The heart as judge: Association of heart rate variability with moral judgment—

A replication study

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Abstract

There is growing research into contributing processes and biological correlates of differences in moral judgements with process dissociation procedures allowing independent quantification of utilitarian and deontic tendencies underlying moral decisions. Recently, Park *et al.* (2016) reported that estimated utilitarianism showed negative associations with heart rate variability (HRV) at rest. Resting HRV is an indicator of cardiac vagal tone and thus of parasympathetic activity and has also been suggested to be a marker of neuro-visceral integration. We aimed to replicate and extend these findings. Using the same set of moral dilemmas in $N = 157$ young adults, we found no such association in the total sample. However, when taking sex and the use of hormonal contraceptives into account, we found a positive association between HRV at rest and estimated deontology in women using combined oral contraceptives and men, while in free cycling women there was a negative association. While we did not replicate the original findings, our results partly indicate similar behavioral consequences of increased HRV, since both reduced utilitarianism (cf. Park *et al.*, 2016) and increased deontology are linked to decreased endorsement of harmful actions. Furthermore, there were no associations between sympathetic activity (assessed via electro-dermal activity) and moral judgements.

Key words: moral judgment; deontology; utilitarianism; heart rate variability, vagal tone; electro-dermal activity

Introduction

Research interest in physiological correlates of moral judgements has been growing but not all reported associations have been independently confirmed yet. In 2016, Park *et al.* found an association between utilitarian judgment and lower resting heart rate variability (HRV). The authors employed a set of 10 *incongruent* and 10 parallel *congruent* dilemmas (cf. Conway and Gawronski, 2013). While responses to moral dilemmas are traditionally scored in a single bipolar utilitarian-deontic index, this dilemma set allowed for an independent estimate of underlying utilitarianism and deontology. Generally, in *incongruent* dilemmas harmful actions are outweighed by their overall benefit and serve a ‘greater good’. Thus, in these dilemmas deontological (i.e., rule-based) and utilitarian (i.e., outcome-based) principles are pitted against each other since moral rules need to be violated to achieve an overall beneficial outcome. Contrariwise, in *congruent* dilemmas harmful choices have no greater benefit since the outcome is outweighed by the inflicted harm. Thus, in congruent dilemmas harmful actions are not condoned by either utilitarian or deontological principles. Importantly, while ‘utilitarian’ answers might indeed be due to strong underlying utilitarian inclinations, they could also result from weak deontological tendencies. Furthermore, these underlying tendencies might not be simply inversely related but the result of independent processes (Greene, 2007). By using the set of *incongruent* and *congruent* dilemmas and applying a process dissociation (PD) procedure (Jacoby, 1991) as suggested by Conway and Gawronski (2013), the effects of underlying deontological and utilitarian inclinations can be disentangled, which was done in the study by Park *et al.* (2016).

Park *et al.* (2016) found in their sample ($N = 64$; 38 women; mean age = 19.4 years) an association between HRV and the independently estimated *utilitarianism* ($r = -.34, p < .01$). Multiple linear regression further confirmed HRV at rest as predictor of utilitarianism ($\beta = -.34, p = .01$),

but not deontology ($p = .90$). Park *et al.* used the root mean square of successive inter-beat interval differences (RMSSD) as an index of HRV. Generally, HRV is generated by various interdependent regulatory systems and reflects neuro-cardiac function (Shaffer and Ginsberg, 2017). RMSSD is one of the HRV measures that, along with high frequency (HF) power, has been confirmed to index vagal activity (Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996; Thayer *et al.*, 1996).

The parasympathetic vagus nerve exerts an inhibitory influence on the heart (Thayer and Lane, 2000). In addition, afferent vagal pathways feed information back from the heart to the brain resulting in a reciprocal exchange (Thayer and Lane, 2000, 2009). Together with sympathetic and other regulatory processes, cardiac activity is adjusted to situational requirements (Thayer and Lane, 2000; Porges, 2003). Higher resting HRV might not only be indicative of greater vagal tone but has been suggested to reflect greater neuro-visceral integration (Thayer and Lane, 2000, 2009) which in turn has been linked to increased self-regulation (Park and Thayer, 2014). The proposed model includes inhibitory pathways from the prefrontal cortex (PFC) to the amygdala and between the amygdala and medullary neurons which modulate heart rate and HRV (Thayer and Lane, 2009; Park and Thayer, 2014). A meta-analysis confirmed links between HRV and activity in the medial PFC and the extended amygdala/ventral striatum (Thayer *et al.*, 2012).

The results of Park *et al.* (2016) thus suggest that reduced neuro-visceral integration (indicated by reduced RMSSD at rest) predict utilitarian tendencies and thus the willingness to endorse harmful actions for the ‘greater good’. We attempted to replicate and extend those findings. We used German versions of the same dilemmas employed by Park *et al.* (2016). As in the original

study, we assessed heart rate data during a five-minute resting period before participants responded to the moral dilemmas. Furthermore, we measured electro-dermal activity (EDA) during this resting period. Changes in electro-dermal activity are caused by alterations of eccrine sweat gland activity which are solely under the influence of the sympathetic branch of the autonomous nervous system (ANS; Figner and Murphy, 2011; Boucsein, 2012). Park *et al.* (2016) had speculated that deontological tendencies might be associated with indicators of sympathetic activity like EDA.

EDA is regularly used to reliably and unobtrusively assess sympathetic activity or even serves as proxy for neural activity (Figner and Murphy, 2011). There are several parameters to assess resting EDA indicating tonic sympathetic activity. We used skin conductance level (SCL) and spontaneous skin conductance responses (sSCR; Boucsein, 2012). SCL is the overall skin conductivity over time intervals ranging from several seconds to several minutes and reflects general levels of arousal with higher SCL levels indicating greater sympathetic arousal (Figner and Murphy, 2011). In turn, sSCR are the result of sporadic and spontaneous activity of the sudomotor nerve (Boucsein, 2012). Brief bursts of postganglionic sudomotor fiber firing, succeeded by longer intervals, cause sweat glands to open and ultimately produce sSCR (Macefield and Wallin, 1996; Nishiyama *et al.*, 2001). An average number of about five sSCR per minute has been reported in participants at rest (Zimmer, 2000). Increased sympathetic arousal manifests in larger sSCR numbers as well as larger amplitudes (Bach *et al.*, 2010). We assessed the averaged area under the curve (AUC) of sSCRs detected during rest to map the strength of spontaneous responses.

Park *et al.* (2016) also reported correlations between moral judgements and personality traits, namely *need for cognition* (NFC), *empathic concern*, and *religiosity*. We attempted to replicate

the associations of NFC and empathic concern using German versions of the questionnaires employed by Park et al. (2016). However, since in a large previous study (Behnke *et al.*, 2020) we found no evidence for potential associations of religiosity and moral judgement in predominantly young and well educated German participants, we did not investigate the trait here. We additionally assessed *psychopathy* since the trait has been repeatedly associated with differences in moral decision making (meta-analysis: Marshall *et al.*, 2018).

Thus, the main aims of the study are threefold: (1) to replicate the findings of Park *et al.* (2016) on the associations of moral judgements with HRV indices reflecting parasympathetic activity, (2) to extend their findings by including EDA measures to assess potential associations between moral judgement and sympathetic activity, and (3) to replicate and extend their findings on the associations between moral judgments and specific personality traits, i.e., *NFC*, *empathic concern*, and *psychopathy*.

Methods

We report how we determined our sample size, all data exclusions, all manipulations, and all measures in the study (Simmons *et al.*, 2012). All materials, data, and analyses of this study are available online (<https://osf.io/vu5kn/>). The study is part of a larger project that includes additional genetic and endocrinological assessment (data not reported here).

Sample

A total of 158 participants were recruited at the Technische Universität Dresden during classes, via flyers on campus or through online information. Sample size was determined based on the size required for endocrine analyses (Armbruster *et al.*, submitted) using G*Power 3.1 (Faul *et*

al., 2007). Regarding HRV, Park et al. (2016) reported correlations of RMSSD and moral judgements ranging from 0.24 and -0.34. Using the lower one for power estimation, we had a power of $1-\beta = 0.92$ to detect such an effect at a significance level of $\alpha = 0.05$ in the total sample.

Students from different faculties were recruited for this study. A list of faculty affiliation can be found in supplemental table 1. Before taking part in the study, participants were informed 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. Furthermore, at the start of their lab session participants completed a demographic questionnaire that also inquired about these variables to ensure that the criteria were met. One lab session was 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). Women either reported to have a free menstrual cycle or to use combined oral contraceptives (COC) with a 21/7 days pill regime. Free cycling women participated either during the early follicular phase (days 1-7) or late luteal phase (during the last six days before menses), while COC users participated during active pill use. Data collection took place from April until December 2019.

Materials

We used German translations of the dilemma set by Conway and Gawronski (2013). All dilemmas used in this study can be found online (<https://osf.io/vu5kn/>) and in the supplement. Briefly, the set consists of 10 dilemmas in two versions: a congruent and an incongruent scenario. For each scenario, participants decided whether a proposed (harmful) action to achieve a particular outcome is appropriate or not. In *incongruent* dilemmas, an action's overall benefit outweighs

concurrent harm. However, since a harmful action is nevertheless necessary to achieve the outcome, in incongruent dilemmas deontological and utilitarian principles vie for influence. In a *congruent* dilemma, the proposed harmful action also prevents an undesired outcome, but the inflicted harm outweighs the benefits. Thus, such actions are not acceptable either by deontological or utilitarian principles.

Similar to previous studies (Conway and Gawronski, 2013; Park *et al.*, 2016), dilemmas were presented in the same fixed random order. Participants were instructed to read each scenario and to decide whether the proposed action is appropriate or inappropriate. To give their answer, participants mouse-clicked a “yes” or “no” button. After responding to each dilemma, participants also rated how difficult it was for them to reach a decision on 5-point Likert scale ranging from 1 (very easy) to 5 (very difficult).

Procedure

Participants were upon arriving first informed in writing about the study’s goals and protocol and gave written consent. Afterwards they completed a short demographic questionnaire and provided a first saliva sample for later hormone analyses (data not reported here). Subsequently, electrodes for assessment of electro-cardiographic (ECG) and electro-dermal activity were attached, and heart rate and EDA data was recorded during a 5-minutes resting period. After removal of the sensors, participants were asked to complete the Positive and Negative Affective Schedule (PANAS; Watson *et al.*, 1988). Next, the computerized moral decision paradigm was employed (cf. Conway and Gawronski, 2013). Participants read the instructions and if they indicated that they had no further questions the experiment was conducted as described above. Following , participants filled out the PANAS a second time and completed German versions of three personality questionnaires: (1) the short version of the Rational-Experiential Inventory

(REI-S; Epstein *et al.*, 1996), to assess *need for cognition* (NFC) and *faith in intuition*; (2) the Interpersonal Reactivity Index (IRI; Davis, 1980), to assess *empathic concern* and *perspective taking*; and (3) the Self-Report of Psychopathy Short Form (SRP-SF; cf. Neumann and Pardini, 2014) which assesses psychopathy on the four sub-scales *interpersonal*, *affective*, *lifestyle*, and *antisocial*. Finally, participants provided two more saliva samples for hormone and DNA analyses, respectively (data not reported here). Participants were subsequently debriefed, thanked and reimbursed. Study design and protocol were approved by the ethics committee of the Technische Universität Dresden (EK 225052019).

Heart rate data

Raw electro-cardiographic data was amplified by a BrainAmp amplifier (Brain Products GmbH, Gilching, Germany), sampled at 1000 Hz and filtered (10-90 Hz band pass, 50 Hz notch). ECG data was analyzed using Kubios HRV software (Tarvainen *et al.*, 2014). We extracted the following parameters: mean heart rate, root-mean square differences of successive RR intervals (RMSSD) and percentage of high frequency power (HF: 0.15–0.4 Hz). Given controlled conditions and normal breathing, the natural logarithm (Ln) of HF power can be used to estimate vagal tone (Egizio *et al.*, 2011; Shaffer and Ginsberg, 2017). Thus, we included ln HF Power as an additional indicator of parasympathetic activity and neuro-visceral integration. RMSSD data was also log transformed using the natural logarithm (Shaffer and Ginsberg, 2017) to achieve a more normal distribution (Tarvainen *et al.*, 2017).

EDA data

Electrodermal activity was measured on the distal phalanges of the index and middle finger of the non-dominant hand. The raw signal was amplified by a BrainAmp amplifier (Brain Products

GmbH, Gilching, Germany), sampled at 500 Hz and filtered (low-pass: 2 Hz, no high-pass). EDA equipment malfunctioned during the session of the final participant leaving $n = 156$ participants for EDA analyses. Mean skin conductance level (SCL) and mean area under the curve of spontaneous skin conductance responses (AUC_sSCR) during the 5min resting period were determined using a matching pursuit (MP) algorithm (see Bach and Staib, 2015 for details).

Statistical Analyses

All analyses were performed using SPSS 27.0 for Windows (IBM Corp., New York, USA). Responses to moral dilemmas were analysed in line with previous work (Conway and Gawronski, 2013). First, the proportion of decisions for outcome-based options in *incongruent* dilemmas was calculated (traditional score). Next, independent estimates of deontology (D) and utilitarianism (U) were calculated using PD (Conway and Gawronski, 2013). Correlation analyses were performed to investigate associations between moral judgements, heart rate parameters (RMSSD, ln RMSSD, ln HF power) and EDA parameters (SCL and AUC_sSCR) in the whole sample as well as the three subsamples (men, free cycling women, COC users). Ancillary correlation analyses were conducted to investigate associations between heart rate and EDA parameters and response times as well as ratings of experienced difficulty when responding to moral dilemmas. Furthermore, correlation analyses were performed to investigate associations between moral decisions and personality traits.

Results

Manipulation check

As previously reported (Conway and Gawronski, 2013; Park *et al.*, 2016) participants judged harmful actions in congruent dilemmas (mean = 17.8% $\pm$ 9.96) less acceptable compared to

incongruent dilemmas (mean = $61.3\% \pm 15.31$; $t(156) = 34.36$, $p < .001$, $d = 2.74$). Furthermore, reaction time to congruent dilemmas was significantly shorter compared to incongruent ones ($t(156) = 8.58$, $p < .001$, $d = 0.68$) and decisions in incongruent trials were perceived as more difficult ($t(156) = 18.95$, $p < .001$, $d = 1.51$).

Heart Rate and Heart Rate Variability

At rest, mean heart rate did not differ between men and women ($F(1,155) = 0.49$, $p = .486$, $\eta_p^2 = .003$). While there were also no sex differences in RMSSD ($F(1,155) = 2.02$, $p = .157$, $\eta_p^2 = .013$) and ln RMSSD ($F(1,155) = 2.30$, $p = .131$, $\eta_p^2 = .015$), HF power ($F(1,155) = 13.06$, $p \leq .001$, $\eta_p^2 = .078$) as well as ln HF power ($F(1,155) = 10.07$, $p = .002$, $\eta_p^2 = .061$) were significantly higher in women. Within the female subsample, no differences were observed between free cycling women and COC users in mean heart rate ($F(1,84) = 1.67$, $p = .200$, $\eta_p^2 = .020$), RMSSD ($F(1,84) = 0.004$, $p = .948$, $\eta_p^2 \leq .001$), and ln RMSSD ($F(1,84) = 0.008$, $p = .929$, $\eta_p^2 \leq .001$). However, COC users presented with slightly higher HF power ($F(1,84) = 6.37$, $p = .013$, $\eta_p^2 = .071$) and ln HF power ($F(1,84) = 4.80$, $p = .031$, $\eta_p^2 = .054$).

We repeated the analyses done by Park *et al.* (2016) and correlated RMSSD with moral judgements. In the total sample, there were no associations with the traditional score ($p = .788$), utilitarianism ($p = .796$) or deontology ($p = .909$). Partial correlation analysis (controlling for sex) also found no effects (all $p \geq .598$). Separate correlation analyses in the three subsamples (free cycling women, COC users, men) also revealed no significant associations between RMSSD and moral judgements (all $p \geq .163$; see also supplemental table 1).

As outlined above, we additionally investigated ln RMSSD and ln HF Power (see Table 1). As expected, both measures were correlated ($r = .498, p \leq .001$). In women, ln HF power, but not ln RMSSD, showed associations with moral judgements. In free cycling women, ln HF power was *negatively* associated with deontology ($r = -.343, p = .018$; see Figure 1A) but not with the traditional score or utilitarianism (all $p \geq .335$). Contrariwise, in COC users, there was, at a descriptive level, a *positive* association between ln HF and deontology ($r = .304, p = .060$; see Figure 1A). To investigate this potential interplay between ln HF power and hormone status in women further, a linear regression analysis was performed. Centered ln HF power, dummy-coded hormone status (free cycling vs. COC use), and their interaction term were entered as predictors of deontology. The interaction was significant ($B = -.189, \beta = -.501, p = .003$), while ln HF power ($p = .061$) and hormone status ($p = .114$) alone did not predict deontology.

Furthermore, in COC users ln HF power was significantly associated with the traditional score ($r = -.364, p = .023$), while an association with utilitarianism ($r = -.273, p = .092$) did not reach the traditional level of significance. In men, there were no correlations between ln HF power and moral judgement (all $p \geq .180$). However, ln RMSSD was associated with deontology ($r = .240, p = .044$; see Figure 1B) albeit not with the traditional score or utilitarianism (all $p \geq .487$).

[Figure 1 and Table 1 about here]

While mean resting heart rate was not linked to moral judgements (all $p \geq .280$), it was related in the total sample to response time in *incongruent* dilemmas ($r = -.171, p = .032$) and, at a descriptive level, with response time in *congruent* dilemmas ($r = -.136, p = .089$). Neither RMSSD nor ln RMSSD or ln HF power were related to response times (all $p \geq .234$). Resting HR was also related to the perceived difficulty of decisions in *incongruent* ($r = -.178, p = .026$),

but not congruent dilemmas ($p = .144$). RMSSD, ln RMSSD, and ln HF power were not related to any difficulty ratings (all $p \geq .107$).

Electrodermal Activity

The two indicators of resting electrodermal activity, mean SCL and mean AUC_sSCR, were highly correlated ($r = .617, p \leq .001$). Furthermore, AUC_sSCR was associated with resting heart rate ($r = .189, p = .018$), while the association between SCL and resting heart rate failed to reach significance ($r = .148, p = .065$). There were no sex differences in SCL ($F(1,154) = 0.41, p = .523, \eta_p^2 = .003$) and AUC_sSCR ($F(1,154) = 1.58, p = .210, \eta_p^2 = .010$) nor were there differences between free cycling women and COC users (SCL: $F(1,83) = 0.26, p = .611, \eta_p^2 = .003$; AUC_sSCR: $F(1,83) = 0.46, p = .499, \eta_p^2 = .006$).

None of the correlations between EDA parameters and moral judgements reached significance in the total sample or in any of the three sub-samples (all $p \geq .096$; see supplemental table 3 for details). However, in the total sample, mean AUC_sSCR at rest predicted response time to *incongruent* ($r = -.212, p = .008$) and *congruent* dilemmas ($r = -.195, p = .014$) while SCL was unrelated to response times (all $p \geq .315$). Neither SCL nor AUC_sSCR were associated with perceived response difficulties in the total sample (all $p \geq .567$) or in any of the sub-samples (all $p \geq .262$).

Personality traits

Unlike in the study by Park *et al.* (2016) there was no associations between *NFC* and the traditional score in the total sample ($p = .433$). *NFC* was also not related to utilitarianism or deontology (all $p \geq .145$). However, similar to Park *et al.* (2016) there was an association between

empathic concern and deontology ($r = .194, p = .015$). In addition, *empathic concern* was linked to the traditional score ($r = -.224, p = .005$), but not utilitarianism ($p = .164$). *Perspective taking* was not associated with moral judgement parameters (all $p \geq .356$) nor was *faith in intuition* (all $p \geq .401$). From the four psychopathy subscales, only *antisocial* showed no associations with moral decisions (all $p \geq .257$), while *interpersonal*, *affective*, and *life style* were all correlated with the traditional score (all $p \leq .045$) and deontology (all $p \leq .036$), but not with utilitarianism (all $p \geq .080$; see supplemental table 4 for details).

Discussion

We attempted to replicate and extend the findings of Park *et al.* (2016) on the association of heart rate variability and moral judgement. Unlike Park *et al.*, we did not find correlations between RMSSD and utilitarianism. In fact, in the total sample of $N = 157$ young healthy adults we did not find any consistent association between HRV indicators and moral judgment. However, when taking possible effects of sex and the use of COC into account a more complex picture emerged. In free cycling women, a negative association between HRV and *deontology* was found while in men and in COC users this association was positive. Furthermore, only in COC users there was, on a descriptive level, a negative association between HRV and utilitarianism similar to the one Park *et al.* reported. However, even in this subsample we were unable to directly replicate the original association between RMSSD and utilitarianism but found an association with another HRV parameter (i.e., $\ln$ HF power).

Overall, our results on HRV and moral judgement appear to be inconsistent with the findings reported by Park *et al.* (2016). However, while we did not find negative associations between HRV parameters indicative of vagal tone and utilitarianism, there were positive associations of

HRV with deontology, at least in women using COC and men. Importantly, both reduced utilitarianism and increased deontology are linked at the behavioral level to decreased endorsement of harmful actions. Thus, reduced neuro-visceral integration (as indicated by decreased HRV at rest) might ultimately further avoidance of harmful actions even if carried out for the ‘greater good’.

Intriguingly, in free cycling women, the pattern was reversed with HRV being negatively associated with deontology. A regression analysis in the female subsample confirmed an interaction effect of HRV and hormone status (free cycling vs. COC use) on deontology. Furthermore, as reported elsewhere (Armbruster *et al.*, submitted), in our sample moral judgements systematically varied between free cycling women, COC users, and men. The highest endorsement of harmful actions was found in men followed by COC users while free cycling women showed the least endorsement. Congruently, utilitarianism was found to be highest in men and lowest in free cycling women while COC users fell in between. Descriptively, the opposite pattern was observed for deontology but did not reach significance (Armbruster *et al.*, submitted).

HRV has previously been reported not to differ between free cycling women and COC users (Wilczak *et al.*, 2013; Nisenbaum *et al.*, 2014). However, our own data indicate that there might be differences depending on which parameter is assessed. While there were no differences in the time domain (RMSSD, ln RMSSD), COC users presented with higher levels in the respective frequency domain (HF power, ln HF power). Generally, COC use results in a significant reduction of endogenous estrogens and progesterone while simultaneously high levels of their synthetic counterparts are maintained (Burkman *et al.*, 2011; Christin-Maitre, 2013). In addition, endogenous androgen levels (e.g., testosterone) are reduced as well (Van der Vange *et al.*,

1990; Coenen *et al.*, 1996; Greco *et al.*, 2007). However, despite decreased androgens, androgen receptor signaling might actually be increased in COC users, since synthetic progestogens also bind (with varying affinity) to the androgen receptor—unlike their natural equivalent (Burkman *et al.*, 2011). In short, interactions between the COC-induced state of high exogenous and low endogenous steroid concentrations and their potential effects on downstream processes are far from clear at this time (Lewis *et al.*, 2019).

We also attempted to extend the findings of Park *et al.* (2016) by investigating potential associations between peripheral indicators of sympathetic activity and moral decisions. However, there was no evidence that sympathetic activity at rest, as assessed by EDA, predicted moral judgement. Neither associations of SCL or AUC_sSCR reached significance. If anything, larger AUC_sSCR were predictive of faster responses as was higher resting heart rate, indicating that higher sympathetic arousal reduces decision times but does not affect the actual judgment—at least when participants can answer in their own time.

Furthermore, we replicated the association between empathic concern and deontology but not the one between NFC and moral judgment. *Empathic concern* has been linked to ‘deontological’ preferences when analyzing the traditional moral score (e.g., Gleichgerrcht and Young, 2013; Patil and Silani, 2014). In studies using a modeling approach to estimate underlying deontic tendencies, i.e., deontology (Park *et al.*, 2016) or sensitivity to norms (Körner *et al.*, 2020), positive associations with empathic concerns emerged. Similarly, in our sample empathic concern was associated with the traditional score and underlying deontology—but not utilitarianism. Thus, empathic concern appears to be linked to greater importance of moral norms and rules rather than reduced concern for overall consequences of an action. Park *et al.* (2016) had also reported a correlation of *NFC* and the traditional moral score, intriguingly indicating a

preference for *deontological* over utilitarian judgements. In a follow-up regression analysis, using the deontology parameter from the PD analysis, this association was confirmed (Park *et al.*, 2016). Contrariwise, previous studies had reported links between NFC and *utilitarian* judgments (Conway and Gawronski, 2013; Wiech *et al.*, 2013). However, a recent study also found in multiple samples greater sensitivity to moral norms and a preference for deontological judgments to be associated with higher NFC (Körner *et al.*, 2020). The authors suggest that instead of being associated with enhanced reflection of cost and benefits, higher NFC might lead to increased deliberation of moral norms (Körner *et al.*, 2020). The lack of association in our own sample might furthermore be partly due to reduced variance since 84.1% of our participants had self-reported NFC levels that were higher than the mean of the NFC scale used (REI-S; Epstein *et al.*, 1996). Although this is not surprising given that participants were recruited in a university context, it might have contributed to a weakened association with moral judgement.

Trait *psychopathy* was systematically related to the traditional moral score and reduced deontology—but not to utilitarianism. Deviant morality has long been recognized as one of the key characteristics of psychopathy and featured prominently in early designations of the syndrome, e.g. “moral derangement” (Rush, 1812) or “moral insanity” (Prichard, 1835). Psychopathy has been generally associated with preferences for ‘utilitarian’ choices (meta-analysis: Marshall *et al.*, 2018) although this does not necessarily mean that psychopaths are more concerned with the ‘greater good’. The disproportionate amount of physical, emotional, social or financial damage caused by psychopaths (cf. Kiehl and Hoffman, 2011; Leedom, 2017) makes this doubtful. Instead, lack of empathy in general and reduced compassion for unfortunate others in particular are contributing to psychopaths’ ‘utilitarian’ choices (Glenn *et al.*, 2009; Seara-Cardosa *et al.*, 2012; Seara-Cardosa *et al.*, 2013). Also, reduced aversion to perform harmful actions mediates the association of psychopathy and ‘utilitarian’ judgments (Patil, 2015). Our own findings point

in a similar direction. Higher trait psychopathy scores were associated with reduced deontology, i.e., less concern for moral norms. However, there was no association with actual utilitarianism, i.e., concern for overall consequences. Similarly, using the CNI model (cf. Gawronski *et al.*, 2017) trait psychopathy was associated with *less* sensitivity to moral norms and even to consequences (Gawronski *et al.*, 2017; Körner *et al.*, 2020).

There are several limitations to our study. First off, while our entire sample was about two and a half times the size of the sample of Park *et al.* (2016), our two female sub-samples might have been too small to detect associations that only occur in certain sub-groups. Furthermore, differences in sample characteristics need to be taken into account. While the U.S. sample of Park *et al.* (2016) was of diverse ethnicity, our sample consisted solely participants of German/Western European origin. In addition, cultural differences between the two samples might have played a role. The U.S. sample was also significantly younger (19.4 vs. 24.22 years). Together these differences might contribute to disparities in moral judgements. For instance, while in both samples harmful actions in incongruent dilemmas were judged as more acceptable than in congruent dilemmas, there were differences in the acceptance rates in *incongruent* dilemmas. In the U.S. sample, there was less endorsement of harmful actions (54.8%, $SD = 17.0$, $n = 64$) compared to the German sample (61.3%, $SD = 15.3$, $n = 157$; $p = .006$). However, there was no difference in responses to congruent dilemmas (U.S. sample: 20.5%, $SD = 14.5$, $n = 64$; German sample: 17.8%, $SD = 9.96$, $n = 157$; $p = .113$).

Although we were unable to directly replicate the results of Park *et al.* (2016), we also did find evidence that reduced vagal tone at rest might be ultimately related to increased endorsement of harmful actions in moral dilemma situations—at least in men and women using COC. Importantly, our findings also highlight the role of sex and COC use as potential modulators of

associations between HRV and moral judgement which warrant further investigation. While we did not find evidence for associations of sympathetic activity (assessed via EDA) and differences in moral judgement, increased sympathetic activity at rest was associated with faster responses to moral dilemmas. Regarding personality, we found no association between *NFC* and moral judgement, but similar to Park *et al.* (2016) we found correlations with *empathic concern*. In addition, trait *psychopathy* showed robust associations with differences in moral judgement, in particular with reduced deontology.

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Declaration of interest

None.

Table 1: Correlations between resting heart rate variability and moral judgements in the total sample, free cycling women, COC users, and men

Sample	<i>n</i>		Traditional Score	Utilitarianism	Deontology
total sample	157	ln RMSSD	-.030 (<i>p</i> = .711)	-.007 (<i>p</i> = .931)	.068 (<i>p</i> = .398)
		ln HF power	-.110 (<i>p</i> = .171)	-.105 (<i>p</i> = .192)	.064 (<i>p</i> = .424)
free cycling women	47	ln RMSSD	.007 (<i>p</i> = .961)	-.105 (<i>p</i> = .483)	-.106 (<i>p</i> = .478)
		ln HF power	.144 (<i>p</i> = .335)	-.030 (<i>p</i> = .839)	-.343 (<i>p</i> = .018)
COC users	39	ln RMSSD	.127 (<i>p</i> = .443)	.026 (<i>p</i> = .875)	-.131 (<i>p</i> = .426)
		ln HF power	-.364 (<i>p</i> = .023)	-.273 (<i>p</i> = .092)	.304 (<i>p</i> = .060)
men	71	ln RMSSD	-.084 (<i>p</i> = .487)	.075 (<i>p</i> = .076)	.240 (<i>p</i> = .044)
		ln HF power	-.120 (<i>p</i> = .321)	-.058 (<i>p</i> = .628)	.161 (<i>p</i> = .180)

ln RMSSD: natural logarithm of the root mean square of successive inter-beat interval differences

ln HF power: natural logarithm of high frequency power (0.15–0.4 Hertz)

Figure 1 (A): Correlation between heart rate variability (ln HF power) and deontology in women (free cycling women: ●/ COC users: ○); **(B)** correlation between heart rate variability (ln RMSSD) and deontology in men

References

- Armbruster, D., Kirschbaum, C. & Strobel, A. (submitted). Androgenic Morality? Associations of sex, oral contraceptive use and basal testosterone levels with moral decision making. *Behavioral Brain Research*.
- Bach, D. R., Friston, K. J. & Dolan, R. J. (2010). Analytic measures for quantification of arousal from spontaneous skin conductance fluctuations. *International Journal of Psychophysiology*, **76**, 52-55.
- Bach, D. R. & Staib, M. (2015). A matching pursuit algorithm for inferring tonic sympathetic arousal from spontaneous skin conductance fluctuations. *Psychophysiology*, **52**, 1106-1112.
- Behnke, A., Strobel, A. & Armbruster, D. (2020). When the killing has been done: Exploring associations of personality with third-party judgment and punishment of homicides in moral dilemma scenarios. *PLoS One*, **15**, e0235253.
- Boucsein, W. (2012). *Electrodermal activity* New York, Springer.
- Burkman, R., Bell, C. & Serfaty, D. (2011). The evolution of combined oral contraception: improving the risk-to-benefit ratio. *Contraception*, **84**, 19-34.
- Christin-Maitre, S. (2013). History of oral contraceptive drugs and their use worldwide. *Best Practice & Research Clinical Endocrinology & Metabolism*, **27**, 3-12.
- Coenen, C. M., Thomas, C. M., Borm, G. F., Hollanders, J. M. & Rolland, R. (1996). Changes in androgens during treatment with four low-dose contraceptives. *Contraception*, **53**, 171-176.
- Conway, P. & Gawronski, B. (2013). Deontological and utilitarian inclinations in moral decision making: a process dissociation approach. *Journal of Personality and Social Psychology*, **104**, 216-235.
- Davis, M. H. (1980). A multidimensional approach to individual differences in empathy. *Catalog of Selected Documents in Psychology*, **10**, 85.
- Egizio, V. B., Eddy, M., Robinson, M. & Jennings, J. R. (2011). Efficient and cost-effective estimation of the influence of respiratory variables on respiratory sinus arrhythmia. *Psychophysiology*, **48**, 488-494.
- Epstein, S., Pacini, R., DenesRaj, V. & Heier, H. (1996). Individual differences in intuitive-experiential and analytical-rational thinking styles. *Journal of Personality and Social Psychology*, **71**, 390-405.
- Faul, F., Erdfelder, E., Lang, A. G. & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods*, **39**, 175-191.
- Figner, B. & Murphy, R. O. (2011). Using skin conductance in judgment and decision making research, in M. Schulte-Mecklenbeck, A. Kühberger & R. Ranyard (eds), *A handbook of process tracing methods for decision research*, New York, Psychology Press.

Gawronski, B., Armstrong, J., Conway, P., Friesdorf, R. & Hutter, M. (2017). Consequences, norms, and generalized inaction in moral dilemmas: The CNI model of moral decision-making. *Journal of Personality and Social Psychology*, **113**, 343-376.

Gleichgerricht, E. & Young, L. (2013). Low levels of empathic concern predict utilitarian moral judgment. *PLoS One*, **8**, e60418.

Glenn, A. L., Iyer, R., Graham, J., Koleva, S. & Haidt, J. (2009). Are All Types of Morality Compromised in Psychopathy? *Journal of Personality Disorders*, **23**, 384-398.

Greco, T., Graham, C. A., Bancroft, J., Tanner, A. & Doll, H. A. (2007). The effects of oral contraceptives on androgen levels and their relevance to premenstrual mood and sexual interest: a comparison of two triphasic formulations containing norgestimate and either 35 or 25 microg of ethinyl estradiol. *Contraception*, **76**, 8-17.

Greene, J. D. (2007). Why are VMPFC patients more utilitarian? A dual-process theory of moral judgment explains. *Trends in Cognitive Sciences*, **11**, 322-323.

Jacoby, L. L. (1991). A Process Dissociation Framework - Separating Automatic from Intentional Uses of Memory. *Journal of Memory and Language*, **30**, 513-541.

Kiehl, K. A. & Hoffman, M. B. (2011). The Criminal Psychopath: History, Neuroscience, Treatment, and Economics. *Jurimetrics*, **51**, 355-397.

Körner, A., Deutsch, R. & Gawronski, B. (2020). Using the CNI Model to Investigate Individual Differences in Moral Dilemma Judgments. *Personality and Social Psychology Bulletin*, **46**, 1392-1407.

Leedom, L. J. (2017). The impact of psychopathy on the family, in F. Durbano (ed), *Psychopathy - New Updates on an Old Phenomenon*, Rijeka, Croatia, InTech.

Lewis, C. A., Kimmig, A. S., Zsido, R. G., Jank, A., Derntl, B. & Sacher, J. (2019). Effects of Hormonal Contraceptives on Mood: A Focus on Emotion Recognition and Reactivity, Reward Processing, and Stress Response. *Current Psychiatry Reports*, **21**, 115.

Macefield, V. G. & Wallin, B. G. (1996). The discharge behaviour of single sympathetic neurones supplying human sweat glands. *Journal of the Autonomic Nervous System* **61**, 277-286.

Marshall, J., Watts, A. L. & Lilienfeld, S. O. (2018). Do psychopathic individuals possess a misaligned moral compass? A meta-analytic examination of psychopathy's relations with moral judgment. *Personality Disorders*, **9**, 40-50.

Neumann, C. S. & Pardini, D. (2014). Factor Structure and Construct Validity of the Self-Report Psychopathy (SRP) Scale and the Youth Psychopathic Traits Inventory (YPI) in Young Men. *Journal of Personality Disorders*, **28**, 419-433.

Nisenbaum, M. G., de Melo, N. R., Giribela, C. R., de Moraes, T. L., Guerra, G. M., de Angelis, K., Mostarda, C., Baracat, E. C. & Consolim-Colombo, F. M. (2014). Effects of a contraceptive containing drospirenone and ethinyl estradiol on blood pressure and autonomic tone: a prospective controlled clinical trial. *European Journal of Obstetrics & Gynecology and Reproductive Biology*, **175**, 62-66.

- Nishiyama, T., Sugeno, J., Matsumoto, T., Iwase, S. & Mano, T. (2001). Irregular activation of individual sweat glands in human sole observed by a videomicroscopy. *Autonomic Neuroscience*, **88**, 117-126.
- Park, G., Kappes, A., Rho, Y. & Van Bavel, J. J. (2016). At the heart of morality lies neuro-visceral integration: lower cardiac vagal tone predicts utilitarian moral judgment. *Social Cognitive and Affective Neuroscience*, **11**, 1588-1596.
- Park, G. & Thayer, J. F. (2014). From the heart to the mind: cardiac vagal tone modulates top-down and bottom-up visual perception and attention to emotional stimuli. *Frontiers in Psychology*, **5**, 278.
- Patil, I. (2015). Trait psychopathy and utilitarian moral judgement: The mediating role of action aversion. *Journal of Cognitive Psychology*, **27**, 349-366.
- Patil, I. & Silani, G. (2014). Reduced empathic concern leads to utilitarian moral judgments in trait alexithymia. *Frontiers in Psychology*, **5**.
- Porges, S. W. (2003). The Polyvagal Theory: phylogenetic contributions to social behavior. *Physiology & Behavior*, **79**, 503-513.
- Prichard, J. C. (1835). *A treatise on insanity and other disorders affecting the mind* London,, Sherwood, Gilbert and Piper.
- Rush, B. (1812). *Medical inquiries and observations upon the diseases of the mind* Philadelphia, Kimber & Richardson.
- Seara-Cardosa, A., Dolberg, H., Neumann, C., Roiser, J. P. & Viding, E. (2013). Empathy, morality and psychopathic traits in women. *Personality and Individual Differences*, **55**, 328-333.
- Seara-Cardosa, A., Neumann, C., Roiser, J. P., McCrory, E. & Viding, E. (2012). Investigating associations between empathy, morality and psychopathic personality traits in the general populati. *Personality and Individual Differences*, **52**, 67-71.
- Shaffer, F. & Ginsberg, J. P. (2017). An Overview of Heart Rate Variability Metrics and Norms. *Frontiers in Public Health*, **5**, 258.
- Simmons, J., Nelson, L. & Simonsohn, U. (2012). A 21 Word Solution. Available at SSRN: <https://ssrn.com/abstract=2160588> or <http://dx.doi.org/10.2139/ssrn.2160588>.
- Tarvainen, M. P., Lipponen, J., Niskanen, J. P. & Ranta-Aho, P. (2017). *Kubios HRV Version 3 – User’s Guide*. University of Eastern Finland, Kuopio.
- Tarvainen, M. P., Niskanen, J. P., Lipponen, J. A., Ranta-Aho, P. O. & Karjalainen, P. A. (2014). Kubios HRV--heart rate variability analysis software. *Computer Methods and Programs in Biomedicine*, **113**, 210-220.
- Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology (1996). Heart rate variability: standards of measurement, physiological interpretation and clinical use. *Circulation*, **93**, 1043-1065.

- Thayer, J. F., Ahs, F., Fredrikson, M., Sollers, J. J., 3rd & Wager, T. D. (2012). A meta-analysis of heart rate variability and neuroimaging studies: implications for heart rate variability as a marker of stress and health. *Neuroscience & Biobehavioral Reviews*, **36**, 747-756.
- Thayer, J. F., Friedman, B. H. & Borkovec, T. D. (1996). Autonomic characteristics of generalized anxiety disorder and worry. *Biological Psychiatry*, **39**, 255-266.
- Thayer, J. F. & Lane, R. D. (2000). A model of neurovisceral integration in emotion regulation and dysregulation. *Journal of Affective Disorders*, **61**, 201-216.
- Thayer, J. F. & Lane, R. D. (2009). Claude Bernard and the heart-brain connection: further elaboration of a model of neurovisceral integration. *Neuroscience & Biobehavioral Reviews*, **33**, 81-88.
- Van der Vange, N., Blankenstein, M. A., Kloosterboer, H. J., Haspels, A. A. & Thijssen, J. H. H. (1990). Effects of 7 Low-Dose Combined Oral-Contraceptives on Sex-Hormone Binding Globulin, Corticosteroid Binding Globulin, Total and Free Testosterone. *Contraception*, **41**, 345-352.
- Watson, D., Clark, L. A. & Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect: the PANAS scales. *Journal of Personality and Social Psychology*, **54**, 1063-1070.
- Wiech, K., Kahane, G., Shackel, N., Farias, M., Savulescu, J. & Tracey, I. (2013). Cold or calculating? Reduced activity in the subgenual cingulate cortex reflects decreased emotional aversion to harming in counterintuitive utilitarian judgment. *Cognition*, **126**, 364-372.
- Wilczak, A., Marciniak, K., Klapcinski, M., Rydlewska, A., Danel, D. & Jankowska, E. A. (2013). Relations between combined oral contraceptive therapy and indices of autonomic balance (baroreflex sensitivity and heart rate variability) in young healthy women. *Ginekologia Polska*, **84**, 915-921.
- Zimmer, H. (2000). [Frequency and mean amplitude of spontaneous electrodermal fluctuations are not interchangeable indicators of psychological processes]. *Zeitschrift für experimentelle und angewandte Psychologie*, **47**, 129-143.