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At the heart of morality lies neuro-visceral integration: lower cardiac vagal tone predicts utilitarian moral judgment

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Abstract

To not harm others is widely considered the most basic element of human morality. The aversion to harm others can be either rooted in the *outcomes* of an action (utilitarianism) or reactions to the *action* itself (deontology). We speculated that the human moral judgments rely on the *integration* of neural computations of harm and visceral reactions. The present research examined whether utilitarian or deontological aspects of moral judgment are associated with cardiac vagal tone, a physiological proxy for neuro-visceral integration. We investigated the relationship between cardiac vagal tone and moral judgment by using a mix of moral dilemmas, mathematical modeling and psychophysiological measures. An index of bipolar deontology-utilitarianism was correlated with resting heart rate variability (HRV)—an index of cardiac vagal tone—such that more utilitarian judgments were associated with lower HRV. Follow-up analyses using process dissociation, which independently quantifies utilitarian and deontological moral inclinations, provided further evidence that utilitarian (but not deontological) judgments were associated with lower HRV. Our results suggest that the functional integration of neural and visceral systems during moral judgments can restrict outcome-based, utilitarian moral preferences. Implications for theories of moral judgment are discussed.

Key words: moral judgment; vagal tone; neuro-visceral integration; heart rate variability; utilitarianism; cardiac

To not harm others is widely considered the most basic element of human morality (Cushman *et al.*, 2006; Haidt, 2007; Gray *et al.*, 2012). There is substantial evidence highlighting the role that aversion to harm plays in moral judgments (Blair, 1995; Cushman *et al.*, 2012; Crockett, 2013; Schein and Ward, 2014). Such harm aversion can arise either from thinking about the *outcome* caused by a specific action—not pushing the person on the tracks which will cause five people to die—or by the *action* itself—pushing a person on the tracks (Crockett, 2013; Cushman, 2013). While harm aversion evoked by outcomes is a result of cognitive computations mediated by brain structures, such as the dorsolateral prefrontal cortex and inferior parietal lobes (Greene *et al.*, 2004), harm aversion evoked by actions is rooted in visceral reactions of the autonomic nervous system (see Blair, 1995). Harmful actions cause immediate physiological reactions that lead people to judge such actions as morally wrong regardless of outcomes (Cushman *et al.*, 2012). In this paper, we examine the relationship between these different forms of harm aversion and a physiological index of neuro-visceral integration.

In practice, moral judgments are most often a compromise between action-based and outcome-based considerations (Kahane, 2015). This raises the question of how cognitive computations about outcomes and visceral reactions evoked by harmful actions are integrated into moral judgment (Moll *et al.*, 2008; Kvaran and Sanfey, 2010; Nucci and Gingo, 2010). We speculated that cardiac vagal tone might help address this issue since it has been linked to neuro-visceral integration during cognitive and emotional regulation (Friedman, 2007; Thayer and Lane, 2009; Park and Thayer, 2014). Specifically, we examined

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whether outcome-based (utilitarianism) or action-based (deontology) moral judgment would be associated with the ability to integrate visceral reactions into judgment—indexed by cardiac vagal tone.

Harm aversion and moral judgment

Aversion to moral actions based on outcomes describes the idea that people judge an action as morally wrong because of the anticipated consequences. A policeman, for instance, might feel that shooting a perpetrator is justified because it will prevent the death of several innocent people. Outcome-based aversion has been linked to deliberation (Greene and Haidt, 2002) or model-based learning (Crockett, 2013; Cushman, 2013). On sacrificial dilemmas where people must decide whether to sacrifice one person to save more, for instance, people might deliberately imagine the anticipated outcomes of each of the possible actions (e.g. pushing the stranger of the footbridge or not) for the people involved (Kahane, 2015). Then, based on their empathetic reactions to these imagined outcomes, they would judge the proposed action (i.e. pushing the stranger onto the train racks to save the life of five strangers) as either permissible or not. Consistently, outcome-based processes have been linked to cognitive computations about utility. And studies that either manipulate or measure individual differences in deliberation find a link between outcome-based decisions and deliberation (e.g. Nichols and Mallon, 2006; Bartels, 2008; Greene *et al.*, 2008; Moore *et al.*, 2008; Conway and Gawronski, 2013). However, recent studies suggest that outcome-based decisions can be based on a lack of visceral or emotional responses to committing harm (Koenigs *et al.*, 2007; Bartels and Pizarro, 2011).

Action-based harm aversion, in contrast, refers to the idea that people judge an action as morally wrong based on the dislike for a particular action, independent of the consequences. A policeman, for instance, might feel that shooting a perpetrator is wrong because of his aversion of shooting someone, not because of his aversion of the outcome (i.e. death of the perpetrator). Action aversion implies that people judge certain actions as wrong not because of their consequences or their concern for another person. Victimless 'crimes' such as cleaning a toilet with a national flag, however, provide examples for moral judgments that do not appear to be dependent on harmful outcomes (Haidt *et al.*, 1993; but see Gray and Keeney, 2015). Similarly, participants perceived actions such as stabbing somebody with a fake knife as aversive even though the action had no aversive outcomes (Cushman *et al.*, 2012). Furthermore, self-rated aversion to such harmless actions is a better predictor of moral judgments on sacrificial moral dilemmas than self-rated aversion to outcomes (Miller *et al.*, 2014). Thus, people seem to base their moral judgments largely on the aversion to performing certain actions.

Action- and outcome-based aversion to actions have been linked to two philosophical traditions: deontology and utilitarianism (Hume, 1739/1978; Kant, 1785/1983; Crockett, 2013; Cushman, 2013). Deontology promotes rule-based morality by focusing on rights and duties whereas utilitarianism focuses on the impartial concern for a greater good as the best outcome, even at personal sacrifices (Kant, 1785/1983; Kahane *et al.*, 2015). Deontological ethics have been linked to action-based harm-aversion, leading to one's resistance to cause personal harm to another person in sacrificial moral dilemmas (e.g. footbridge dilemma; Greene *et al.*, 2001, 2004, 2008). In contrast, utilitarian ethics have been linked to outcome-based harm aversion and the willingness to harm few to save more people in moral dilemmas (Greene *et al.*, 2001, 2004, 2008). In line with the vast majority of research on moral judgments, we refer to action-based judgments as deontological, and outcome-based ones as utilitarian. However, it is important to note that both, deontology and utilitarianism, represent extreme philosophical positions, and human morality might be better described as a mixture of both outcome- and action-based judgments (Kahane, 2015).

Action-based harm aversion is often associated with physiological threat and stress indicators, such as total peripheral resistance (Mendes *et al.*, 2007). People, for instance, show stronger physiological aversion to performing harmless actions (e.g. hitting a rubber hand with a hammer) compared with viewing somebody else performing the same actions (Cushman *et al.*, 2012). Furthermore, such physiological reactions to stress predict responses on sacrificial moral dilemma, the stronger the threat response, the more people prefer deontological judgments (Cushman *et al.*, 2012). Accordingly, people with reduced awareness of their physiological states (i.e. alexithymia) make utilitarian judgments (Patil and Silani, 2014). People potentially acquire such physiological reactions via learning; the repeated pairing of a suffering person (an unconditioned aversive stimulus) with a specific action might lead to an automatic aversive response (Blair, 1995). Yet, we know very little about the physiological processes that indicate the extent to which visceral responses are integrated into moral judgments.

HRV and neuro-visceral integration

According to the neuro-visceral integration model, cardiac vagal tone—that reflects activity of vagus nerve in the heart—mediates the relationship between cardiac autonomic function and neural circuits implicated in cognitive, social and emotional regulation (Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996; Berntson *et al.*, 1997; Thayer and Lane, 2000, 2009; Park and Thayer, 2014). The vagus nerve is the 10th cranial nerve that innervates a number of peripheral (visceral) organs such as the heart, the lungs, the stomach and the liver (Berntson *et al.*, 1997). Through afferent and efferent pathways of the vagus nerve, the brain can exchange information with visceral organs such as the heart and reciprocally influence activities to meet situational demands (Berntson *et al.*, 1997; Thayer and Lane, 2000; Porges, 2003). Specifically, the vagus nerve provides inhibitory inputs to the heart via the parasympathetic nervous system to regulate cardiac activity in accordance with the situation (Thayer and Lane, 2000; see also Porges, 2003). Although the heart is innervated by both the sympathetic and the parasympathetic nervous systems, greater tonic inhibitory control of the parasympathetic nervous system permits energy conservation in the cardiac autonomic function (Thayer and Lane, 2000; see also Porges, 2003).

Greater cardiac vagal tone—indexed by higher resting heart rate variability (HRV)—reflects highly integrated neuro-visceral systems (Thayer and Lane, 2000, 2009; Park and Thayer, 2014). Therefore, higher HRV reflects robust regulation of the heart via the vagus nerve and is often associated with effective self-regulatory functioning (Park and Thayer, 2014). This allows for making flexible and adaptive responses to meet environmental needs (Thayer and Lane, 2000; Thayer et al., 2009). Conversely, reduced cardiac vagal tone—low resting HRV—is associated with difficulty in integrating neuro-visceral systems that results in a trouble to inhibit an automatic response and recruiting executive function—mediated by the prefrontal cortex—to successfully master the task at hand (Johnson *et al*., 2003; Park and Thayer, 2014). Similar results have been reported for experimental task probing the procession of fearful faces (Park *et al*., 2012a), inhibitory control and selective attention (Park et al., 2012b, 2013a), as well as attentional control (Park *et al*., 2013b). Thus, cardiac vagal tone might also indicate the extent to which visceral reactions associated with action aversion are integrated into moral judgments.

This idea is also in line with the psychophysiology of moral judgment. Specifically, participants with damage to the ventromedial prefrontal cortex (vmPFC) are less likely to endorse deontological moral judgments (Ciaramelli *et al*., 2007; Koenigs *et al*., 2007; Moretto *et al*., 2010). The vmPFC is the key region for integrating values into decision-making (Hare et al., 2010; Hunt *et al*., 2012) and plays a key role in moral judgment (see Greene and Haidt, 2002; Van Bavel *et al*., 2015). The regulatory input of the cardiac vagal tone on emotional responses has also been related to neural activity in the vmPFC (Lane *et al*., 2009; Thayer *et al*., 2012), suggesting that cardiac vagal tone and the vmPFC are part of the same regulatory system implicated in integrating visceral responses into moral judgments.

Overview

In the current research, we examined whether resting cardiac vagal tone is associated with moral judgment. We suggest that cardiac vagal tone may indicate the extent to which visceral systems associated with action aversion are integrated into neural systems. A failure of the integration might result in strong utilitarian tendencies. Previous research has shown that strong deontological moral judgments stem from visceral reactions—indexed by peripheral vasoconstriction/total peripheral resistance—to perform certain actions (Cushman *et al*., 2012). Thus, making deontological moral judgments may not require neuro-visceral integration. To make moral judgments which represent non-extreme philosophical positions, harm aversion needs to be balanced with outcome-based considerations mediated primarily by the prefrontal cortex, which may depend on one's capacity to integrate visceral reactions into judgment. However, an inability to integrate visceral reactions into moral judgment might lead to strong outcome-based, utilitarian judgments, similar to research on people with vmPFC damage (e.g. Koenigs *et al*., 2007). Previous research has linked reduced cardiac vagal tone to difficulty in integrating neurovisceral systems (Thayer and Lane, 2000; Thayer et al., 2009; Park and Thayer, 2014). Thus, lower vagal tone would predict stronger utilitarian tendencies.

Furthermore, previous research has found that psychopathic tendencies correlate with utilitarian judgments (e.g. Bartels and Pizarro, 2011), and people with antisocial and psychopathic traits have lower cardiac vagal tone (Raine, 1997; Hansen *et al*., 2007). Therefore, a failure to integrate visceral harm aversion into moral judgments might increase utilitarian judgment. Based on these findings, one might expect that lower vagal tone would be associated with stronger utilitarian tendencies on sacrificial moral dilemmas.

Previous research with moral dilemmas has often confounded utilitarian and deontological tendencies. For instance, the tendency to endorse utilitarian judgments on sacrificial dilemmas might either be due to strong outcome-based, utilitarian tendencies or a lack of action-based, deontological tendencies. In order to disentangle the underlying processes, Conway and Gawronski (2013) recently adapted the process dissociation (PD) procedure to independently quantify utilitarian and deontological tendencies during moral judgment. Research employing this approach found that the utilitarian PD parameter was associated with the need for cognition and cognitive capacity, whereas the deontological PD parameter was associated with empathic concern (Conway and Gawronksi, 2013). Hence, by examining if either the deontological or utilitarian PD is associated with vagal tone, we can isolate the precise relationship between cardiac vagal tone and moral decision-making.

Methods

Participants

Sixty-four undergraduate students at Azusa Pacific University (38 women; mean age = 19.4) successfully completed the experiment for partial course credit.[1] All participants were identified as non-smokers and were asked to refrain from alcohol, drug use and caffeinated beverages for 4 h prior to participation (Hansen *et al*., 2003; Park *et al*., 2012a, b). People with a history of neurological or psychiatric disorders, cardiovascular disorders or medical conditions such as diabetes were excluded from this experiment. Participants were of diverse ethnicity: 22.7% Latino(a)/Hispanic, 53% Caucasian/non-Hispanic White, 13.6% Asian/Asian American, 1.5% African American and 6.1% Other.

Procedure

All participants were tested individually in a dimly lit room. Participants were fitted with the chest band. After confirming that inter-beat intervals (IBIs) were being recorded in the watch (which displays beat-to-beat changes in HR), the experimenter moved the watch away from the participant's gaze. A stopwatch was used to time successive 5-min intervals, during which the participant sat and rested quietly in a partially sound isolated room. After the 5-min baseline period, participants were presented with the moral judgment task. In the task, participants read and responded to a series of moral dilemmas. After reading each dilemma, participants were asked to indicate whether the described action would be appropriate or inappropriate. The moral dilemmas and the questions about the appropriateness of the relevant action were presented consecutively on the same screen. Dilemmas were presented in a fixed random order. Then, on the next slide, participants were asked to indicate how difficult it was for them to reach a decision on 5-point scale ranging from 1 (*very easy*) to 5 (*very difficult*). Difficulty perception was measured for each dilemma separately. After the task, participants went through a 5-min recovery period. After the recovery period, participants completed several questionnaires.[2]

We then assessed a series of individual differences used in previous PD research to help validate our approach. We measured religiosity using the Duke University *Religion Index* (DUREL; Koenig *et al*., 1997), which consists of 5 items ($\alpha = 0.88$, $M = 21.61$, s.d. = 4.86). We also measured *empathy* ($\alpha = 0.64$, $M = 27.57$, s.d. = 3.55) and *perspective-taking* ($\alpha = 0.80$, $M = 25.61$, s.d. = 4.39)

1 The behavioral and cardiovascular data from three participants were lost due to equipment failure and a computer error. We excluded three participant whose PD utilitarian score is 0, which is suggested by Conway and Gawronski (2013). According to *G*Power* (Faul *et al*., 2007), the sample size of 64 was proposed to detect medium effects of about $\rho = 0.30$.

2 The questionnaire data from eight participants were lost due to equipment failure and failure to complete questionnaires.

using two subscales of Davis's (1983) interpersonal reactivity index (IRI), and *need for cognition* ($\alpha = 0.69$, $M = 34.23$, s.d. $= 4.91$) and *faith in intuition* ($\alpha = 0.86$, $M = 34.23$, s.d. $= 4.91$) using a short version of Epstein *et al.*'s (1996) rational-experiential inventory. Participants' self-concept as a moral person was measured using the *moral identity internalization* ($\alpha = 0.67$, $M = 48.41$, s.d. $= 18.27$) scale developed by Aquino and Reed (2002). All materials (including a full list of moral dilemmas) are available online at https://osf.io/dvc2h/.

Materials

Moral dilemmas. We adopted a series of moral dilemmas from a previously published set (Conway and Gawronski, 2013). Each dilemma depicted participants as actors who must choose whether or not to take a harmful action to achieve a particular outcome. There were 10 moral dilemmas in total, each of which was presented in both congruent and incongruent versions. In *congruent* dilemmas, the outcomes of harmful actions were described as more harmful than beneficial. In this case, people might consider harmful action as acceptable to prevent the undesired event from occurring, but it cannot be considered unacceptable by either deontological or utilitarian perspectives. In *incongruent* dilemmas, the outcomes of harmful action were described as more beneficial than harmful, thereby directly placing deontological and utilitarian views in conflict.

As can be seen in Figure 1, there are three paths in which moral judgments are delivered: (a) utilitarianism ultimately drives the response, represented by U (top path), (b) deontology ultimately drives the response, represented by D (middle path) and (c) neither utilitarianism, represented by $1 - U$, nor deontology, represented by $1 - D$, drives the response (bottom path). In congruent dilemmas, the probability of making unacceptable responses to harm occurs when both utilitarianism (U) and deontology (D) drive the responses, which is algebraically represented as: (i) $p(\text{unacceptable}|\text{congruent}) = U + [(1 - U) \times D]$. The probability of making acceptable responses occurs when neither utilitarianism ($1 - U$) nor deontology ($1 - D$) drive the responses, which is represented as: (ii) $p(\text{acceptable}|\text{congruent}) = (1 - U) \times (1 - D)$. The same logic applies to the incongruent dilemmas. In incongruent dilemmas, the probability of making unacceptable responses occurs when deontology drives the response and when utilitarianism does not drive the response, which is algebraically represented as: (iii) $p(\text{unacceptable}|\text{incongruent}) = (1 - U) \times D$. The probability of making acceptable responses occurs when utilitarianism drives the response and (b) neither deontology nor utilitarianism drives the response, which is represented as: (iv) $p(\text{acceptable}|\text{incongruent}) = U + [(1 - U) \times (1 - D)]$. Two parameters representing deontology (D) and utilitarianism (U) can be computed using these equations. For example, U can be obtained by subtracting Equation (3) from Equation (1): (5) $U = p(\text{unacceptable}|\text{congruent}) - p(\text{unacceptable}|\text{incongruent})$. D can be computed by: (6) $p(\text{unacceptable}|\text{incongruent})|(1 - U)$. As such, PD algebraically derives two parameters that are independently assessing the strength of deontology and utilitarianism, respectively, based on participants' responses to both congruent and incongruent dilemmas (see Figure 1 for a processing tree; Conway and Gawronski, 2013; Friesdorf *et al.*, 2015).

Physiological measurements

HRV can be measured in several time and frequency methods (Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996). Simple time-domain measures of HRV can be directly derived from the IBI time series and include (i) the standard deviation of the time series, (ii) the square root of the mean of squared successive IBI differences [root mean square successive differences (RMSSD) or mean successive differences (MSD)] and (iii) the percentage of differences between consecutive IBIs that are greater than 50 ms (pNN50). In the frequency domain methods, the HR time series is decomposed into its frequency components, which then can be described in terms of a spectral density function that provides the distribution of power as a function of frequency (Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996; Berntson *et al.*, 1997; Thayer and Friedman, 2004). The high frequency power (HFP) of HRV ranges from 0.15 to 0.4 Hz and is exclusively mediated by the vagus nerves (Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996; Thayer and

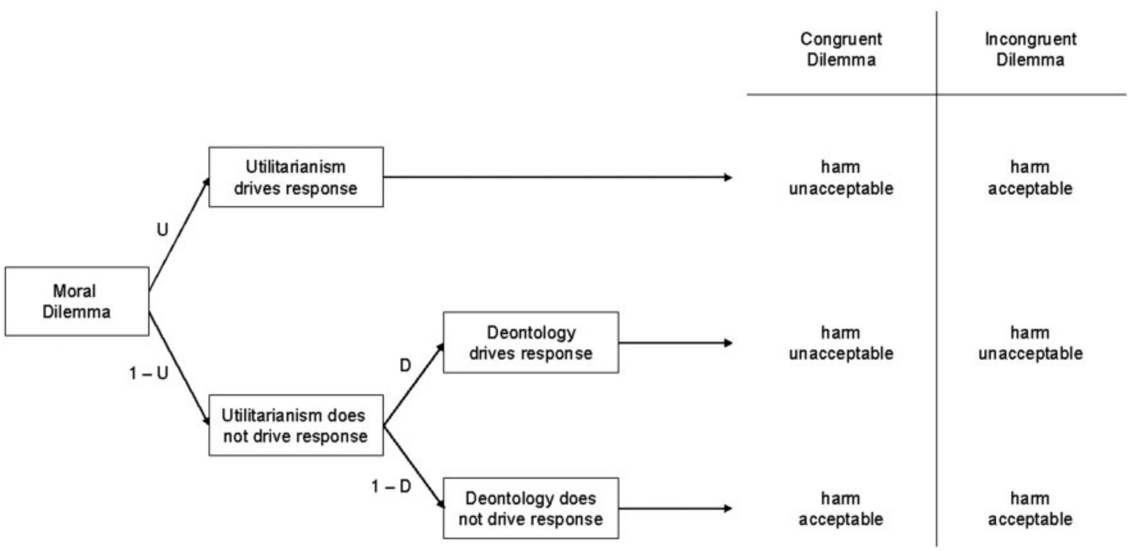

Fig. 1. Processing tree that illustrate the components leading to moral judgments that harmful action is either acceptable or unacceptable in congruent and incongruent moral dilemmas. This figure is taken from Conway and Gawronski (2013; Reproduced with permission of authors and publisher).

Friedman, 2004). The low frequency band ranges from 0.04 to 0.15 and is thought to reflect both sympathetic and vagal modulation on cardiac activity (Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996; Thayer et al., 1996; Berntson *et al.*, 1997; Thayer and Friedman, 2004). High frequency HRV power and RMSSD are considered to effectively quantify vagal activity (Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996; Thayer et al., 1996; Buchheit *et al.*, 2007). In this experiment, to investigate the extent to which visceral and neural systems are integrated in making moral judgment, we used RMSSD as the primary measure of HRV as it is less affected by respiration (Penttila *et al.*, 2001; Park *et al.*, 2013a).

In this research, a Polar RS800cx HR monitor (Polar Electro, Finland; www.polar.fi) was used to record electrocardiographic activity (Park *et al.*, 2012c). The RS800cx is a portable heart rate (HR) monitor tool that is sampled at 1000 Hz, which yields time- and frequency-domain estimates of HRV comparable to those obtained via standard 3- or 12-electrode ECG setups (e.g. Vanderlei et al., 2008; Nunan *et al.*, 2009). In the RS800cx, participants wore an elastic band around the chest, just below the sternum. A sensor was attached to the elastic band that detected R spikes and transmitted an infrared signal to the watch, which recorded the time of each R spike. Successive IBIs (in ms) within the baseline period were written in a single text file and analyzed using the Kubios HRV analysis package 2.0 (http://basmig.uku.fk/biosignal) through which time and frequency domain indices of the heart period power spectrum were computed. The Kubios software provides spectral estimates based upon the more modern autoregressive algorithm that has numerous advantages over the fast Fourier transform-based algorithms (see Thayer *et al.*, 2008). We obtained high frequency HRV power which primarily reflects vagal influences using autoregressive estimates. Time domain indices included estimates of root mean square successive difference in milliseconds (RMSSD) and HR in beats per minute. For spectral analyses, we used autoregressive estimates following the Task Force of the European Society of Cardiology and the North American Society of Pacing Electrophysiology (1996) guidelines.

Results

Manipulation check. We first ensured that participants perceived congruent and incongruent dilemmas differently (Conway and Gawronski, 2013). Replicating previous results, participants judged harmful actions in the incongruent dilemmas ($M = 54.8\%$, s.d. = 17.0) as significantly more acceptable than the congruent dilemmas ($M = 20.5\%$, s.d. = 14.5), $t(63) = 17.06$, $P < 0.01$, $d = 2.17$. Participants further took longer to read and respond to incongruent ($M = 41.8$ s, s.d. = 13.3) than congruent dilemmas ($M = 33.2\%$, s.d. = 14.5), $t(63) = 7.90$, $P < 0.01$, $d = 0.78$, and rated it more difficult to answer incongruent ($M = 3.19$, s.d. = 0.85) than congruent ones ($M = 2.50$, s.d. = 0.82), $t(63) = -8.47$, $P < 0.01$, $d = 0.81$. These analyses validated the distinction between congruent and incongruent dilemmas.

Traditional analysis. Following previous work (Conway and Gawronski, 2013), we calculated the proportion of judging outcome-based actions as inappropriate on incongruent moral dilemmas and obtained traditional scores of deontology *vs* utilitarianism. Higher values indicate stronger deontological tendencies, whereas lower values indicate stronger utilitarian tendencies. The traditional bipolar deontology-utilitarianism index was positively correlated with HRV (RMSSD; $r = 0.24$, $P = 0.054$), indicating that lower HRV was associated with higher utilitarian tendencies.[3]

Table 1. Correlations between traditional bipolar deontology *vs* utilitarianism scores, process dissociation deontology scores, process dissociation utilitarianism scores and individual difference variables

Variable	Traditional score	PD deontology	PD utilitarian	RMSSD (HRV)
Traditional score		0.75*	−0.62*	0.24*
PD deontology	0.75*		0.03	0.02
PD utilitarian	−0.62*	0.03		−0.34*
RMSSD (HRV)	0.24*	0.02	−0.34*	
DUREL (religiosity)	0.20	0.35*	0.04	0.06
Need for cognition	0.31*	0.24	−0.2	0.03
Faith in intuition	−0.02	−0.24	−0.23	0.08
Empathic concern	0.23	0.37*	0.05	−0.18
Perspective-taking	0.13	0.09	−0.12	−0.06
Moral identity internalization	0.05	−0.06	−0.09	0.14

PD, process dissociation; RMSSD, root mean square successive difference in milliseconds; HRV, heart rate variability; DUREL, the Duke University Religion Index.
*$P < 0.05$.

Research also reported that gender is a predictor of moral dilemma judgments (Friesdorf *et al.*, 2015). The relationship between the traditional bipolar deontology-utilitarianism and RMSSD (HRV) was then subjected to a first-order partial correlation in order to explore the relationship controlling for the effect of gender. The first-order correlation was found to be statistically significant for the traditional bipolar deontology-utilitarianism index, $r(61) = 0.27$, $P < 0.03$, indicating that a relationship between HRV and utilitarian tendencies exists after adjusting for the effect of gender (Table 1).

The traditional bipolar deontology-utilitarianism index was also positively correlated with the need for cognition ($r = 0.31$, $P < 0.02$). However, we did not observe a correlation between the deontology-utilitarianism index and any other measures, such as religiosity, faith in intuition, empathetic concern, perspective-taking, and moral identity internalization (P's > 0.16).

PD analysis. To help disentangle the relationship between cardiac vagal tone and moral judgment, we calculated independent estimates of deontology and utilitarianism using PD (Conway and Gawronski, 2013). First, the respective probabilities of rejecting harm in congruent and incongruent dilemmas were calculated for each participant. The utilitarian score was obtained by Equation (5) (see P. 10), which subtracts the probability of rejecting harm in incongruent dilemmas from the probability of rejecting harm in congruent dilemmas. The deontological score was obtained by Equation (6) (see p. 10), which divides the probability of rejecting harm in incongruent dilemmas by the difference between one and utilitarian parameter (1 − utilitarian parameter).

Replicating previous results (Conway and Gawronski, 2013), the deontology parameter was positively correlated with the traditional bipolar index of moral judgment ($r = 0.75$, $P < 0.01$),

3 We also conducted a correlation analysis between the traditional bipolar deontology-utilitarianism index and pNN50, another measure of vagally mediated HRV. Consistent with RMSSD data, the traditional bipolar deontology-utilitarianism index was positively correlated with pNN50 ($r = 0.31$, $P = 0.012$), indicating that lower HRV was associated with higher utilitarian tendencies.

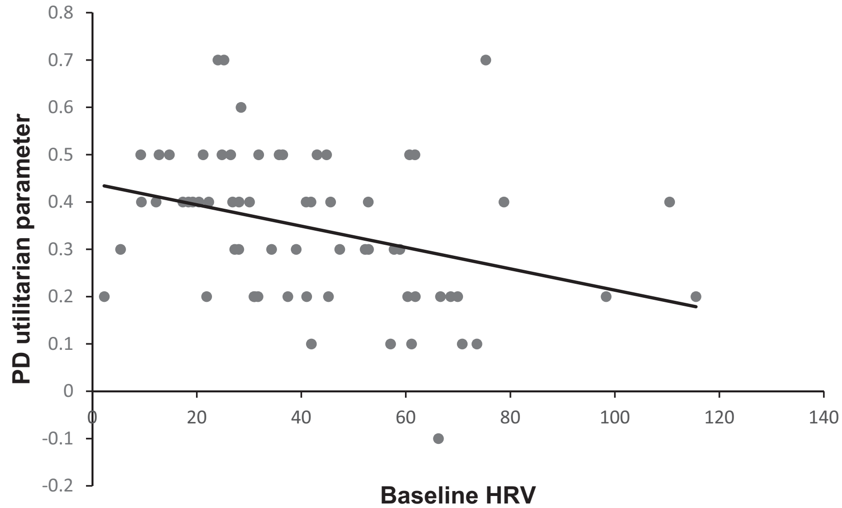

Fig. 2. A scatterplot indicating a negative correlation between heart rate variability (HRV) (x-axis) and the utilitarian parameter derived from process dissociation (PD) (y-axis). $r = -0.34$, $P < 0.01$.

whereas the utilitarian parameter was negatively correlated with the traditional bipolar index ($r = -0.62$, $P < 0.01$). However, the utilitarian and deontological parameters were *not* correlated ($r = 0.03$, $P = 0.83$), suggesting that they should be treated as independent constructs. Also replicating the previous results (Conway and Gawronski, 2013), the deontology parameter was positively correlated with religiosity ($r = 0.35$, $P < 0.01$) and empathetic concern ($r = 0.37$, $P < 0.01$).

We tested the hypothesis that lower resting HRV, which reflects weaker neural and visceral integration, would be associated with strong outcome-based, utilitarian moral judgments. HRV (RMSSD) was indeed negatively correlated with the utilitarian parameter ($r = -0.34$, $P < 0.01$),[4] suggesting that lower cardiac vagal tone is associated with stronger utilitarian tendencies (see Figure 2).

To further analyze the relationship between the PD parameters and the individual difference variables, we conducted linear regression analyses. Confirming the results of the correlation analyses, the utilitarian parameter was associated with HRV, whereas the deontology parameter was associated with religiosity and empathetic concern (see Table 2). However, the deontology parameter was not associated with HRV ($r = 0.02$, $P = 0.90$).[5] In sum, replicating previous results, the traditional bipolar index was positively correlated with deontological and negatively with the utilitarian parameter. More importantly, lower cardiac vagal tone was correlated with stronger utilitarian tendencies, but not deontological tendencies.

Discussion

In the current research, we utilized cardiac vagal tone to evaluate the functional integration of neural and visceral systems involved in moral judgment. We investigated the relationship between cardiac vagal tone and moral judgment using a mix of moral dilemmas, mathematical modeling and psychophysiological measures. We found that lower resting HRV was correlated with stronger outcome-based, utilitarian inclinations, suggesting that strong utilitarian moral judgments are associated with poor neuro-visceral integration. This research provides evidence that cardiac vagal tone may be associated with the integration of visceral responses into moral judgments, potentially via the vmPFC. When people lack the ability to integrate visceral reactions, they might have a tendency to base their moral judgments solely on outcomes, leading to utilitarian responses (Carmona-Perera *et al.*, 2013).

Our results suggest that utilitarian judgments are associated with a lack of neuro-visceral integration. Cardiac vagal tone is a hallmark of the ability of the body to respond to the demands of the situation. In particular, cardiac vagal tone is linked to the ability to regulate the parasympathetic influence on the heart to optimally respond to changes in circumstance by modifying arousal, HR and attention (Porges, 1995). In line with this idea, individuals high in cardiac vagal tone have, for example, better cognitive and autonomic flexibility (Hansen *et al.*, 2003; Park *et al.*, 2013c), higher ability to inhibit dominate responses (Park et al., 2012b; Johnsen *et al.*, 2003), and are better to regulate negative facial expressions (Park *et al.*, 2012a; Quintana *et al.*, 2012). The ability to react adaptively might also underlie the relationship between cardiac vagal tone and positive emotions in daily life and social connectedness (Kok and Fredrickson, 2010). For moral judgments, we find that lower vagal tone is associated with utilitarian tendencies. This suggests that the capacity

Table 2. Results of multiple regression analyses regressing individual difference variables onto process dissociation deontology and process dissociation utilitarianism scores

	PD deontology			PD utilitarian		
Variable	β	t	P	β	t	P
HRV	0.02	0.13	0.90	−0.34	−2.84	0.01
DUREL	0.35	2.74	0.01	0.04	0.32	0.75
Need for cognition	0.24	1.85	0.07	−0.20	−1.51	0.14
Empathic concern	0.37	2.92	0.01	0.05	0.37	0.72

PD, process dissociation; HRV, heart rate variability; DUREL, the Duke University Religion Index.

4 When we used pNN50, a consistent result was found, ($r = -0.43$, $P < 0.01$). The first-order correlation was found to be statistically significant for the PD utilitarian parameter, $r(61) = -0.34$, $P < 0.01$, after adjusting for gender.

5 When we used pNN50, a consistent result was found ($r = 0.03$, $P = 0.85$).

to integrate visceral reactions with the central nervous system might moderate utilitarian tendencies.

Dual process theories of moral judgments argue that utilitarian responses are driven by deliberative reasoning and have been favored to be more rational moral judgments (Greene *et al.*, 2008; see also Feinberg *et al.*, 2012). However, growing research has reported that utilitarian moral judgments are associated with antisocial traits, such as primary psychopathy, rational egoism, and explicit amoral and self-centered judgments (Bartels and Pizarro, 2011; Kahane *et al.*, 2015). Here, we provide additional evidence showing that utilitarian inclinations are associated with lower abilities to integrate visceral responses into moral judgment. Interestingly, it has been reported that people with antisocial and psychopathic traits—who are characterized by deficits in such pro-social traits—have lower cardiac vagal tone (Raine, 1997; Hansen *et al.*, 2007). These findings cast further doubt on whether utilitarian moral judgments in standard dilemmas should be considered the optimal responses to these dilemmas.

Furthermore, there is a growing concern that dominant research in moral psychology may not accurately capture the philosophical view of utilitarianism (Kahane *et al.*, 2015). Utilitarian moral judgments typically observed in hypothetical moral dilemmas—which often reflects one's willingness to harm or sacrifice few individuals in an attempt to save more people—may not correspond to the philosophical view of utilitarianism—which highlights an impartial concern for the greater good (Kahane *et al.*, 2015). In fact, recent research has failed to find the direct relationship between utilitarian judgments in the hypothetical moral dilemmas and a wide range of traits, attitudes, judgment and behaviors that reflect an impartial concern for the greater good (Kahane *et al.*, 2015). This new emerging perspective calls for further research to understand the nature of the relationship between cardiac vagal tone and strong utilitarian tendencies defined by a philosophical view—that is an impartial concern for the greater good.

Previous research often characterized deontological responses as lacking flexibility (Greene, 2008). In line with this research, we predicted that deontological moral judgments are largely dependent on visceral responses, which do not require neuro-visceral integration. And indeed we did not find any relationship between cardiac vagal tone and deontological judgments. Deontological judgments may be better associated with physiological indicators sensitive to sympathetic nervous systems, such as vasoconstriction/total peripheral resistance or skin conductance (Mendes *et al.*, 2007), which then lead directly to action-based moral judgments.

Conclusion

The current research provides initial evidence that low cardiac vagal tone is related to outcome-based, utilitarian judgments. The results suggest that neuro-visceral integration may be an important element of moral judgments. Outcome-based judgments seem to involve the integration of visceral reactions into their moral judgments in conjunction with pre-frontal regions. This form of integration might help individuals move beyond simple outcome-based, utilitarian judgments.

Authors' contributions

G.P. designed the experiments with input from J.V.B. and G.P. collected data, analyzed the data with input from Y.R. and J.V.B., respectively, and G.P. wrote the manuscript with critical edits from A.K., Y.R. and J.V.B.

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