

Pharmacologically induced stress affects moral decision certainty but not choice in military personnel

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Abstract

Throughout their careers, military personnel must make decisions during stressful situations with potential far-reaching moral consequences. It is currently unclear exactly how key components of the acute stress response affect moral decision-making. To this end, Dutch military personnel were recruited and exposed to pharmacological stress, in which noradrenaline was increased through administration of yohimbine and cortisol through hydrocortisone. Moral decision-making was tested using fictional war scenarios, in which deontological and utilitarian tendencies, or a compromise between the two, were assessed in a computer task. Simultaneously, markers of stress and subjective experience were measured. Stress response was confirmed, as salivary alpha-amylase, heart rate and pupil size were amplified under yohimbine, while salivary cortisol was elevated under hydrocortisone. We observed that stress did not affect moral choice tendencies, as the number of deontological, compromise, and utilitarian choices remained comparable. Similarly, other indices of morality and decision consistency were not affected by pharmacological stress. Interestingly, utilitarian decision certainty remained stable under noradrenaline, while other conditions showed utilitarian uncertainty. Moreover, cortisol increased decision certainty and decreased reaction time when more choice options were presented. Further research is needed to investigate the effects of acute stress on moral decision certainty.

1. Introduction

Uniformed professions, such as military personnel, are exposed to copious amounts of stress with varying duration during their years of service. Certain situations, for instance during military deployment, are associated with intense levels of stress in particular, while decisions have to be made with possible profound moral repercussions^{1,2}. Indeed, recent years, a stronger emphasis is being put on a concept known as moral injury, in which experience of morally challenging stressful events is being linked to psychopathology³. Furthermore, military personnel exposed to acute stress mistook friends more often as foes and wrongfully pulled the trigger, showing the possible moral consequences of the effects of stress in a laboratory setting⁴. However, other research in both rats and humans shows that empathy was found to be positively related to cortisol implying a complicated effect of stress for morally pro-social behaviour, while also debilitating decision-making capabilities⁵⁻⁸.

When exposed to acute stress, the body is readied to act against potential threatening stimuli through a complex interaction of several neurotransmitters and hormones. The sympathetic-adrenal-medullary (SAM) and hypothalamic-pituitary-adrenal (HPA) axes are activated, altering the autonomic and endocrine systems^{9,10}. Noradrenaline (NA) plays a key role in sympathetic activation through activation of the adrenoceptors, while glucocorticoids such as cortisol affect the body through genomic and non-genomic means^{11,12}. Evidence suggests that when the brain is exposed to higher levels of NA and cortisol, it switches from executive processes to a more automatic state of functioning, which could be implicated in the pro-social tendency and impaired decision-making as stated before^{9,10,13}. In addition, a

synergistic role between catecholamines and glucocorticoid activity has also been suggested, further complicating the role of acute stress on moral behaviour^{9,14}.

Morality is a complex phenomenon in which Kantian ethics, or deontology, and utilitarianism are theories that have emerged throughout history as key concepts of modern ethics¹⁵. Deontology poses that individuals have a moral duty to adhere to established rules and principles, constructed both internally and through societal pressure, regardless of the actual consequences¹⁶. In contrast, utilitarianism focuses on the outcome of one's actions with an emphasis on the greatest good for the greater number of people¹⁷. Several frameworks have been proposed investigating these core concepts, of which dual-process models of moral judgement have played a central role^{18,19}, yet heterogeneous results using these frameworks question their generalisability. A novel approach, the Moral Trade-off System (MTS), aims to address this discrepancy by allowing deontology and utilitarianism to exist simultaneously on a spectrum with compromise in the middle, more closely resembling the complexity of human moral decision-making²⁰.

It is currently unclear how acute stress affects moral decision-making in military personnel in particular. By implementing pharmacological stressors, we can specifically target only the SAM and/or the HPA axes, and thus selectively observe their effects on moral choice. Yohimbine hydrochloride (YOH) has been shown to consistently elicit stress-like effects, across species, by increasing NA activity^{21–23}. Similarly, hydrocortisone (CORT) can be administered, potentially simultaneously, to enhance glucocorticoid activity^{24,25}. To this end, we recruited military personnel and exposed them to YOH and/or CORT. Participants were then instructed to answer 21 moral dilemmas of a warfare like scenario in a computerised task based on the MTS framework, while physiology was observed. We hypothesised that glucocorticoid stimulation in particular would lead to pro-social behaviour as observed before, which we expected to be more in line with deontological thinking. Furthermore, NA activation, through YOH, was predicted to also lead to more deontological reasoning, as the brain switches from higher order cognition in favour of automatic processing, as we similarly expect deontology to be less cognitively demanding than utilitarianism.

2. Methods

The study received ethical approval by the Medical Research Ethics Committee NedMec located in Utrecht, and is in accordance with Good Clinical Practice and the Declaration of Helsinki 2024. Furthermore, the study was preregistered in the Clinical Trials Information System according to EU pharmaceutical law in the Clinical Trial Regulation - EUCT number: 2023-508731-31-01. Anonymised data, analyses scripts, and raw output are made publicly available on The Open Science Framework (OSF, <https://osf.io/aj82x>).

2.1. Participants

Healthy military personnel of the Netherlands Armed Forces (NAF) on active duty, aged 18–60, were recruited. An overview of sample characteristics can be seen in *Table S3*. Exclusion criteria included medication intake four weeks prior to participation and ongoing psychological treatment, with additionally any contraceptives besides a copper intrauterine device (IUD) for women. A sample size calculation given an alpha of .05 and a power of .80 a priori revealed that a sample size of $n = 100$ would be sufficient to find similar effects as reported in other work investigating the effects of acute stress on decision-making^{26–28}.

2.2 Study Design and Procedure

The study was a double-blind, placebo-controlled, and 2 x 2 factorial design. Participants were randomly distributed to 1 of 4 groups: 1) 30 mg YOH and CORT ($n = 25$), 2) 30 mg YOH and placebo ($n = 25$), 3) 30 mg CORT and placebo ($n = 26$), or 4) double placebo ($n = 24$). Two hours prior to testing, participants were advised to abstain from food and caffeine intake, as well as moderate to high intensity exercise. The full procedure can be seen in *Fig. 1*.

Care was taken to consult a medical doctor about eligibility of participants for suitability and safety. After giving informed consent, participants' weight, height and abdominal circumference were measured, and the electrocardiogram (ECG) was connected, gathering data continuously. Next, participants were asked to provide demographic-, military- and health-related information, and fill in several verified questionnaires. Before drugs were orally administered, baseline measurements ($T_0 = 0$ min) of pupil size using an eye tracker, baseline levels of alpha-amylase and cortisol in saliva, and baseline subjective perceived stress using an affect grid were taken. These measurements were repeated an additional 3 times at different time points ($T_1 = + 50$; $T_2 = + 65$; $T_3 = + 80$ min) during the experiment, to observe the mimicked stress response of the drugs. After baseline measurements, CORT or placebo was first orally administered, while YOH or placebo was taken 10 min thereafter. When both drugs reached their peak concentration (T_1), participants performed two behavioural tasks on the computer, followed by T_2 . Participants followed two more behavioural tasks and at the end the final repeated measurements took place (T_3). Behavioural task order was randomised using a Latin square design. The results of three behavioural tasks relating to more cognitive aspects of decision-making will be reported elsewhere. Lastly, the ECG lead was removed, participants were debriefed and compensated for their participation.

The behavioural task was programmed using PsychoPy (version 2024.1.1)²⁹. All participants were tested at the Central Military Hospital in Utrecht, the Netherlands.

2.3. Drug Manipulation

For the SAM-axis noradrenergic activity, two tablets of Yocoral 5 mg with the active substance of YOH were encapsulated and further filled with microcrystalline cellulose, resulting in capsules of 10 mg. Similarly, for HPA-axis glucocorticoid activity, one tablet of hydrocortisone Teva 10 mg was encapsulated and further filled with microcrystalline cellulose, resulting in capsules of 10 mg of CORT. Placebo capsules would only contain the microcrystalline cellulose. During the experiment, participants were

instructed to take 3 capsules of CORT (30 mg) or placebo and 3 capsules of YOH (30 mg) or placebo thereafter. Considering pharmacokinetics, peak activity of YOH was expected after around 40 min^{30–32}, while peak activity of CORT was expected after 50 min^{33–35}. Both drugs were expected to be washed out of the body relatively quickly^{30–35} and after the experiment participants were able to continue with their daily activities.

2.4. Moral Trade-off System Task

To measure moral decision-making behaviour, a computerised version of the task first used to test the MTS with slight adjustments was implemented²⁰. Framing of willingness influences decision-making as seen by Guzman et al.²⁰, thus we opted to use the soldiers willing and civilians unwilling frame to mimic our sample characteristics. Participants responded to 21 warfare scenarios in which choice options were expressed in the number of civilians or soldiers that would be sacrificed. Choices could be labelled as deontological, utilitarian or compromise. Each scenario varied in number of options, with a range of two to seven, of which six scenarios forced a binary deontological/utilitarian solution (see *Table S1* for a full overview). Second, moral phenotypes were established based on certain criteria, in which someone was labelled deontological or utilitarian if their respective choice was chosen all 21 times. If someone alternated solely between deontological and utilitarian choice, flip-flop was attributed, while people making at least one compromise choice were labelled compromisers. Third, in an effort to capture nuance between deontology and utilitarianism, moral decision-making was quantified on a spectrum, in which utilitarian and deontological choice were represented by 0 and 100%, respectively. This allowed moral choice to be examined on a continuous scale instead of three forced categories (see *Supplementary Materials*). Fourth, preference consistency was measured using the generalised axiom of revealed preferences (GARP) structure, in which participants were assessed on their choice rationality. Fifth, participants indicated how certain they were after making each choice on a 1–5 visual analogue scale (VAS), with higher numbers indicating greater decision certainty. Lastly, a moral rightness function was compared using the implicit moral weight attributed to soldiers and civilians based on the total lives at risk in each scenario, from most equal ($S / C \approx 1.167$) to least equal weight ($S / C = 7$). The resulting outcomes of interest were 1) the total amount of deontological, utilitarian and compromise choices; 2) moral phenotype distribution; 3) moral spectrum score; 4) preference consistency score; 5) rightness function; and 6) certainty.

2.5. Questionnaires

To further examine characteristics of our sample, several questionnaires were taken before stress exposure. First, a Dutch short version of the Behavioural Approach System and Behavioural Inhibition System Scales (BIS/BAS) was utilised to measure risk-taking and inhibition characteristics³⁶. Second, to assess both personality traits and mental stability, the short form of the Dutch Personality Inventory for DSM-5 (PID-5) was implemented³⁷. Lastly, the Dutch short Perceived Stress Scale with 14 items (PSS-14) was used to measure trait levels of perceived stress³⁸.

2.6. Electrocardiography

For ECG the BIOPAC MP160 was utilised, including the BioNomadix RSPEC-R wireless wearable module (BIOPAC Systems Inc., Goleta, CA, USA). Two ECG electrodes were placed just below either clavicle and the third was placed just below the lowest left rib. Electrodes were allowed to accommodate to body temperature before recording. Participants remained seated throughout the recording session. Recording was done continuously during the experiment using BIOPAC AcqKnowledge software (version 5.0.5). Data was examined and cleaned for artifacts. Timepoints (T0 – T3) were selected in the data and four epochs of 30 s were selected for each timepoint. Next, multi-epoch HRV was run, resulting in Root Mean Square of Successive Differences (RMSSD) for each epoch. Four epochs of both RMSSD and heart rate per timepoint were then averaged to reduce noise, as done previously³⁹, and then used as data for the final analysis.

2.7. Pupillometry

As a confirmatory measurement of arousal, pupil size in mm was measured using a Tobii Pro Spark eye-tracker (Tobii AB, Danderyd, Sweden), which was mounted just below a LG 27GL850-B 27" QHD desktop monitor. Participants were placed roughly 50 cm in front of the monitor and were instructed to keep their posture still during recording. Light intensity in the windowless lab was monitored using a Testo 540 lux meter (testo SE & Co. KGaA, Lenzkirch, Germany), which was measured right next to the participant's left eye. Average lux for all participants was measured at 270 (SD = 57). Using Python and the Tobii Pro SDK, calibration, validation and measurement scripts were developed. Calibration and validation were done by looking at specific points in the corners of the screen while keeping posture steady. This procedure was repeated at each timepoint, as seen in *Fig. 1*. If validation showed poor results, the eye-tracker was recalibrated. For the actual pupil size measurements, participants had to stare at a focal point for 20 seconds while having postural stability. Data was collected with a sample rate of 60 Hz and was corrected for screen distance and blinks. Corrected pupil size data of both eyes were averaged for each timepoint and used for the final analysis.

2.8. Saliva Samples

To assess pharmacological manipulation, salivary alpha-amylase and cortisol were obtained using a Salivette synthetic swab, repeated at each timepoint, as seen in *Fig. 1*. Participants were instructed to put the swab in their mouth, specifically next to the inner cheeks of the lower jaw. This ensured salivary absorption through passive diffusion from the submandibular glands, known to be more involved in sympathetic sAA relative activity^{40,41}. Passive diffusion lasted 4 min for each timepoint. Swabs were returned to their caps and immediately put into a cooler and stored in a freezer at -80 degrees Celsius. After all samples had been collected in a span of 6 months, they were removed from the freezer and prepared for enzyme-linked immunosorbent assay (ELISA) for both alpha-amylase and cortisol. Standard analysis procedures were followed.

2.9. Statistical Analyses

For all statistical analyses, YOH and CORT were treated as separate factors using a 2 x 2 factorial design, including an interaction term. To test if blinding was successful, participants' and researchers' expected

condition were compared to the actual condition using unweighted Cohen's κ . Socio-demographic characteristics were tested using Fisher's Tests, Kruskal-Wallis and multivariate analysis of variance (MANOVA). Stress manipulation (i.e. sAA, cortisol, HRV, pupil size, and affect grid scores) was tested using linear mixed-models (LMMs). For the moral task, first, three binomial generalised linear-mixed models (GLMMs) were used to assess probabilities of making a deontological, utilitarian or compromise decision, and corrected for multiple testing using Holm. Second, for moral phenotype, since there was only enough data for deontological and compromise phenotypes analysis, a binomial generalised linear model (GLM) was utilised. Third, for moral spectrum scores and moral consistency, linear models (LMs) were implemented. Fourth, certainty scores and time spent on trials were assessed using LMMs. Lastly, a nonlinear least squares (NLS) regression analysis was performed to model parameters of the rightness function. Differences in YOH and CORT were compared using a multivariate analysis of covariance (MANCOVA). All tests for the moral task implemented age and education as covariates, as both have been extensively reported to affect moral decision-making^{42–44}. Details of all models can be found in the *Supplementary Materials*.

For all statistical tests significance was set to $p < .05$. All statistical tests were conducted using R.

3. Results

To confirm whether blinding was done successfully, we compared participants' expected condition compared to actual condition, using unweighted Cohen's κ . Agreement was low ($\kappa = .24$). Comparatively, condition expected by researchers compared to actual condition also showed a low agreement ($\kappa = .17$), confirming blinding success.

For stress manipulation outcomes, several factors were taken into account during model building. All stress outcomes except HRV showed model improvement when each participant was allowed its own effect on timepoint. Consequently, timepoint was added as a random slope for each stress outcome except HRV (see *Table S5*). Next, age was proven to explain variance for alpha-amylase, pupil size, HRV, and subjective arousal, and was thus included in the final model as a fixed effect for each of these outcomes. Moreover, participants were tested either in the late morning or early afternoon, and this attributed timeslot explained variance in only heart rate. Again we included timeslot as a fixed effect for the final heart rate model.

Looking at the MTS task, models for several outcomes (e.g. moral choice, certainty scores) showed improvement when scenario was treated as a random effect (see *Tables S5 and S9*). Additionally, several models did not improve in fit when education and age were added as fixed effects (see *Tables S5 – S9*). However, since these factors were added based on theoretical grounds, we decided to include them in their final models.

3.1. Socio-Demographic Characteristics

The four experimental groups did not differ in age, height, BMI, abdominal circumference, education, military operating branch, current military rank, number of deployments, and years since last deployment (see *Table S3*). A significant difference in weight was found, in which the group that was administered CORT was heavier than the group that was administered YOH/CORT. Nevertheless, since this effect was not found for BMI and abdominal circumference, and since this predictor did not improve any of the other statistical models, this was of no concern. Additionally, questionnaire scores of the PID-5 and BAS indicate some potential differences between groups, yet similarly, questionnaire scores as a whole did not improve any statistical model thus this was also deemed unproblematic (see *Table S4*).

3.2. Stress Manipulation

For both the HRV and heart rate analyses, one participant was fully excluded, as the ECG data proved to be too noisy with artifacts. Additionally, one other participant had noisy ECG data, however, by eye QRS peaks could still be observed and manually placed, allowing HRV analysis. However, heart rate could not be manually determined in AcqKnowledge, thus two people in total were excluded from the heart rate analysis.

Salivary results show that YOH administration significantly increased sAA at T1, T2 and T3 (all $p < .001$; *Table S10* and *Figure 2A*). Similarly, CORT administration significantly increased salivary cortisol at T1, T2 and T3 (all $p < .001$; *Table S11* and *Figure 2B*). Additionally, YOH administration elevated cortisol levels at later timepoints, although this effect is less strong in comparison to CORT, suggesting slight activation of the HPA-axis through noradrenergic means.

In accordance with the biochemical analysis, physiology shows sympathetic effects of YOH on pupil size and heart rate, as pupil size is significantly increased at T1, T2 and T3 (all $p < .001$; *Table S12* and *Figure 2C*), and heart rate remains elevated at T1 and T2 (both $p < .05$; *Table S13* and *Figure 2D*). In contrast, YOH did not affect HRV ($p = .713$; *Table S14*). Looking at CORT, no sympathetic elevation was observed in either pupil size, heart rate, and HRV (all $p > .05$).

Lastly, subjective measures show no effects of YOH and CORT on affect valence and arousal (all $p > .05$), although there are effects of time on both, as valence decreased and arousal increases over time (valence: all $p < .05$; arousal: all $p < .05$; *Tables S15* and *S16*).

3.3. Moral Decision-Making

No effects of YOH and CORT were found in the number of deontological, compromise, and utilitarian choices (all $p > .05$; *Figure 3A*). Participants were most likely to choose deontological, followed by compromise, and least likely to choose utilitarian. However, when categorizing people in moral phenotypes, most people were classified as compromisers, while no differences were found between groups (all $p > .05$; *Figure 3B*). Furthermore, when quantifying morality on a spectrum, no effects of YOH and CORT administration were found (all $p > .05$; *Figure 3C*). Similarly, YOH and CORT did not affect consistency score, as most people remained quite consistent in their decision-making logic (all $p > .05$;

Figure 3D). Lastly, looking at the moral rightness function, we did observe a trend effect in which it is suggested that CORT devalues the importance of a soldier's life compared to a civilian's life (asymptotic maximum α : $p = .069$; see *Supplementary Materials*).

Looking at people's certainty of their moral choice, we did find a significant three-way interaction between YOH, CORT and choice type ($p = .007$; *Table 1* and *Figure 4A*) and post-hoc comparisons revealed that YOH in particular prevents a decrease in certainty when making utilitarian choices ($p = .548$), while other groups are significantly less certain (all $p < .05$). When looking at one's certainty with regard to the number of choice options, CORT significantly increased certainty when more choice options were presented ($p = .003$; *Table 2* and *Figure 4B*). This CORT effect was emphasised by a decrease in reaction time when more choice options were presented ($p = .042$; *Table S21* and *Figure 4D*). Changes in reaction time were not found with regard to YOH and choice type (all

4. Discussion

We aimed to test if noradrenergic SAM axis activation through yohimbine and glucocorticoid HPA axis activation through cortisol would affect moral decision-making in military personnel of the NAF. We were able to induce pharmacologically-induced stress, as salivary markers of noradrenaline and cortisol, pupil size, and heart rate show signs of enhanced sympathetic and endocrinal activity. We observed that the tendency to respond deontologically, utilitarian or with a compromise between the two remained unaffected by either stress molecule. Furthermore, someone's overall phenotype and consistency in decision-making was unaffected by the pharmacological stress manipulation. More strikingly, participants were most certain when making deontological choices and least when making utilitarian choices, yet when noradrenergic activity is increased, this utilitarian uncertainty is mitigated. Furthermore, certainty tended to decrease as more choice options were presented under placebo and noradrenaline, while cortisol administration reversed this pattern and certainty increased when more choice options were presented.

Military personnel, despite choosing the deontological option most frequently, show a second preference to pick a compromise choice when available as an option. As we utilised the scenario framing in which civilians were against the war and soldiers were not forcefully drafted but voluntarily in service, we suspect deontological tendency was emphasised, as observed previously²⁰. Nevertheless, the fact that compromise choice options were still abundantly chosen strengthens the framework on which the Moral Trade-off System (MTS) is built, as deontology and utilitarianism coexist in tandem when contemplating moral choice²⁰. In contrast, earlier work in moral decision-making tends to regard deontology and utilitarianism more as separate modes, with varying levels of distance between decision maker and dilemma^{15,19,45–47}. Further strengthening the MTS, our phenotype distributions are comparable to the ratios seen in the "soldier's willing" framing first reported by the theory's founders, in which deontology and compromise take precedence²⁰. However, utilitarian and flip-flop phenotypes are remarkably minimal in our sample, suggesting differences in moral characteristics between civilians and military personnel, given the MTS war scenario.

Unexpectedly, our results suggest that morality, with regard to deontology and utilitarianism, is a stable trait-like phenomenon which remains largely unaffected by states such as acute stress. Similarly, moral choice remained consistent in logic across trials, also seemingly unaffected by stress. Conversely, stress has earlier been associated with changes in deontology and utilitarianism, as acute stress has led to a decrease in utilitarian choices, while a preference for inactivity led to more deontological responses in a chronic stress study^{48,49}. Moreover, heightened emotional states, such as anger and fear, have also been shown to affect moral decision-making, while regulation of those emotions seemed to decrease their effects on choice⁵⁰. It should be noted that these studies implemented different paradigms to test moral choice outcomes and included civilian students instead of military personnel. It could be that moral choice preference remains more robust against the deleterious effects of stress in populations that are known to be thrill-seeking⁵¹, although our sample's BIS/BAS characteristics remain within moderate levels (see *Supplementary Materials*). Additionally, military personnel are rigorously trained to withstand stress and learn how to mitigate their effects by exercises such as breath control, thus possibly preventing moral decision-making to be affected^{52,53}.

Certainty in one's moral choice was affected by stress, as noradrenaline seems to prevent potential insecurity about utilitarian choices. A study investigating the effects of acute stress on moral decision-making using an altruism vs. egoism framework found that stress overall did not affect decision certainty, though it did increase the number of altruistic decisions, which in turn were associated with elevated levels of cortisol and higher decision certainty⁸. It should be noted that in this work, stress was elicited through the Trier Social Stress Test (TSST), and alpha-amylase was not taken as a biomarker of noradrenergic activity, thus it cannot be excluded that increased moral decision certainty actually manifested through noradrenergic means. In addition, deontology and utilitarianism are both not inherently linked to being more altruistic than the other, so it would seem that the framing of our moral dilemma inherently elicited more uncertainty when making utilitarian choices, while noradrenaline might negate uncertainty in general. However, we did not observe increased certainty through noradrenergic means when comparing moral decision certainty and the number of choice options presented, suggesting the effect of noradrenaline to be specific to utilitarian moral choice. Surprisingly, cortisol was associated with stronger decision certainty as more moral choice options were presented, an effect supported by decreased reaction times. This effect might be representative of the more automated faster cognitive processing associated with stressful situations, while higher executive function and contemplative reasoning is suppressed^{9,10,13}. Interestingly, this effect could solely be attributed to cortisol, suggesting that non-genomic glucocorticoid receptor activation might specifically be involved in the cognitive switch of the brain to more automated processing, as more genomic effects of cortisol are suspected to arise several hours after exposure^{54,55}.

As acute stress is linked to maintained or increased moral certainty, speculations arise if these effects might be associated with phenomena such as moral injury. Although tendencies of moral choice did not change in presence of heightened noradrenaline and cortisol, one's perceived certainty might decrease sometime after the event, possibly resulting in feelings of remorse or guilt common to moral injury. If an

individual's perception of certainty during a stressful moment was actually the result of the brain switching to a more reflexive and automated state, future reflection when relaxed might introduce doubts in the certainty of one's choices. However, earlier research suggests that the intolerance of uncertainty and possible inaction related to that uncertainty might play a role in the development of moral injury⁵⁶, effectively suggesting that acute stress could counteract moral injury by making people more decisive. All in all, more research is needed to investigate the intricate mechanisms in which acute stress might affect moral decision-making certainty and moral injury.

Potential limitations of the study include the fact that we unfortunately did not include a lot of female participants. Science has set a precedence of investigating phenomena in men in the past and we should strive to make research more inclusive. However, in an effort to make sure that effects of pharmacological stress were not affected by residual noise such as cortisol interactions with contraceptives, stricter criteria were necessary for women to participate. Additionally, although both men and women enlist in the military, as of today military personnel of the NAF are predominantly male, as women account for 12.9 percent of military personnel on active duty⁵⁷. With this in mind we thus deem the sample of this research to be representative of Dutch military forces. Other than unequal gender distributions, our participants mainly consisted of (non-)commissioned officers, with enlisted personnel only being represented by 11 percent of our sample. Although (non-)commissioned officers are very much involved in moral decision-making aspects in the military, it would have been interesting to examine the effects of acute stress on moral judgement in enlisted members of the military as well.

Lastly, we opted to utilise the framing of the original MTS study in which soldiers were willing to fight in the war scenario, mimicking the voluntary military career aspect of our sample. However, many participants answered all trials from a deontological point of view, even so that a formal analysis of moral phenotype could not include utilitarian as one of the phenotypes. Possibly, it would have been better to select a different framing in which both soldiers and civilians were non-supportive of the fictional war. This might have prevented a potential deontology ceiling effect, perhaps allowing more variation in moral choice in which more subtle effects of acute stress could be noticed. Nonetheless, military personnel could answer this specific fictional scenario more deontologically in general, despite the effects of framing. It would be interesting in the future to observe if moral decision-making remains robust under the effects of acute stress in differing MTS scenario frameworks.

5. Conclusion

Heightened noradrenergic and glucocorticoid activity, through pharmacological means, is shown not to shift deontological and utilitarian moral tendencies of military personnel. Even so, certainty about utilitarian moral choice is maintained for people exposed to noradrenaline, while overall utilitarian choice is characterised with decreased certainty. Cortisol seems to shift the brain to more reflexive automatic processing, as counterintuitively decision certainty increased and reaction time decreased when more choice options were presented. These findings emphasise that moral uncertainty might be mitigated by initial bouts of acute stress, while, when looking back retrospectively, doubt about the choices made

might arise when the effects of stress are weaned off. Future research is needed to investigate if these time-dependent discrepancies in moral certainty exist and might play a role in phenomena such as moral injury.

Declarations

Generative AI Statement

Generative AI (ChatGPT 5.3, 5.4) was used in helping write some of the R code used in the analyses. The R code is made publicly available via OSF (<https://osf.io/aj82x>).

References

1. Stephenson, M. D., Schram, B., Canetti, E. F. D. & Orr, R. Effects of Acute Stress on Psychophysiology in Armed Tactical Occupations: A Narrative Review. *Int. J. Environ. Res. Public Health* **19**, 1802 (2022).
2. Richardson, N. M. et al. Defining Moral Injury Among Military Populations: A Systematic Review. *J. Trauma. Stress* **33**, 575–586 (2020).
3. Jamieson, N., Carey, L. B., Jamieson, A. & Maple, M. Examining the Association Between Moral Injury and Suicidal Behavior in Military Populations: A Systematic Review. *J. Relig. Health* **62**, 3904–3925 (2023).
4. Gamble, K. R. et al. Different profiles of decision making and physiology under varying levels of stress in trained military personnel. *International Journal of Psychophysiology* **131**, 73–80 (2018).
5. Wolf, O. T. et al. Enhanced emotional empathy after psychosocial stress in young healthy men. *Stress* **18**, 631–637 (2015).
6. Karakilic, A. et al. The effects of acute foot shock stress on empathy levels in rats. *Behavioural Brain Research* **349**, 31–36 (2018).
7. Zilioli, S., Ponzi, D., Henry, A. & Maestripieri, D. Testosterone, Cortisol and Empathy: Evidence for the Dual-Hormone Hypothesis. *Adaptive Human Behavior and Physiology* **1**, 421–433 (2015).
8. Singer, N. et al. Acute psychosocial stress and everyday moral decision-making in young healthy men: The impact of cortisol. *Horm. Behav.* **93**, 72–81 (2017).
9. Arnsten, A. F. T. Stress signalling pathways that impair prefrontal cortex structure and function. *Nature Reviews Neuroscience* vol. 10 410–422 Preprint at <https://doi.org/10.1038/nrn2648> (2009).
10. Joëls, M. & Baram, T. Z. The neuro-symphony of stress. *Nat. Rev. Neurosci.* **10**, 459–466 (2009).
11. Reul, J. M. H. M. & Kloet, E. R. D. E. Two Receptor Systems for Corticosterone in Rat Brain: Microdistribution and Differential Occupation. *Endocrinology* **117**, 2505–2511 (1985).
12. Reul, J. M. H. M., van den Bosch, F. R. & de Kloet, E. R. Relative occupation of type-I and type-II corticosteroid receptors in rat brain following stress and dexamethasone treatment: functional implications. *Journal of Endocrinology* **115**, 459–467 (1987).

13. Yu, R. Stress potentiates decision biases: A stress induced deliberation-to-intuition (SIDI) model. *Neurobiology of Stress* vol. 3 83–95 Preprint at <https://doi.org/10.1016/j.ynstr.2015.12.006> (2016).
14. Gründemann, D., Schechinger, B., Rappold, G. & Schömig, E. Molecular identification of the corticosterone-sensitive extraneuronal catecholamine transporter. *Nat. Neurosci.* **1**, 349–351 (1998).
15. Christensen, J. F. & Gomila, A. Moral dilemmas in cognitive neuroscience of moral decision-making: A principled review. *Neuroscience and Biobehavioral Reviews* vol. 36 1249–1264 Preprint at <https://doi.org/10.1016/j.neubiorev.2012.02.008> (2012).
16. Misselbrook, D. Duty, Kant, and Deontology. *British Journal of General Practice* **63**, 211 (2013).
17. Taylor, R. M. Chapter 1 - Ethical principles and concepts in medicine. in *Handbook of Clinical Neurology* (eds. Bernat, J. L. & Beresford, H. R.) vol. 118 1–9 (Elsevier, 2013).
18. Greene, J. D., Sommerville, R. B., Nystrom, L. E., Darley, J. M. & Cohen, J. D. An fMRI Investigation of Emotional Engagement in Moral Judgment. *Science* (1979). **293**, 2105–2108 (2001).
19. Greene, J. D. Why are VMPFC patients more utilitarian? A dual-process theory of moral judgment explains. *Trends Cogn. Sci.* **11**, 322–323 (2007).
20. Guzmán, R. A., Barbato, M. T., Sznycer, D. & Cosmides, L. A moral trade-off system produces intuitive judgments that are rational and coherent and strike a balance between conflicting moral values. *Proceedings of the National Academy of Sciences* **119**, e2214005119 (2022).
21. Adams, W. K. et al. Dissociable effects of systemic and orbitofrontal administration of adrenoceptor antagonists on yohimbine-induced motor impulsivity. *Behavioural Brain Research* **328**, 19–27 (2017).
22. Georgiou, P. et al. Dopamine and stress system modulation of sex differences in decision making. *Neuropsychopharmacology* **43**, 313–324 (2018).
23. Sun, H. S. et al. Yohimbine Increases Impulsivity Through Activation of cAMP Response Element Binding in the Orbitofrontal Cortex. *Biol. Psychiatry* **67**, 649–656 (2010).
24. Klue, L. M., Agorastos, A., Wiedemann, K. & Schwabe, L. Noradrenergic stimulation impairs memory generalization in women. *J. Cogn. Neurosci.* **29**, 1279–1291 (2017).
25. Klue, L. M., Agorastos, A., Wiedemann, K. & Schwabe, L. Cortisol boosts risky decision-making behavior in men but not in women. *Psychoneuroendocrinology* **84**, 181–189 (2017).
26. Papalini, S. et al. Stress matters: Randomized controlled trial on the effect of probiotics on neurocognition. *Neurobiol. Stress* **10**, 100141 (2019).
27. Taverniers, J., Van Ruysseveldt, J., Smeets, T. & Von Grumbkow, J. High-intensity stress elicits robust cortisol increases, and impairs working memory and visuo-spatial declarative memory in Special forces candidates: A field experiment. *Stress* **13**, 324–334 (2010).
28. Bogdanov, M. & Schwabe, L. Transcranial Stimulation of the Dorsolateral Prefrontal Cortex Prevents Stress-Induced Working Memory Deficits. *The Journal of Neuroscience* **36**, 1429 (2016).
29. Peirce, J. et al. PsychoPy2: Experiments in behavior made easy. *Behav. Res. Methods* **51**, 195–203 (2019).

30. Le Corre, P., Dollo, G., Chevanne, F. & Le Verge, R. Biopharmaceutics and metabolism of yohimbine in humans. *European Journal of Pharmaceutical Sciences* **9**, 79–84 (1999).
31. Sturgill, M. G. et al. Yohimbine Elimination in Normal Volunteers Is Characterized by Both One- and Two-Compartment Behavior. *J. Cardiovasc. Pharmacol.* **29**, (1997).
32. Grasing, K. et al. Effects of Yohimbine on Autonomic Measures are Determined by Individual Values for Area Under the Concentration–Time Curve. *The Journal of Clinical Pharmacology* **36**, 814–822 (1996).
33. Toothaker, R. D. et al. Oral Hydrocortisone Pharmacokinetics: A Comparison of Fluorescence and Ultraviolet High-Pressure Liquid Chromatographic Assays for Hydrocortisone in Plasma. *J. Pharm. Sci.* **71**, 573–576 (1982).
34. Patel, R. B. et al. Bioavailability of Hydrocortisone From Commercial 20-mg Tablets. *J. Pharm. Sci.* **73**, 964–966 (1984).
35. D., R., Craig, W. A. & Welling, P. G. Effect of Dose Size on the Pharmacokinetics of Oral Hydrocortisone Suspension. *J. Pharm. Sci.* **71**, 1182–1185 (1982).
36. Franken, I. H. A., Muris, P. & Rassin, E. Psychometric Properties of the Dutch BIS/BAS Scales. *J. Psychopathol. Behav. Assess.* **27**, 25–30 (2005).
37. Krueger, R. F., Derringer, J., Markon, K. E., Watson, D. & Skodol, A. E. Initial construction of a maladaptive personality trait model and inventory for DSM-5. *Psychol. Med.* **42**, 1879–1890 (2012).
38. van Eck, M., Berkhof, H., Nicolson, N. & Sulon, J. The Effects of Perceived Stress, Traits, Mood States, and Stressful Daily Events on Salivary Cortisol. *Biopsychosocial Science and Medicine* **58**, (1996).
39. Quigley, K. S. et al. Publication guidelines for human heart rate and heart rate variability studies in psychophysiology—Part 1: Physiological underpinnings and foundations of measurement. *Psychophysiology* **61**, e14604 (2024).
40. Bellagambi, F. G. et al. Saliva sampling: Methods and devices. An overview. *TrAC Trends in Analytical Chemistry* **124**, 115781 (2020).
41. Bosch, J. A., Veerman, E. C. I., de Geus, E. J. & Proctor, G. B. a-Amylase as a reliable and convenient measure of sympathetic activity: don't start salivating just yet! *Psychoneuroendocrinology* **36**, 449–453 (2011).
42. Huang, S. et al. Age differences in intuitive moral decision-making: Associations with inter-network neural connectivity. *Psychol. Aging* **36**, 902–916 (2021).
43. Pratt, Michael W, Golding, Gail, Hunter, William & Norris, Joan. From Inquiry to Judgment: Age and Sex Differences in Patterns of Adult Moral Thinking and Information-Seeking. *The International Journal of Aging and Human Development* **27**, 109–124 (1988).
44. Rosen, J. B., Brand, M. & Kalbe, E. Empathy Mediates the Effects of Age and Sex on Altruistic Moral Decision Making. *Front. Behav. Neurosci.* **Volume 10-2016**, (2016).

45. Cecchetto, C. & Parma, V. Promoting cross-culture research on moral decision-making with standardized, culturally-equivalent dilemmas: The 4CONFiDe set. *J. Health Soc. Sci.* **2**, 173–194 (2017).
46. Gawronski, B., Armstrong, J., Conway, P., Friesdorf, R. & Hütter, M. Consequences, norms, and generalized inaction in moral dilemmas: The CNI model of moral decision-making. *J. Pers. Soc. Psychol.* **113**, 343–376 (2017).
47. Lotto, L., Manfrinati, A. & Sarlo, M. A New Set of Moral Dilemmas: Norms for Moral Acceptability, Decision Times, and Emotional Salience. *J. Behav. Decis. Mak.* **27**, 57–65 (2014).
48. Youssef, F. F. et al. Stress alters personal moral decision making. *Psychoneuroendocrinology* **37**, 491–498 (2012).
49. Zhang, L., Kong, M., Li, Z., Zhao, X. & Gao, L. Chronic stress and moral decision-making: An exploration with the CNI model. *Front. Psychol.* **9**, (2018).
50. Kligyte, V., Connelly, S., Thiel, C. & Devenport, L. The Influence of Anger, Fear, and Emotion Regulation on Ethical Decision Making. *Hum. Perform.* **26**, 297–326 (2013).
51. Hatch, A. M. et al. Personality Traits and Occupational Demands Are Linked to Dietary Supplement Use in Soldiers: A Cross-sectional Study of Sensation Seeking Behaviors. *Mil. Med.* **184**, e253–e262 (2019).
52. Ibrahim, F., Schumacher, J., Schwandt, L. & Herzberg, P. Y. The first shot counts the most: Tactical breathing as an intervention to increase marksmanship accuracy in student officers. *Military Psychology* **36**, 689–700 (2024).
53. Röttger, S., Theobald, D. A., Abendroth, J. & Jacobsen, T. The Effectiveness of Combat Tactical Breathing as Compared with Prolonged Exhalation. *Appl. Psychophysiol. Biofeedback* **46**, 19–28 (2021).
54. Henckens, M. J. A. G., van Wingen, G. A., Joëls, M. & Fernández, G. Time-Dependent Effects of Corticosteroids on Human Amygdala Processing. *The Journal of Neuroscience* **30**, 12725 (2010).
55. Henckens, M. J. A. G., van Wingen, G. A., Joëls, M. & Fernández, G. Time-dependent corticosteroid modulation of prefrontal working memory processing. *Proceedings of the National Academy of Sciences* **108**, 5801–5806 (2011).
56. Birch, M. J., Inhaber, J. & Ashbaugh, A. R. Morally uncertain: the influence of intolerance of uncertainty and perceived responsibility on moral pain. *Anxiety Stress Coping* **38**, 423–435 (2025).
57. Ministerie van Defensie. Current numbers of personnel, both military and civilian, in the Dutch Armed Forces. <https://www.defensie.nl/onderwerpen/o/overdefensie/het-verhaal-van-defensie/aantallen-personeel>.

Tables

Table 1. Model estimates of a linear mixed model of certainty scores in relation to choice type (U = utilitarian; C = compromise; D = deontological). Estimation was done with REML. Post-hoc pairwise contrasts were run with Holm correction, of which U - D contrasts are specifically shown. Final model included 100 participants.

Fixed effects	Estimate (SE)	df	t	p
Intercept	4.162 (0.201)	105	20.682	0.000***
YOH	0.088 (0.225)	114	0.390	0.697
CORT	-0.082 (0.221)	109	-0.372	0.711
Δ U-D	-0.497 (0.131)	1975	-3.794	0.000***
Δ C-D	-0.499 (0.117)	1910	-4.280	0.000***
Δ Education med-low	0.013 (0.202)	93	-0.064	0.949
Δ Education med-high	0.146 (0.196)	93	0.745	0.458
Age	0.014 (0.007)	93	1.887	0.062
YOH * CORT	0.229 (0.315)	109	0.727	0.469
YOH * Δ U-D	0.422 (0.180)	1992	2.345	0.019*
YOH * Δ C-D	0.129 (0.161)	1948	0.802	0.422
CORT * Δ U-D	-0.287 (0.167)	2060	-1.715	0.086
CORT * Δ C-D	0.004 (0.143)	2020	0.026	0.979
YOH * CORT * Δ U-D	-0.614 (0.229)	2061	-2.678	0.007**
YOH * CORT * Δ C-D	-0.396 (0.207)	2046	-1.909	0.056
Contrasts ΔU-D	Estimate (SE)	df	t	p
PLAC	0.497 (0.131)	1975	3.787	0.000***
YOH	0.074 (0.124)	2006	0.601	0.548
CORT	0.783 (0.104)	2068	7.537	0.000***
YOH * CORT	0.975 (0.097)	2085	10.070	0.000***
Random effects	Variance (SD)			
Intercept participant	0.515 (0.718)			
Residual	0.388 (0.623)			

*: p-value <.05

** : p-value <.01

***: p-value <.001

Table 2. Model estimates of a linear mixed model of certainty scores in relation to the number of choice options. Estimation was done with REML. Final model included 100 participants.

Fixed effects	Estimate (SE)	df	t	p
Intercept	3.869 (0.206)	95	18.761	0.000***
YOH	0.225 (0.223)	93	1.009	0.316
CORT	-0.077 (0.223)	93	-0.347	0.729
Options	-0.041 (0.036)	99	-1.148	0.254
ΔEducation med-low	0.088 (0.213)	93	0.414	0.680
ΔEducation med-high	0.169 (0.206)	93	0.820	0.414
Age	0.010 (0.008)	93	1.337	0.184
YOH * CORT	-0.075 (0.318)	93	-0.237	0.813
YOH * Options	-0.020 (0.036)	97	-0.550	0.584
CORT * Options	0.109 (0.036)	97	3.002	0.003**
Random effects	Variance (SD)	r		
Intercept participant	0.578 (0.760)	-		
Slope options	0.025 (0.160)	-0.02		
Intercept scenario	0.012 (0.108)	-		
Residual	0.351 (0.592)	-		

*: p-value <.05

** : p-value <.01

***: p-value <.001

Figures

Figure 1. Study design and procedures. Participants were randomised in one of four groups: yohimbine and cortisol (YOH/CORT), double placebo (plac/plac), YOH/plac, and CORT/plac. Biometric information was first taken, followed by questionnaires. At baseline (T0), +50 min (T1), +65 min (T2), and +80 min (T3), pupil size, saliva and subjective experience of stress was measured. Directly after baseline measurements, CORT or plac was taken, followed by YOH or plac 10 min thereafter. After T1, participants performed two computer tasks, followed by T2, followed by another two tasks and closing with T3. All experiments were done in the same lab.

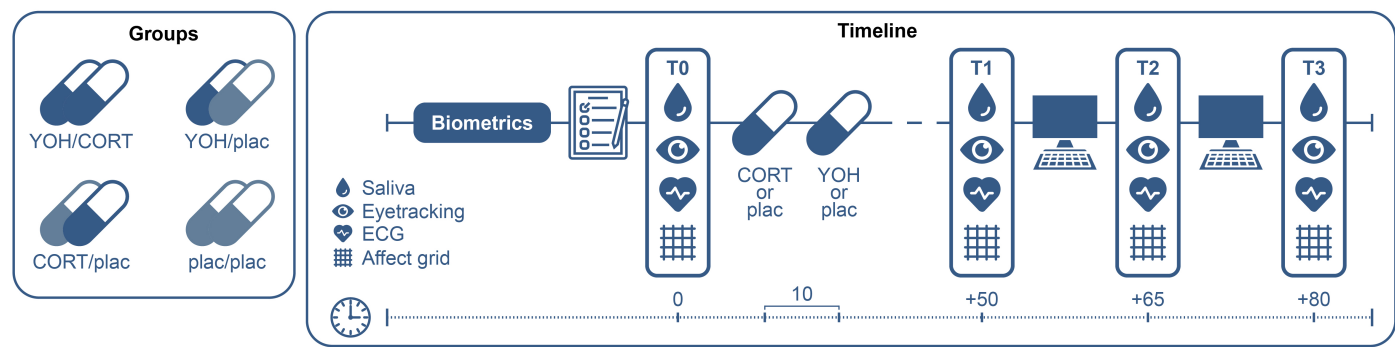


Figure 1

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Figure 2. Effects of YOH and CORT over four timepoints (T0 = baseline; T1 = +50 min; T2 = +65 min; T3 = +80 min) on: A) Salivary alpha-amylase; B) Salivary cortisol; C) Pupil size; D) Heart-rate. Figures show emmeans of linear mixed models (LMMs). Salivary outcomes were log transformed for analysis. Salivary and pupil outcomes included all 100 participants; heart-rate included 98 participants. Full model specifications can be found in the Supplemental Materials. * $p < .05$; ** $p < .01$; *** $p < .001$.

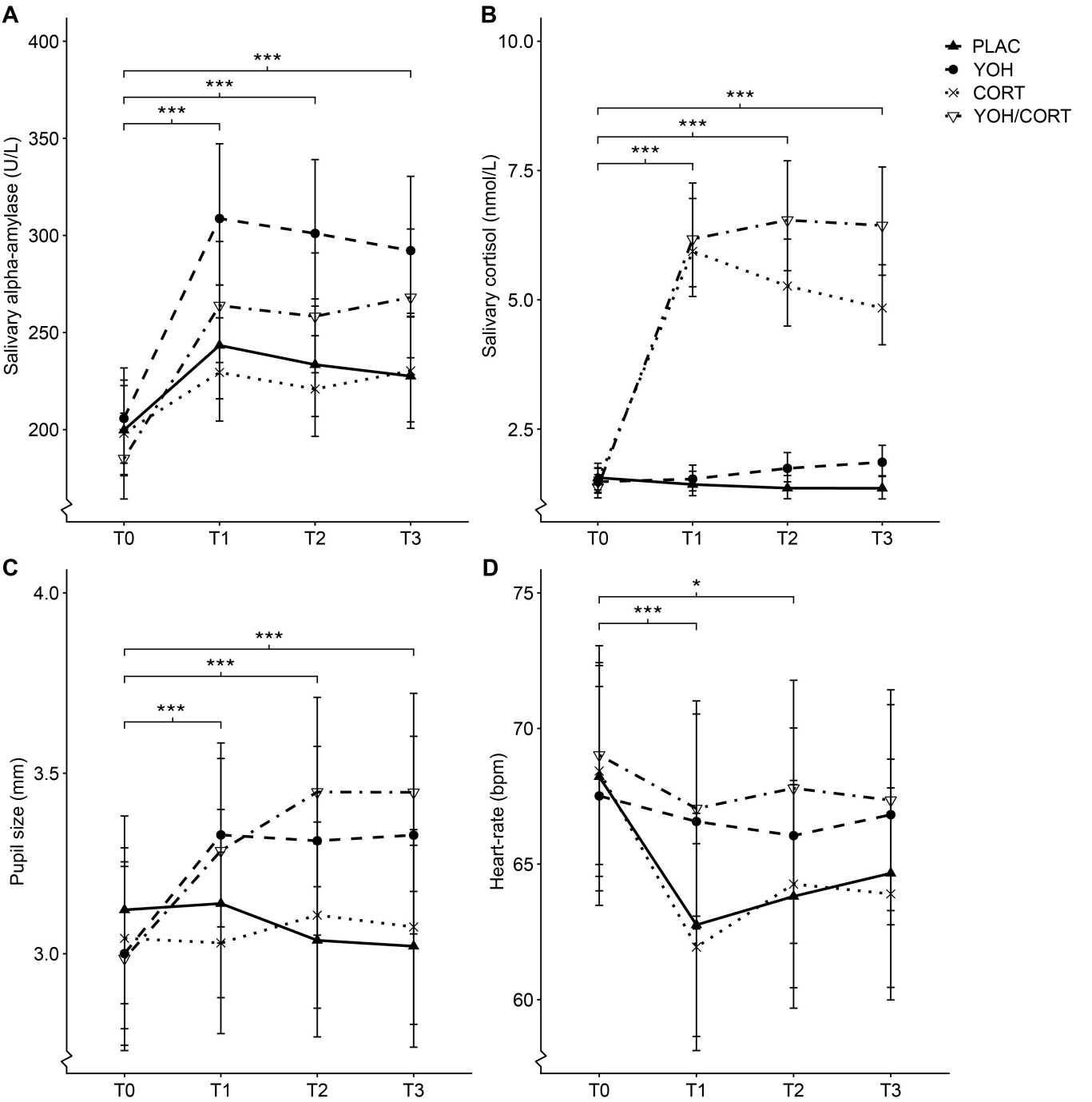


Figure 2

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Figure 3. Effects of YOH and CORT on moral decision-making: A) Mean participant-level proportions of deontological, compromise, and utilitarian choices. Statistical analysis was performed using three separate binomial generalized linear mixed models; B) Distribution of moral phenotypes across conditions. Because utilitarian and flip-flop phenotypes were rare, statistical analysis was conducted using a binomial generalized linear model comparing deontological and compromise phenotypes; C) Distribution of moral spectrum scores; D) Distribution of consistency scores. All outcomes included all 100 participants. Full model specifications are reported in the Supplementary Materials.

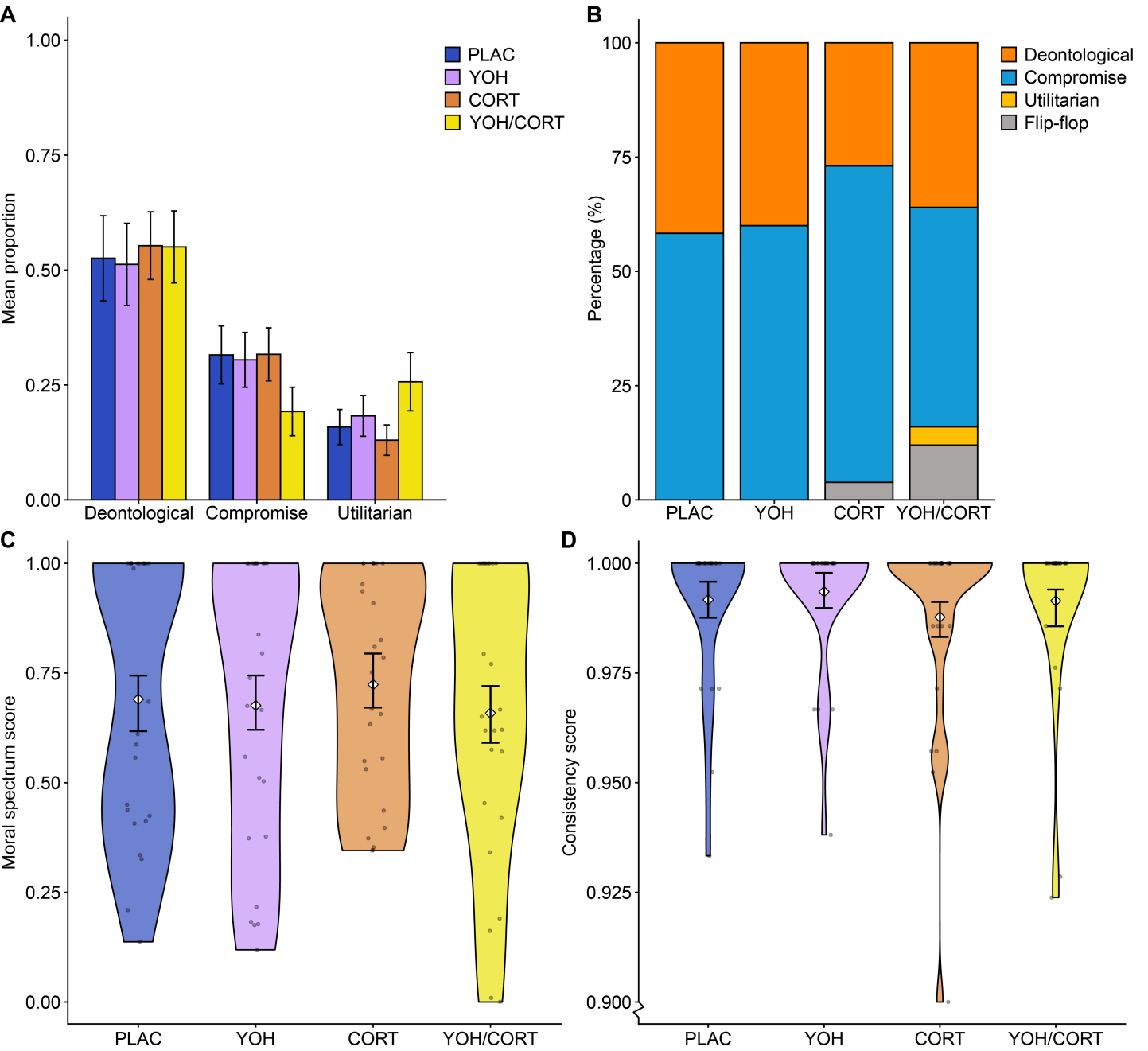


Figure 3

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Figure 5. Effects of YOH and CORT on moral decision-making certainty and response time: A) Predicted mean certainty score of moral choice type; B) Predicted mean certainty score of number of choice options; C) Predicted mean certainty response time of moral choice type; D) Predicted mean certainty response time of number of choice options. Figures show emmeans of linear mixed models (LMMs). All outcomes included all 100 participants. Full model specifications are reported in the Supplementary Materials. * $p < .05$; ** $p < .01$; *** $p < .001$.

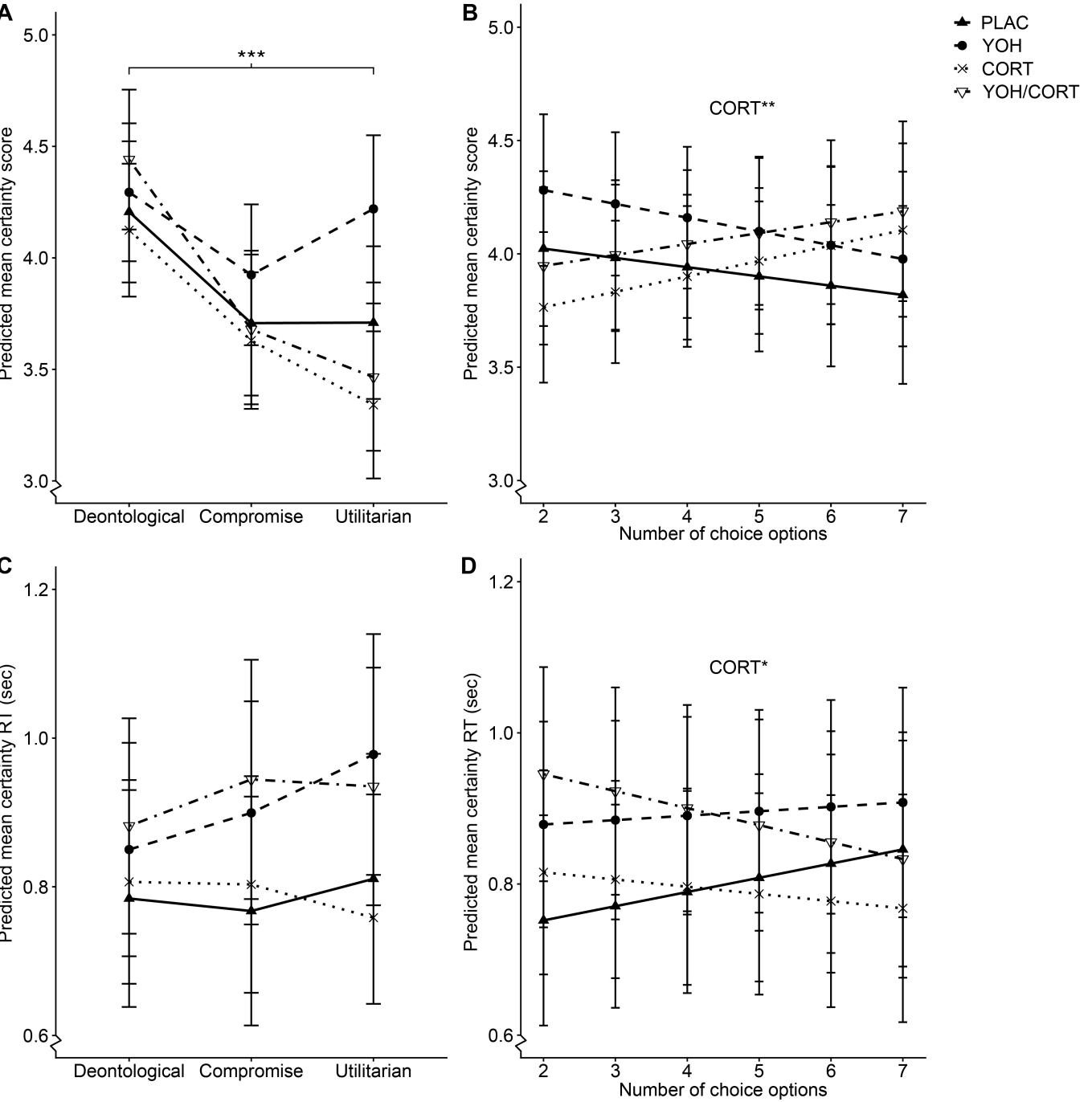


Figure 4

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