apart. At the conclusion of day three of testing, participants were asked whether they believed they received testosterone on the 2nd or 3rd day of testing. A binomial test indicated that participants were no better than chance at guessing which day they received testosterone ($p = .20$).

Serum Testosterone Concentrations

Serum samples were stored at −60 C until assayed using commercially available enzyme immunoassay kits (DRG International, NJ, USA). All samples were assayed in duplicate, and the average of the duplicates was used for all statistical analyses. Average intra- and inter-assay coefficients of variation were below 6 %.

Digit Ratio and Self-Report Psychopathy

2D:4D ratios were measured by two research assistants from a scan of the left and right hands of participants. Lengths of the second and fourth digits were computed by measuring the distance between the ventral proximal creases of the digits to the fingertips using ImageJ software. The intraclass correlation coefficient (ICC) was used to determine the repeatability of measurements across the two raters. Repeatability was high for left 2D:4D ratio, ICC = .91, $F = 10.51$, $p < .001$, and right 2D:4D ratio, ICC = .95, $F = 18.81$, $p < .001$.

The Self-Report Psychopathy-Short Form (SRP-SF; Paulhus et al. 2015) was used to assess individual differences in psychopathic traits. The SRP-SF consists of 29 items assessing the interpersonal, affective, lifestyle, and antisocial facets of psychopathy using a 5-point Likert-type scale ranging between 1 = "*disagree strongly*" and 5 = "*agree strongly*". The interpersonal facet consists of items such as "I have pretended to be someone else in order to get something." The affective facet consists of items such as "I sometimes dump friends that I don't need anymore". The lifestyle facet includes items such as "I admit that I often mouth off without thinking." The antisocial facet includes items such as "I have broken into a building or vehicle in order to steal something or vandalize." Scale reliabilities ranged from $\alpha = .60$ to $\alpha = .88$ (Interpersonal = .88, Affective = .73, Lifestyle = .70, Antisocial = .60). Consistent with previous literature (e.g., Carré et al. 2015), interpersonal and affective items were summed to create "Factor 1" scores, whereas the lifestyle and antisocial items were summed to create "Factor 2" scores.

Moral Dilemma Responding

On each testing day, participants responded to four types of moral dilemmas derived from Lotto et al. (2013), with two of each type being present in a series (a total of eight

moral dilemmas per day). The four types were: (1) *incidental others* – participants relation to the events was mediated and passive (by a switch or lever, for example) and their own well-being was not threatened, (2) *incidental self* – participants relation to the events was mediated but their own well-being was threated, (3) *instrumental others* – participants relation to the events was direct but their own well-being was not threatened, and (4) *instrumental self* – participants relation to the events was direct and their own well-being was threatened. To avoid learning effects, two unique series of moral dilemmas were created. The two series were counterbalanced and randomized across testing days. In order to ensure equality between the two series, dilemmas were first sorted in order of moral acceptability (based on Lotto et al. 2013) and then divided across each day of testing such that each set contained moral dilemmas that were similarly morally-acceptable ($ps > .30$). For each trial, participants read the presented dilemma at their own pace, after which a proposed resolution to the moral dilemma was presented. Participants were asked to indicate whether they would do the proposed action by pressing "1" for yes, and "0" for no.

Results

Effects of Drug Treatment on Testosterone Concentrations

A 2 (drug; testosterone vs. placebo) × 3 (time; baseline, 60 min, 120 min) repeated measures ANOVA was performed on serum testosterone concentrations. As previously reported (Carré et al. 2015), results indicated a significant drug × time interaction, $F(2,58) = 46.05$, $p < .001$. Testosterone concentrations were significantly higher after Androgel® versus placebo at 1 h ($M_{\text{Testosterone}} = 6.9$ ng/mL vs. $M_{\text{Placebo}} = 4.7$ ng/mL; $t_{27} = 5.59$, $p < .001$, Cohen's $d = 1.13$) and 2 h ($M_{\text{Testosterone}} = 6.4$ ng/mL vs. $M_{\text{Placebo}} = 4.6$ ng/mL, $t_{29} = 7.39$, $p < .001$, Cohen's $d = 1.37$) after drug administration. There were no differences in serum testosterone concentrations prior to drug application ($M_{\text{Testosterone}} = 4.2$ ng/mL vs. $M_{\text{Placebo}} = 4.3$ ng/mL; $t_{29} = .53$, $p = .60$, Cohen's $d = .13$).

Effects of Testosterone on Utilitarian Behavior

A 2 (drug; testosterone vs. placebo) × 2 (type of dilemma; instrumental vs. incidental) ANOVA was performed on endorsement of utilitarian responses[1]. There was no main effect of drug condition, $F(1,29) = .00$, $p = 1$, but there was a significant effect of type of dilemma, $F(1,29) = 41.61$, $p < .001$). Here, participants were more likely to endorse incidental dilemmas compared to instrumental dilemmas. Also, there was a significant drug × type of dilemma interaction, $F(1,29) = 4.66$, $p = .039$. Post-hoc analyses suggested that utilitarian behavior for incidental dilemmas was higher after testosterone relative to placebo ($t(29) = 1.57$, $p = .13$; Cohen's $d = .29$), and utilitarian behavior for

[1] Half of the instrumental/incidental dilemmas involved situations in which the participant could save themselves and others, and the other half of the dilemmas involved situations in which the participant could save only others. Because this self vs. other factor did not interact with drug condition or with type of dilemma, we collapsed our main analyses across these levels.

instrumental dilemmas was lower after testosterone relative to placebo ($t(29) = 1.33$, $p = .19$; Cohen's $d = .25$) – however, both comparisons failed to yielded statistically significant differences. Order of drug administration did not interact with any of the factors to predict utilitarian responses (all $ps > .21$). See Figs. 1 and 2.

Exploratory Analyses

Digit Ratio (2D:4D) We investigated the extent to which prenatal testosterone exposure, as indexed using 2D:4D ratio, would moderate the effect of drug condition on utilitarian behavior. Here, we performed a repeated measures ANCOVA on utilitarian responses with drug condition (T vs. P) and dilemma type (instrumental vs. incidental) as within-subject factors and left/right 2D:4D ratios (mean centered) as covariates. Results indicated that 2D:4D ratio did not interact with drug condition to predict moral decision making (all $ps > .90$). Also, there were no 2D:4D × drug condition × type of dilemma interactions ($ps > .60$). Furthermore, 2D:4D ratio on its own did not predict variability in moral decision making (all $ps > .46$).

Psychopathic Traits We examined whether variability in psychopathic traits would moderate the effect of testosterone on moral decision-making. For this analysis, we performed a repeated-measures ANCOVA on utilitarian responses with drug condition (T vs. P) and dilemma type (instrumental vs. incidental) as within-subject factors and Factor 1 and Factor 2 (mean centered) of the SRP entered as covariates. Results indicated that Factor 1 and Factor 2 did not interact with drug condition to predict variability in moral decision-making (all

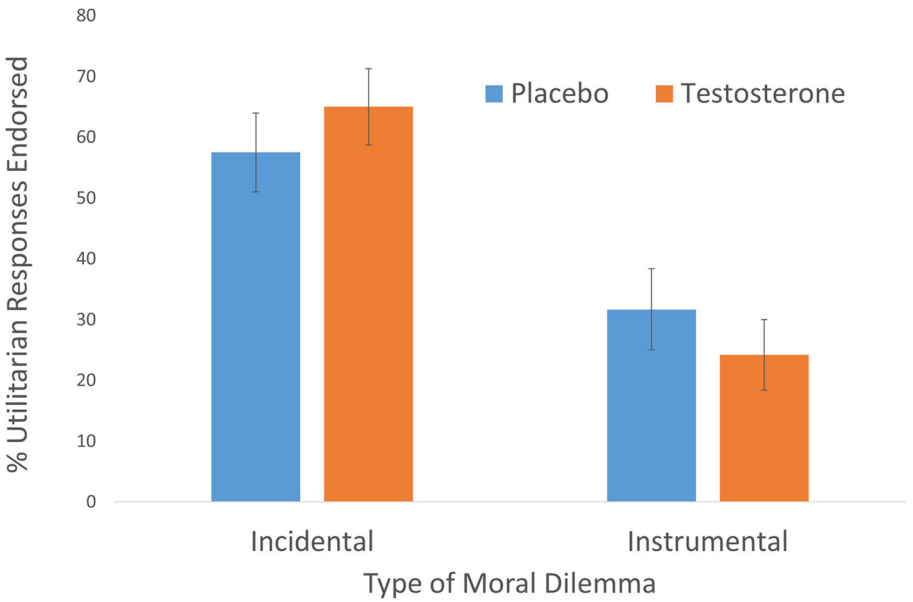

Fig. 1 Percentage of utilitarian responses endorsed for incidental and instrumental dilemmas across drug condition

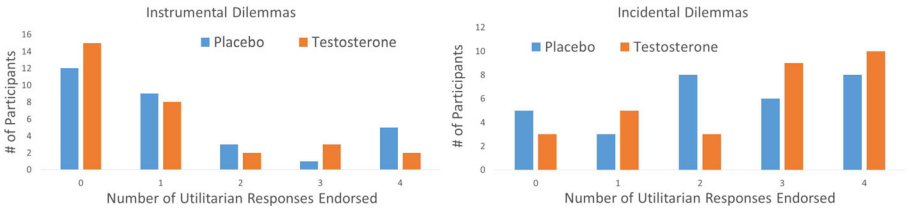

Fig. 2 Number of utilitarian responses as a function of type of moral dilemma (incidental vs. instrumental) and drug condition

ps > .40). Moreover, there were no Factor 1/Factor 2 × drug condition × type of dilemma interactions (*ps* > .67). However, Factor 1 did predict variability in moral decision making, $F(1, 29) = 7.62$, $p = .01$. Specifically, Factor 1 was positively correlated with utilitarian responses (see Fig. 3). In contrast, Factor 2 did not predict variability in moral decision making, $F(1, 29) = 1.62$, $p = .214$.

Baseline T Concentrations We also investigated whether variability in baseline testosterone concentrations would map onto moral decision-making and/or interact with drug condition to predict moral decision-making. Again, we performed a repeated-measures ANOVA on utilitarian responses with drug condition and dilemma type entered as within-subjects factors, and baseline testosterone (mean centered) entered as a covariate. There was no baseline T × drug condition ($p = .92$) or baseline T × drug condition × type of dilemma ($p = .39$) interactions. However, there was a marginally significant main effect of baseline testosterone concentrations, $F(1, 29) = 3.23$, $p = .08$. Here, baseline testosterone concentrations were negatively (albeit marginally) associated with utilitarian responses.

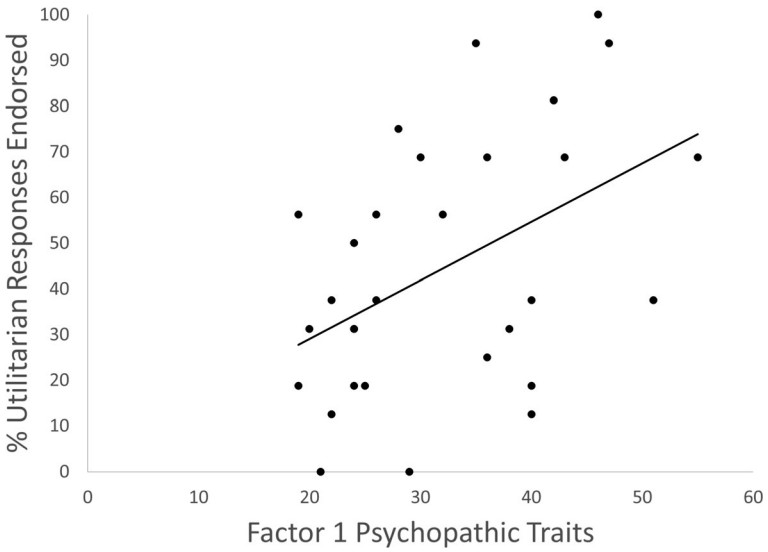

Fig. 3 Bivariate correlation between Factor 1 Psychopathy scores and utilitarian decision making (collapsed across instrumental and incidental dilemmas)

Discussion

Previous findings suggest that testosterone may be related to morality, such that basal salivary T levels positively correlated with individuals' willingness to engage in utilitarian behavior (Carney and Mason 2010). However, cross-sectional studies preclude directional conclusions about the T and moral decision-making relationship. Pharmacologic T administration increases testosterone concentrations in healthy eugonadal men within 1–2 h of administration (Eisenegger et al. 2013; Carré et al. 2015), and evidence suggests that single-dose T administration affects ethical facets of men's behavior, such as lying (Wibral et al. 2012). The current study built on this line of enquiry by examining the causal role of testosterone administration on men's utilitarian decision-making. Our findings indicated that drug condition (T versus placebo) interacted with moral dilemma type (incidental versus instrumental) to predict the total number of utilitarian responses men made. Similar to the direction of findings from Carney and Mason's (2010) correlational study, T administration was associated with increased utilitarian behavior, but only within the context of *incidental* moral dilemmas. Conversely, in the *instrumental* dilemmas, T administration was associated with decreased utilitarian decision-making, relative to a within-subject placebo control (although post-hoc tests revealed neither effect to be statistically-significant).

Why might instrumental (i.e., more morally difficult) decisions have become *less* frequent when T was administered? Heightened amygdala reactivity to moral dilemmas correlates negatively with ratings of the moral acceptability of utilitarian responses (Shenhav and Greene 2014). Shenhav & Greene have speculated that the amygdala provides an affective assessment of the course of action and that the vmPFC subsequently integrates that signal with the anticipated utilitarian outcome. Hu and Jiang (2014) suggest that this mechanism functions via reappraisal of the initial emotional meaning of the utilitarian option against the current situation/goal. In this manner, the vmPFC weakens the negative emotional response to the utilitarian option, making it more likely to be adopted (Hu and Jiang 2014). This hypothesis is relevant to the present study given evidence that T concentrations are positively correlated with threat-related amygdala functioning (Hermans et al. 2008; Manuck et al. 2010) and exogenous T administration increases threat-related amygdala reactivity in men and women (Goetz et al. 2014; Radke et al. 2015; van Wingen et al. 2009). Furthermore, exogenous T administration has been shown to decrease amygdala-vmPFC functional coupling (van Wingen et al. 2010). Taken together, this body of research suggests that perhaps T may lead to heightened amygdala reactivity and/or decreased amygdala-vmPFC coupling during instrumental dilemmas, ultimately promoting an aversive affective response to the more morally and emotionally-difficult instrumental utilitarian moral dilemmas.

Also contrary to Carney and Mason, we did not find a relationship between baseline T and utilitarian moral decision-making, nor did we find any interactions between basal T and drug condition or type of dilemma. There was a marginally significant main effect of baseline testosterone concentrations which were *negatively* associated with overall utilitarian responses. Similar null main and interaction effects were observed for a separate marker of prenatal androgen exposure – the 2D:4D ratio – in relation to utilitarian decision making. Taken together, our findings suggest that basal T indices may not be directly positively linked to utilitarianism, especially within the context of

instrumental decision-making. Future research should seek to explore this relationship in a larger and more diverse sample of males.

Finally, we hypothesized that psychopathic traits would moderate links between T and utilitarian moral decision-making. We observed a positive correlation between Factor 1 (but not Factor 2) of the SRP and utilitarian decision-making. This finding is consistent with previous work identifying links between psychopathic traits and moral reasoning (Koenigs et al. 2012; but see Cima et al. 2010), perhaps stemming from reduced negative emotionality regarding the prospect of harming others (Patil 2015; see also Schaich Borg et al. 2013). Factor 1 scores constitute the interpersonal and affective components of psychopathy; perhaps these facets are more applicable to making moral judgements about the self and others (especially given evidence that affect influences utilitarian moral reasoning; see Hu and Jiang 2014). However, psychopathic traits (Factor 1 and 2) did not interact with drug condition to predict variability in utilitarian decision-making.

Limitations and Future Directions

Although the interaction between drug condition and dilemma type was statistically-significant, thus indicating the effect of testosterone on moral decision-making depends on the type of decision (instrumental vs. incidental), the specific directional trends for testosterone's effects did not meet conventional statistical metrics for significance. The effect-sizes for both were between small and medium (Cohen's *d*'s = .25 and .29, respectively) (Cohen 1988). This may be due, in part, to our limited sample size, which is nevertheless to our knowledge the largest testosterone administration study investigating moral decision-making. Replications and extensions of this research are necessary. For instance, if reduced instrumental endorsement among individuals with high T is a function of T's influence on amygdala-vmPFC connectivity, then we would expect these results to be replicable in women. Finally, future research might also consider the role of risk taking in relation to T's influence on moral reasoning, given evidence that T is positively correlated with risk-taking (Stanton et al. 2011), and that some forms of risk taking may be inversely related to moral reasoning (e.g., Hubbs-Tait and Garmon 1995).

Conclusion

In summary, results from the current experiment suggest that testosterone influences men's moral decision-making by increasing endorsement of incidental dilemmas while decreasing endorsement of instrumental moral dilemmas. These findings highlight the importance of considering more complex models of testosterone's influence on moral reasoning, as well as the need for further research into the relation between T and moral reasoning.

Acknowledgments The authors wish to thank Steve Hansen, Benjamin Moreau, and Erika Ruddick for their help with data collection. We also thank Algonquin Pharmasave for help with preparing Androgel® and Placebo gels (in particular, Meghan Heintz, and Jen Zou). Finally, we thank Terri Moreau for performing the

blood draws and for medical supervision. This project was funded by a Natural Sciences and Engineering Research Council of Canada (NSERC) Discovery Grant (to JMC) and by a Northern Ontario Heritage Fund Corporation (NOHFC) grant (to JMC). NSERC and NOHFC played no further role in data collection, analysis, and interpretation.

References

Carney, D. R., & Mason, M. F. (2010). Decision making and testosterone: when the ends justify the means. *Journal of Experimental Social Psychology, 46*(4), 668–671. doi:10.1016/j.jesp.2010.02.003.

Carré, J. M., Ortiz, T. L., Labine, B., Moreau, B. J., Viding, E., Neumann, C. S., & Goldfarb, B. (2015). Digit ratio (2D: 4D) and psychopathic traits moderate the effect of exogenous testosterone on socio-cognitive processes in men. *Psychoneuroendocrinology, 62*, 319–326. doi:10.1016/j.psyneuen.2015.08.023.

Cima, M., Tonnaer, F., & Hauser, M. D. (2010). Psychopaths know right from wrong but don't care. *Social Cognitive and Affective Neuroscience, 5*(1), 59–67. doi:10.1093/scan/nsp051.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale: Lawrence Earlbaum Associates.

Eisenegger, C., von Eckardstein, A., Fehr, E., & von Eckardstein, S. (2013). Pharmacokinetics of testosterone and estradiol gel preparations in healthy young men. *Psychoneuroendocrinology, 38*(2), 171–178. doi:10.1016/j.psyneuen.2012.05.018.

Field, A. E., Colditz, G. A., Willett, W. C., Longcope, C., & McKinlay, J. B. (1994). The relation of smoking, age, relative weight, and dietary intake to serum adrenal steroids, sex hormones, and sex hormone-binding globulin in middle-aged men. *The Journal of Clinical Endocrinology and Metabolism, 79*(5), 1310–1316. doi:10.1210/jcem.79.5.7962322.

Foot, P. (1978). *Virtues and vices*. Oxford: Blackwell.

Glenn, A. L., Raine, A., Schug, R. A., Gao, Y., & Granger, D. A. (2011). Increased testosterone-to-cortisol ratio in psychopathy. *Journal of Abnormal Psychology, 120*(2), 389–399. doi:10.1037/a0021407.

Goetz, S. M. M., Tang, L., Thomason, M. E., Diamond, M. P., Hariri, A. R., & Carré, J. M. (2014). Testosterone rapidly increases neural reactivity to threat in healthy men: a novel two-step pharmacological challenge paradigm. *Biological Psychiatry, 76*(4), 324–331. doi:10.1016/j.biopsych.2014.01.016.

Haidt, J. (2007). The new synthesis in moral psychology. *Science, 316*(5827), 998–1002. doi:10.1126/science.1137651.

Hermans, E. J., Ramsey, N. F., & van Honk, J. (2008). Exogenous testosterone enhances responsiveness to social threat in the neural circuitry of social aggression in humans. *Biological Psychiatry, 63*(3), 263–270. doi:10.1016/j.biopsych.2007.05.013.

Hu, C., & Jiang, X. (2014). An emotion regulation role of ventromedial prefrontal cortex in moral judgment. *Frontiers in Human Neuroscience, 8*, 873. doi:10.3389/fnhum.2014.00873.

Hubbs-Tait, L., & Garmon, L. C. (1995). The relationship of moral reasoning and AIDS knowledge to risky sexual behavior. *Adolescence, 30*(119), 549–564.

Knickmeyer, R., Baron-Cohen, S., Raggatt, P., Taylor, K., & Hackett, G. (2006). Fetal testosterone and empathy. *Hormones and Behavior, 49*(3), 282–292. doi:10.1016/j.yhbeh.2005.08.010.

Koenigs, M., Young, L., Adolphs, R., Tranel, D., Cushman, F., Hauser, M., & Damasio, A. (2007). Damage to the prefrontal cortex increases utilitarian moral judgments. *Nature, 446*(7138), 908–911. doi:10.1038/nature05631.

Koenigs, M., Kruepke, M., Zeier, J., & Newman, J. P. (2012). Utilitarian moral judgment in psychopathy. *Social Cognitive and Affective Neuroscience, 7*(6), 708–714. doi:10.1093/scan/nsr048.3389/fnhum.2014.00873.

Lee, J. J., & Gino, F. (2015). Poker-faced morality: concealing emotions leads to utilitarian decision making. *Organizational Behavior and Human Decision Processes, 126*, 49–64. doi:10.1016/j.obhdp.2014.10.006.

Lotto, L., Manfrinati, A., & Sarlo, M. (2013). A new set of moral dilemmas: norms for moral acceptability, decision times, and emotional salience. *Journal of Behavioral Decision Making, 27*(1), 57–65. doi:10.1002/bdm.1782.

Lutchmaya, S., Baron-Cohen, S., Raggatt, P., Knickmeyer, R., & Manning, J. T. (2004). 2nd to 4th digit ratios, fetal testosterone and estradiol. *Early Human Development, 77*(1–2), 23–28. doi:10.1016/j.earlhumdev.2003.12.002.

Manfrinati, A., Lotto, L., Sarlo, M., Palomba, D., & Rumiati, R. (2013). Moral dilemmas and moral principles: when emotion and cognition unite. *Cognition and Emotion, 27*(7), 1276–1291. doi:10.1080/02699931.2013.785388.

Manuck, S. B., Marsland, A. L., Flory, J. D., Gorka, A., Ferrell, R. E., & Hariri, A. R. (2010). Salivary testosterone and a trinucleotide (CAG) length polymorphism in the androgen receptor gene predict amygdala reactivity in men. *Psychoneuroendocrinology, 35*(1), 94–104. doi:10.1016/j.psyneuen.2009.04.013.

Miller, S. A., & Maner, J. K. (2010). Scent of a woman: men's testosterone responses to olfactory ovulation cues. *Psychological Science, 21*(2), 276–283. doi:10.1177/0956797609357733.

Moll, J., & de Oliveira-Souza, R. (2007). Moral judgments, emotions and the utilitarian brain. *Trends in Cognitive Sciences, 11*(8), 319–321. doi:10.1016/j.tics.2007.06.001.

Moll, J., Oliveira-Souza, R. D., & Zahn, R. (2008). The neural basis of moral cognition: sentiments, concepts, and values. *Annals of the New York Academy of Sciences, 1124*(1), 161–180. doi:10.1196/annals.1440.005.

Montoya, E. R., Terburg, D., Bos, P. A., Will, G., Buskens, V., Raub, W., et al. (2013). Testosterone administration modulates moral judgments depending on second-to-fourth digit ratio. *Psychoneuroendocrinology, 38*(8), 1362–1369. doi:10.1016/j.psyneuen.2012.12.001.

Moretto, G., Làdavas, E., Mattioli, F., & di Pellegrino, G. (2010). A psychophysiological investigation of moral judgment after ventromedial prefrontal damage. *Journal of Cognitive Neuroscience, 22*(8), 1888–1899. doi:10.1162/jocn.2009.21367.

Patil, I. (2015). Trait psychopathy and utilitarian moral judgement: the mediating role of action aversion. *Journal of Cognitive Psychology, 27*(3), 349–366. doi:10.1080/20445911.2015.1004334.

Paulhus, D. L., Neumann, C. S., & Hare, R. D. (2015). *Manual for the self-report psychopathy* (4th ed.). Toronto: Multi-Health Systems.

Pinker, S. (2008). *The moral instinct*. The New York Times.

Puts, D. A., Gaulin, S. J. C., Sporter, R. J., & McBurney, D. H. (2004). Sex hormones and finger length: what does 2D:4D indicate? *Evolution and Human Behavior, 25*(3), 182–199. doi:10.1016/j.evolhumbehav.2004.03.005.

Radke, S., Volman, I., Mehta, P., van Son, V., Enter, D., Sanfey, A., … Roelofs, K. (2015). Testosterone biases the amygdala toward social threat approach. *Science Advances, 1*(5), e1400074. doi:10.1126/sciadv.1400074

Rai, T. S., & Fiske, A. P. (2011). Moral psychology is relationship regulation: moral motives for unity, hierarchy, equality, and proportionality. *Psychological Review, 118*(1), 57–75. doi:10.1037/a0021867.

Sarlo, M., Lotto, L., Manfrinati, A., Rumiati, R., Gallicchio, G., & Palomba, D. (2012). Temporal dynamics of cognitive–emotional interplay in moral decision-making. *Journal of Cognitive Neuroscience, 24*(4), 1018–1029. doi:10.1162/jocn_a_00146.

Schaich Borg, J., Kahn, R. E., Sinnott-Armstrong, W., Kurzban, R., Robinson, P. H., & Kiehl, K. A. (2013). Subcomponents of psychopathy have opposing correlations with punishment judgments. *Journal of Personality and Social Psychology, 105*(4), 667–687. doi:10.1037/a0033485.

Shenhav, A., & Greene, J. D. (2014). Integrative moral judgment: dissociating the roles of the amygdala and ventromedial prefrontal cortex. *The Journal of Neuroscience, 34*(13), 4741–4749. doi:10.1523/JNEUROSCI.3390-13.2014.

Stanton, S. J., Liening, S. H., & Schultheiss, O. C. (2011). Testosterone is positively associated with risk taking in the Iowa gambling task. *Hormones and Behavior, 59*(2), 252–256. doi:10.1016/j.yhbeh.2010.12.003.

Starcke, K., Ludwid, A. C., & Brande, M. (2012). Anticipatory stress interferes with utilitarian moral judgment. *Judgment and Decision Making, 7*(1), 61–68.

Suhler, C. L., & Churchland, P. (2011). Can innate, modular "foundations" explain morality? challenges for Haidt's moral foundations theory. *Journal of Cognitive Neuroscience, 23*(9), 2301–2316. doi:10.1162/jocn.2011.21637.

Thomson, J. J. (1985). The trolley problem. *The Yale Law Journal, 94*(6), 1395–1415.

van Honk, J., Schutter, D. J., Bos, P. A., Kruijt, A., Lentjes, E. G., & Baron-Cohen, S. (2011). Testosterone administration impairs cognitive empathy in women depending on second-to-fourth digit ratio. *Proceedings of the National Academy of Sciences, 108*(8), 3448–3452. doi:10.1073/pnas.1011891108.

van Wingen, G. A., Zylicz, S. A., Pieters, S., Mattern, C., Verkes, R. J., Buitelaar, J. K., & Fernández, G. (2009). Testosterone increases amygdala reactivity in middle-aged women to a young adulthood level. *Neuropsychopharmacology, 34*(3), 539–547. doi:10.1038/npp.2008.2.

van Wingen, G. A., Mattern, C., Verkes, R. J., Buitelaar, J. K., & Fernández, G. (2010). Testosterone reduces amygdala–orbitofrontal cortex coupling. *Psychoneuroendocrinology, 35*(1), 105–113. doi:10.1016/j.psyneuen.2009.09.007.

Voracek, M., & Dressler, S. G. (2006). Lack of correlation between digit ratio (2D:4D) and Baron-Cohen's "Reading the Mind in the Eyes" test, empathy, systemising, and autism-spectrum quotients in a general population sample. *Personality and Individual Differences, 41*(8), 1481–1491. doi:10.1016/j.paid.2006.06.009.

Weisman, O., Pelphrey, K.A., Leckman, J.F., Feldman, R., Lu, Y., Chong, A. … Ebstein, P. (2015). The association between 2D: 4D ratio and cognitive empathy is contingent on a common polymorphism in the oxytocin receptor gene (OXTR rs53576). *Psychoneuroendocrinology, 58*, 23–32. doi:10.1016/j.psyneuen.2015.04.007

Welker, K. M., Lozoya, E., Campbell, J. A., Neumann, C. S., & Carré, J. M. (2014). Testosterone, cortisol, and psychopathic traits in men and women. *Physiology & Behavior, 129*, 230–236. doi:10.1016/j.physbeh.2014.02.057.

Wibral, M., Dohmen, T., Klingmüller, D., Weber, B., & Falk, A. (2012). Testosterone administration reduces lying in men. *PloS One, 7*(10), e46774.

Yildirim, B. O., & Derksen, J. J. (2012). A review on the relationship between testosterone and the interpersonal/affective facet of psychopathy. *Psychiatry Research, 197*(3), 181–198. doi:10.1016/j.psychres.2011.08.016.

Youssef, F.F., Dookeeram, K., Basdeo, V., Francis, E., Doman, M., Mamed, D., … Legall, G. (2012). Stress alters personal moral decision making. *Psychoneuroendocrinology, 37*(4), 491–498. doi:10.1016/j.psyneuen.2011.07.017.

Zhen, Z., Cohn, M.J. (2011). Developmental basis of sexually dimorphic digit ratios. *Proceedings of the National Academy of Sciences USA, 108*(39), 16289–94. doi:10.1073/pnas.1108312108.