LETTERS

Damage to the prefrontal cortex increases utilitarian moral judgements

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The psychological and neurobiological processes underlying moral judgement have been the focus of many recent empirical studies[1–11]. Of central interest is whether emotions play a causal role in moral judgement, and, in parallel, how emotion-related areas of the brain contribute to moral judgement. Here we show that six patients with focal bilateral damage to the ventromedial prefrontal cortex (VMPC), a brain region necessary for the normal generation of emotions and, in particular, social emotions[12–14], produce an abnormally 'utilitarian' pattern of judgements on moral dilemmas that pit compelling considerations of aggregate welfare against highly emotionally aversive behaviours (for example, having to sacrifice one person's life to save a number of other lives)[7,8]. In contrast, the VMPC patients' judgements were normal in other classes of moral dilemmas. These findings indicate that, for a selective set of moral dilemmas, the VMPC is critical for normal judgements of right and wrong. The findings support a necessary role for emotion in the generation of those judgements.

The basis of our moral judgements has been a long-standing focus of philosophical inquiry and, more recently, active empirical investigation. In a departure from traditional rationalist approaches to moral cognition that emphasize the role of conscious reasoning from explicit principles[15], modern accounts have proposed that emotional processes, conscious or unconscious, may also play an important role[16,17]. Emotion-based accounts draw support from multiple lines of empirical work: studies of clinical populations reveal an association between impaired emotional processing and disturbances in moral behaviour[1–4]; neuroimaging studies consistently show that tasks involving moral judgement activate brain areas known to process emotions[5–9]; and behavioural studies demonstrate that manipulation of affective state can alter moral judgements[10,11]. However, neuroimaging studies do not settle whether putatively 'emotional' activations are a cause or consequence of moral judgement; behavioural studies in healthy individuals do not address the neural basis of moral judgement; and no clinical studies have specifically examined the moral judgements (as opposed to moral reasoning or moral behaviour) of patients with focal brain lesions. In brief, none of the existing studies establishes that brain areas integral to emotional processes are necessary for the generation of normal moral judgements. As a result, there remains a critical gap in the evidence relating moral judgement, emotion and the brain.

Investigating moral judgements in individuals with focal damage to the ventromedial prefrontal cortex (VMPC) provides a key test. The VMPC projects to basal forebrain and brainstem regions that execute bodily components of emotional responses[18], and neurons within the VMPC encode the emotional value of sensory stimuli[19]. Patients with VMPC lesions exhibit generally diminished emotional responsivity and markedly reduced social emotions (for example, compassion, shame and guilt) that are closely associated with moral values[1,2,12–14,16], and also exhibit poorly regulated anger and frustration tolerance in certain circumstances[20,21]. Despite these patent defects both in emotional response and emotion regulation, the capacities for general intelligence, logical reasoning, and declarative knowledge of social and moral norms are preserved[20–23]. We selected a sample of six patients with adult-onset, focal bilateral VMPC lesions (Fig. 1) as well as both neurologically normal (NC) and brain-damaged comparison (BDC) subjects. Importantly, each of the VMPC patients had striking defects in social emotion but generally intact intellect and normal baseline mood (Tables 1 and 2, see also Supplementary Table 1). In particular, all six VMPC patients had impaired autonomic activity in response to emotionally charged pictures (Table 2), as well as severely diminished empathy, embarrassment and guilt (Table 2). All comparison subjects (NC and BDC) had intact emotional processing.

Subjects evaluated moral dilemmas designed to pit two competing considerations against one another. A paradigmatic dilemma of this type presents subjects with the choice of whether or not to sacrifice one person's life to save the lives of others. One consideration is a utilitarian calculation of how to maximize aggregate welfare, whereas the other is a strong emotional aversion to the proposed action. One model holds that endorsement of the proposed action (the utilitarian response) requires the subject to overcome an emotional response against inflicting direct harm to another person (a 'personal' harm[7,8]). If emotional responses mediated by VMPC are indeed a critical influence on moral judgement, individuals with VMPC lesions should exhibit an abnormally high rate of utilitarian judgements on the emotionally salient, or 'personal', moral scenarios (for example, pushing one person off a bridge to stop a runaway boxcar from hitting five people), but a normal pattern of judgements on the less emotional, or 'impersonal', moral scenarios (for example, turning a runaway boxcar away from five people but towards one person). If, alternatively, emotion does not play a causal role in the generation of moral judgements but instead follows from the judgements[24,25], then individuals with emotion defects due to VMPC lesions should show a normal pattern of judgements on all scenarios.

To test for between-group differences in the probability of utilitarian responses given for each scenario type (non-moral, impersonal moral, personal moral), we used a logistic regression fitted with the generalized estimating equations method (Fig. 2). There were no significant differences between groups on the non-moral or impersonal moral scenarios (all P values >0.29, corrected for multiple

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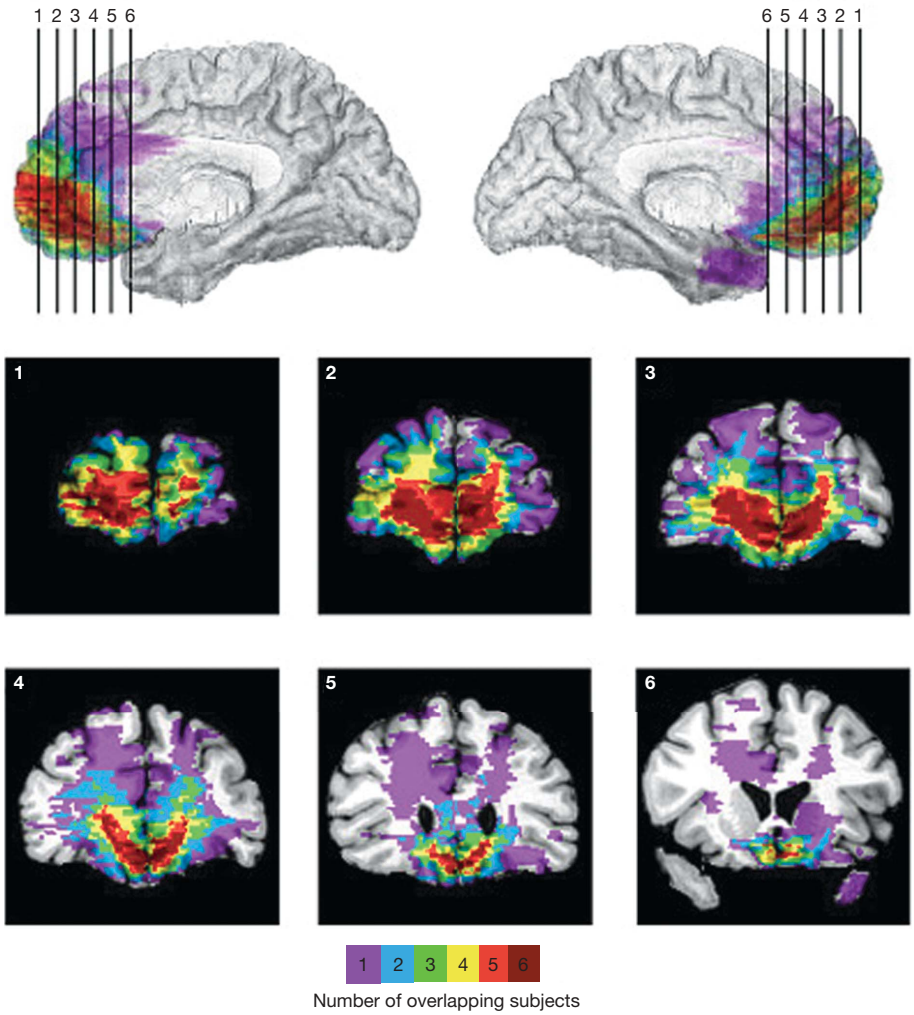

Figure 1 | Lesion overlap of VMPC patients. Lesions of the six VMPC patients displayed in mesial views and coronal slices. The colour bar indicates the number of overlapping lesions at each voxel.

comparisons). In contrast, for personal moral scenarios, the VMPC group was more likely to endorse the proposed action than either the NC group (odds ratio = 2.81; $P = 0.04$, corrected) or BDC group (odds ratio = 3.30; $P = 0.006$, corrected). There was no difference between the NC and BDC groups (odds ratio = 0.85; $P = 0.68$, uncorrected). These data indicate that the VMPC group's responses differed only for personal moral scenarios, suggesting that VMPC-mediated processes affect only those moral judgements involving emotionally salient actions.

In a more fine-grained analysis, we examined response patterns within the personal moral scenarios. For seven out of the 21 personal moral scenarios, both comparison groups were at 100% agreement in their judgements. An additional eighth scenario elicited 100% agreement from the BDC group, and near-perfect agreement from the NC group (with only one participant deviating from the shared response). These eight scenarios were therefore classified as 'low-conflict' (for example, abandoning one's baby to avoid the burden of caring for it). The remaining 13 scenarios (none of which elicited 100% agreement from either comparison group) were classified as 'high-conflict' (for example, smothering one's baby to save a number

Table 1 | VMPC patient neuropsychological data

Subject	WAIS-III			WMS-III		TT	WCST	Stroop	BDI
	VIQ	PIQ	FSIQ	GMI	WMI				
1	142	134	143	109	124	44	6	70	0
2	89	97	91	59	102	44	6	49	3
3	111	96	104	74	105	44	6	67	10
4	108	102	106	109	124	44	6	57	1
5	110	107	109	105	102	44	6	54	8
6	89	80	84	96	88	44	0	77	7

WAIS-III, Wechsler Adult Intelligence Scale-III scores (VIQ, verbal IQ; PIQ, performance IQ; FSIQ, full-scale IQ). WMS-III, Wechsler Memory Scale-III scores (GMI, general memory index; WMI, working memory index). TT, Token Test (from the Multilingual Aphasia Examination), a measure of basic verbal comprehension. WCST, Wisconsin Card Sort Test categories, a measure of executive function. Stroop, *T*-score on the Interference trial of the Stroop Colour-Word Test, a measure of response inhibition. BDI, Beck Depression Inventory, a measure of baseline mood. All patients were within normal ranges except for subjects 2 and 3 on GMI and subject 6 on WCST and Stroop.

Table 2 | VMPC patient social emotion data

Subject	SCRs	Empathy	Embarrassment	Guilt
1	Impaired	3	3	3
2	Impaired	3	3	3
3	Impaired	3	3	3
4	Impaired	2	2	1
5	Impaired	3	3	3
6	Impaired	3	3	3

SCRs, skin conductance responses to emotionally charged socially significant stimuli (for example, pictures of social disasters, mutilations, nudes), using methods previously described[12]. The same SCR experiment was performed in ten of twelve BDC patients, and all ten demonstrated normal SCRs to emotionally charged pictures. A clinical neuropsychologist blind to the hypotheses of the current study rated each VMPC patient's demonstrated capacity for empathy, embarrassment and guilt in his or her personal life. The rating used a four-point scale denoting severity of impairment, where 0 = normal, 1 = mild, 2 = moderate and 3 = severe. Ratings were based on data derived from spouse or family member reports in the Iowa Rating Scales of Personality Change[29] and from data from clinical interviews. Both of these sources provide direct observations about the patient's basic and social emotions, and include questions about whether the patient experiences and manifests emotions such as sadness, anxiety, empathy, embarrassment and guilt.

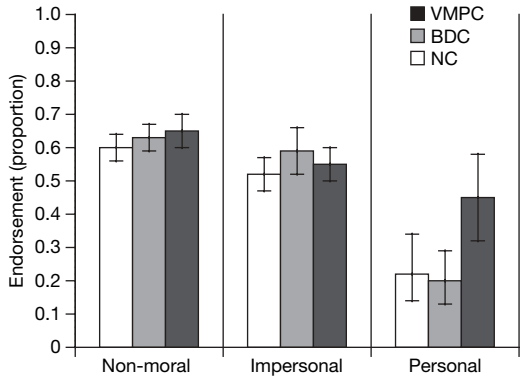

Figure 2 | Moral judgements for each scenario type. Proportions of 'yes' judgements are shown for each subject group. Error bars indicate 95% confidence intervals. We used three classes of stimuli: non-moral scenarios ($n = 18$), impersonal moral scenarios ($n = 11$), and personal moral scenarios ($n = 21$). On personal moral scenarios, the frequency of endorsing 'yes' responses was significantly greater in the VMPC group than in either comparison group (P values < 0.05, corrected).

of people). Reaction-time data support this distinction: response latencies in the NC group on high-conflict scenarios were significantly longer than on low-conflict scenarios (t-test with 19 degrees of freedom, $t(19) = -3.63$; $P = 0.002$).

Like the patients in the comparison groups, the VMPC patients uniformly rejected the proposed action in every one of the low-conflict scenarios (Fig. 3). In contrast, significant differences emerged for the high-conflict scenarios: the VMPC group was more likely to endorse the proposed action than either the NC (odds ratio = 4.70; $P = 0.05$, corrected) or BDC group (odds ratio = 5.38; $P = 0.02$, corrected), with no difference between the NC and BDC participants (odds ratio = 0.87; $P = 0.77$, uncorrected). Every high-conflict personal scenario elicited the same pattern: a greater proportion of the VMPC group endorsed the action than either comparison group.

To recapitulate, VMPC patients' judgements differed from comparison subjects' only for the high-conflict personal moral dilemmas, all of which featured competing considerations of aggregate welfare on the one hand, and, on the other hand, harm to others that would normally evoke a strong social emotion. Low-conflict personal moral scenarios lacked this degree of competition. This difference probably

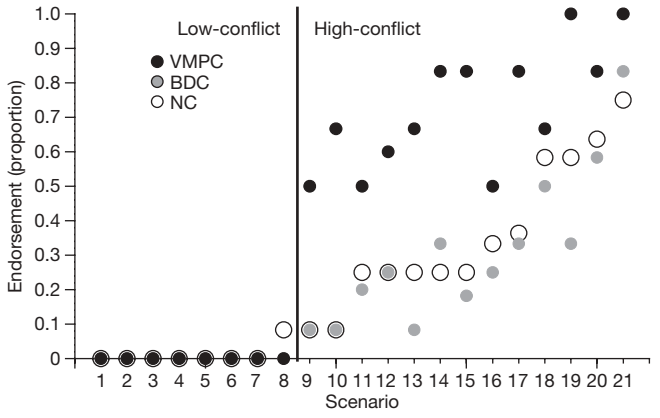

Figure 3 | Moral judgements on individual personal moral scenarios. Proportions of 'yes' judgements given by each subject group for each of the 21 personal moral scenarios. Individual scenarios (numbered 1–21 on the x axis) are ordered by increasing proportion of 'yes' responses given by the normal comparison group. Responses did not differ between subject groups for the low-conflict scenarios (left of the vertical line). The VMPC group made a greater proportion of 'yes' judgements than either comparison group for every one of the high-conflict scenarios (right of the vertical line).

accounts for the greater consensus and faster reaction times on low-conflict personal dilemmas in the comparison groups, and it can also account for the VMPC patients' pattern of judgements. Evidence suggests that knowledge of explicit social and moral norms is intact in individuals with VMPC damage[21,22]. In the absence of an emotional reaction to harm of others in personal moral dilemmas, VMPC patients may rely on explicit norms endorsing the maximization of aggregate welfare and prohibiting the harming of others. This strategy would lead VMPC patients to a normal pattern of judgements on low-conflict personal dilemmas but an abnormal pattern of judgements on high-conflict personal dilemmas, precisely as was observed. The specificity of this result argues against a general deficit in the capacity for moral judgement following VMPC damage. Rather, VMPC seems to be critical only for moral dilemmas in which social emotions play a pivotal role in resolving moral conflict[4,8,16,17].

It is important to note that the effects of VMPC damage on emotion processing depend on context. In this study, the VMPC patients' abnormally high rate of utilitarian judgements is attributed to diminished social emotion, whereas in a recent study of the Ultimatum Game, theVMPC patients' abnormally high rate of rejection of unfair monetary offers was attributed to poorly controlled frustration, manifested as exaggerated anger[20]. These seemingly contradictory findings highlight two distinct aspects of emotion impairment that are due to VMPC damage. In most circumstances, VMPC patients exhibit generally blunted affect and a specific defect of social emotions, but in response to direct personal frustration or provocation, VMPC patients may exhibit short-temper, irritability, and anger. In the moral judgement task we report here, participants respond to hypothetical actions and outcomes that elicit social emotions related to concern for others. In the Ultimatum Game, in contrast, participants respond to unfair take-it-or-leave-it offers that trigger frustration. In brief, the tasks in the two studies are different in that the Ultimatum Game involves self-interest in a real behavioural setting, whereas the task in the present study focuses on the interest of others described in a hypothetical scenario.

To conclude, the present findings are consistent with a model in which a combination of intuitive/affective and conscious/rational mechanisms operate to produce moral judgements[8,22,24–27]. Though the precise characterization of these potential systems awaits further work, the current results suggest that the VMPC is a critical neural substrate for the intuitive/affective but not for the conscious/rational system.

METHODS

Subjects. Six patients with bilateral, adult-onset damage to the VMPC and twelve brain-damaged comparison patients who had lesions that excluded structures thought to be important for emotions (VMPC, amygdala, insula, right somatosensory cortices) were recruited from the Patient Registry of the Division of Cognitive Neuroscience at the University of Iowa. Twelve healthy comparison subjects with no brain damage were recruited from the Iowa community. Groups were age-, gender- and ethnicity-matched. All participants gave written informed consent.

Neuroanatomical analysis. The neuroanatomical analysis of VMPC patients (Fig. 1) was based on magnetic resonance data for two subjects (those with lesions due to the surgical resection of orbital meningiomas) and on computerized tomography data for the other four subjects (with lesions due to rupture of an anterior communicating artery aneurysm). All neuroimaging data were obtained in the chronic epoch. Each patient's lesion was reconstructed in three dimensions using Brainvox[28]. Using the MAP-3 technique, the lesion contour for each patient was manually warped into a normal template brain. The overlap of lesions in this volume, calculated by the sum of n lesions overlapping on any single voxel, is colour-coded in Fig. 1.

Stimuli and task. Participants made judgements on a series of 50 hypothetical scenarios, which were adapted from a previously published set[8]. See the Supplementary Information for the full text of the actual scenarios used. Each scenario was presented as text through a series of three screens. The first two described the scenario and the third posed a question about a hypothetical action related to the scenario ("Would you … in order to …?"). Participants read and responded at their own pace, pressing an 'up' arrow key to advance from one

screen to the next, and a 'yes' or 'no' button to indicate an answer to the question. 'Yes' responses always indicated commission of the proposed action. There was no time limit for reading the scenario description (screens 1 and 2). Participants had a maximum of 25 s to read the final question screen and respond.

We used three classes of stimuli: non-moral scenarios ($n = 18$), and two classes of moral scenarios subdivided according to the emotional reaction elicited by the proposed action: 'personal' ($n = 21$) or 'impersonal' ($n = 11$), as described previously[7,8]. To validate this subdivision, an independent group of ten neurologically normal subjects rated the emotional salience of the actions proposed in the moral scenarios. The actions described in personal scenarios were rated as significantly more emotionally salient than the actions described in impersonal scenarios (means were 5.9 and 3.0 on a scale from 1 to 7, respectively; $t(31) = -8.90$, $P < 0.0001$). Within either class of moral scenarios (personal or impersonal), it was not valid to separately analyse judgements based on the emotional salience of the proposed action (that is 'high-emotion' versus 'low-emotion' scenarios) because emotionality ratings were remarkably similar for scenarios within each class: 9 of the 11 impersonal scenarios received a mean emotion rating between 1.1 and 3.0, while 20 of the 21 personal scenarios received a mean emotion rating between 5.3 and 6.7.

We further subdivided the personal moral scenarios into 'low-conflict' and 'high-conflict' on the basis of the reaction times and consensus produced on them by normal subjects. Reaction times on high-conflict scenarios were significantly longer than on low-conflict scenarios ($t(19) = -3.63$, $P = 0.002$). Importantly, low-conflict and high-conflict scenarios did not differ in their rated emotional salience ($t(19) = -0.85$, $P = 0.41$).

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Supplementary Information is linked to the online version of the paper at www.nature.com/nature.

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Do abnormal responses show utilitarian bias?

Arising from: M. Koenigs *et al.* *Nature* 446, 908–911 (2007)

Neuroscience has recently turned to the study of utilitarian and non-utilitarian moral judgement. Koenigs *et al.*[1] examine the responses of normal subjects and those with ventromedial–prefrontal–cortex (VMPC) damage to moral scenarios drawn from functional magnetic resonance imaging studies by Greene *et al.*[2–4], and claim that patients with VMPC damage have an abnormally ''utilitarian'' pattern of moral judgement. It is crucial to the claims of Koenigs *et al.* that the scenarios of Greene *et al.* pose a conflict between utilitarian consequence and duty: however, many of them do not meet this condition. Because of this methodological problem, it is too early to claim that VMPC patients have a utilitarian bias.

Greene *et al.* reported that brain areas typically associated with affect are activated when subjects make moral judgements about 'personal' scenarios, where one alternative requires directly causing serious harm to persons. They found that in the minority, who judge such choices to be appropriate, areas associated with cognition and cognitive conflict are activated as well. On the basis of a later study reporting similar results in responses to 'difficult' personal scenarios, Greene suggested that the controversies between utilitarian and non-utilitarian views of morality ''might reflect an underlying tension between competing subsystems in the brain''[4], a claim taken up by leading ethicists[5].

Koenigs *et al.* draw on the battery of moral scenarios of Greene *et al.* to compare normal subjects with six subjects who have focal bilateral damage to the VMPC, a brain region associated with the normal generation of emotions and, in particular, social emotions. They report that these patients ''produce an abnormally 'utilitarian' pattern of judgements on [personal] moral dilemmas… In contrast, the VMPC patients' judgements were normal in other classes of moral dilemmas''[1]. These claims are based on VMPC patients' pattern of response to 'high-conflict' scenarios, a subset of personal scenarios on which normal subjects tended to disagree and that elicited greater response times.

However, the methodology used by Koenigs *et al.* cannot support claims about a utilitarian bias. Data from the categorization of the scenarios by five professional moral philosophers show that many are not of the required type. Only 45% of their impersonal scenarios and 48% of the personal ones were classified as involving a choice between utilitarian and non-utilitarian options. The distinction by Koenigs *et al.* between low- and high-conflict scenarios does not correspond to a difference in the scenarios' content. The high-conflict scenarios are not all clear cases of utilitarian choice and some low-conflict ones are very clear cases of such choice: of the 13 high-conflict scenarios, our judges classified only eight as pure cases of utilitarian versus non-utilitarian choice; conversely, two low-conflict scenarios were classified as such.

The battery of personal scenarios is therefore not an adequate measure of utilitarian choice, and the distinction between low and high conflict reflects only a difference in behavioural response, rather than consistent differences in the content of the scenarios. Thus it is too early to claim that VMPC patients have a bias towards utilitarian judgement. Furthermore, whereas Koenigs *et al.* found that normal subjects rated personal scenarios as having significantly higher emotional salience than impersonal scenarios, they found no such significant difference between low- and high-conflict scenarios. So their proposal that an affective deficit explains the VMPC patients' abnormal pattern of response to high-conflict scenarios is not clearly true. Similarly, it is unclear that this pattern of response is due to VMPC patients following ''explicit social and moral norms''[1], as their choices in high-conflict scenarios are contrary to familiar social norms to prevent harm.

In conclusion, to establish that a response pattern manifests a tendency to utilitarian moral judgement, the stimuli used need to be classified in terms of content and not by purely behavioural or emotional criteria as was done here and in other studies such as those of Greene *et al.*[2,4,6].

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Koenigs et al. *reply*

Replying to: G. Kahane & N. Shackel *Nature* 452, doi:10.1038/06785 (2008)

Kahane and Shackel argue[1], on the basis of a re-classification of the moral scenarios used in our study[2], that our conclusion of a utilitarian bias among patients with ventromedial–prefrontal–cortex (VMPC) damage is unwarranted. Here we provide a re-analysis of our data based on precisely the classification scheme that Kahane and Shackel suggest. This re-analysis confirms our conclusion that damage to the VMPC results in an increase in utilitarian judgements.

Kahane and Shackel propose a classification scheme based solely on assessments of the scenario content. They suggest that utilitarian responses pertain only to those scenarios that pit ''consequences'' versus ''duty.'' We neither endorse nor disagree with this view; both their and our classification schemes are defensible.

In a re-analysis of our original data on the basis of the classification scheme suggested by Kahane and Shackel, we find that VMPC

patients generated the "utilitarian" judgement (as defined by Kahane and Shackel) in a substantially greater proportion than did either control group (71% by the VMPC group compared to 51% and 49% by the healthy and brain-damaged control groups, respectively; multinomial logistic regression, $P = 0.012$). Furthermore, among the 15 scenarios that present a utilitarian option, there was not one case where either control group endorsed a greater proportion of "utilitarian" responses than the VMPC group. We should note that this pattern of greater endorsement by the VMPC group was specific to the "consequence versus duty" scenarios: for the 9 "self-interest versus duty" moral scenarios in Kahane and Shackel's scheme, VMPC patients endorsed the proposed action in similar proportions to control groups (6% by the VMPC group compared to 2% and 10% by the healthy and brain-damaged control groups, respectively; $P = 0.31$). Likewise, in all 9 of the "self-interest versus duty" scenarios in Kahane and Shackel's scheme, at least one control group endorsed the proposed action in the same or greater proportion than did the VMPC group.

Kahane and Shackel also suggest that our results fail to demonstrate a causal role for emotion in moral judgements, because low- and high-conflict scenarios do not differ in emotional salience yet show differential effects of VMPC damage on moral judgements. Although the harms described in low- and high-conflict scenarios may be similarly emotionally salient, we reiterate that only in the high-conflict scenarios do these emotionally salient harms constitute morally ambiguous actions—in the low-conflict scenarios the emotionally aversive harms are quickly and unanimously condemned. In these scenarios, VMPC patients give normal responses, relying, we propose, on their capacity to use learned social rules, such as rules against harming others purely for self-interest.

This pattern of findings, together with VMPC patients' defects in processing social emotions, makes a causal role for emotion in moral judgement a plausible interpretation. This interpretation is consistent with studies showing that independent manipulations of emotion can influence moral judgement[3,4]. Furthermore, the main result from our original study (a selective effect of VMPC damage on moral judgement) has recently been replicated[5]. A final piece of data that is so far missing is concurrent monitoring of psychophysiological indices of emotion while subjects respond to moral scenarios, a technically challenging approach given the complex and temporally extended nature of the stimuli.

In summary, the re-analysis supports our original conclusion that VMPC patients are abnormally utilitarian in their moral judgement, regardless of how "utilitarian" is defined. Although we disagree with Kahane and Shackel about the conclusions of our original study, we certainly share the view that precise characterizations of distinct brands of moral judgement will prove fruitful in future studies of normal and pathological moral cognition[6–8].

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