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**The Neural Foundation of Moral Decision-Making: an
fMRI Investigation**

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1. Abstract & Deutsche Zusammenfassung

1.1. Abstract

The nature of moral judgments has received considerable attention not only in philosophy and psychology but lately in neuroscience as well. There are two major paradigms that consider moral judgments either mainly rational, or as emotional-/ intuition-based processes. Relatively recent neuroimaging studies revealed however that both rational and emotional processes may support moral judgments. In line with these results, this doctoral thesis focused on ways that could better elucidate the supporting cognitive and/ or emotional processes of moral judgments. In a first study, moral judgments were compared to esthetic judgments by employing a whole-brain analysis. This idea was based on the philosophical and the psychological frameworks of moral sense theory and social intuitionist model respectively. Both models view moral judgments akin to esthetic judgments, as decision-making processes based on emotions/ subjective feelings. The fMRI data suggest a common denominator between the judgment modalities - a network involved in both cognitive and emotion processing. However, moral judgments seem to rely on an additional social component. In a second fMRI study, the two main paradigms of moral research were investigated. A main difference between the paradigms is the perspective the participants have towards the moral stimuli (i.e. first- or third-perspective). The fMRI data revealed that neural differences may emerge, and that they may be related to the so-called “actor-observer bias”, a tendency to attribute one’s own behavior to the situation, and the behaviors of others to their inner characteristics. Several hypotheses are put forth, which try to explain the complex neural mechanisms of moral decision-making.

1.2. Deutsche Zusammenfassung

Die Natur moralischer Urteile hat nicht nur in der Philosophie und Psychologie, sondern neuerdings auch in den Neurowissenschaften beträchtliche Aufmerksamkeit erhalten. Es gibt zwei Haupt-Paradigmen, die moralische Urteile entweder als vorwiegend rationale, oder als emotionale und auf Intuition basierende Prozesse betrachten. Bildgebende Studien haben jedoch gezeigt, dass moralische Urteile sowohl durch rationale als auch durch emotionale Prozesse beschrieben werden können. Auf diesen Befunden aufbauend ist die vorliegende Doktorarbeit einer vertiefenden Untersuchung der zugrundeliegenden neuro-kognitiven und emotionalen Prozesse moralischer Urteile gewidmet. In einer ersten Studie wurden moralische und ästhetische Urteile durch den Einsatz einer „*whole brain*“ Analyse verglichen. Dieser Idee liegen philosophische und psychologische Hypothesen der „Moral Sense Theorie“ und dem „Social Intuitionist Model“ zu Grunde. Die fMRT-Daten legen einen gemeinsamen Nenner der beiden Urteilsarten nahe; es konnte ein Netzwerk identifiziert werden, das sowohl für kognitive und als auch für emotionale Verarbeitung zuständig ist. Bei moralischen Urteilen werden allerdings weitere neuronale Areale kooptiert, die eine soziale Komponente des Urteilens repräsentieren. In einer zweiten fMRT-Studie wurden zentrale Paradigmen der moralischen Forschung untersucht. Ein Hauptunterschied zwischen den Paradigmen ist die Perspektive der Teilnehmer auf die moralischen Stimuli (d.h. der ersten oder dritten Perspektive). Die fMRT-Daten legen nahe, dass Unterschiede in neuronalen Aktivierungen auf den sogenannten „Actor-Observer-Bias“ zurückgeführt werden können. Dieser Bias stellt eine Tendenz dar, das eigene Verhalten jeweils der äußeren Situation zuzuschreiben, und das Verhalten der anderen jeweils deren persönlichen Merkmalen. Auf der Grundlage neuro-kognitiver und psychologischer Hypothesen werden die komplexen neuronalen Mechanismen der moralischen Entscheidungsfindung zu erklären versucht.

2. Theoretical foundation

2.1. Moral judgments in neuroscience

The debate about the nature of moral judgments began in philosophy, reaching climax with David Hume and Immanuel Kant (Zangwill, 2010). One of the promoters of moral sense theory, David Hume, regarded moral and esthetic judgments to be similar in nature, and defined them as subjective evaluations relying on feelings of pleasure or displeasure (Haidt, 2001). Immanuel Kant on the other hand, although accepting Hume's view on esthetic judgments, promoted a pure rational notion of morality (e.g. categorical imperative). Thus the question followed whether moral judgments were emotion or reason-based? The rational view on morality was further promoted in psychology, mainly through Kohlberg's work, based on Piaget's model of cognitive development (Kohlberg, 1963). This rationalist approach dominated up to the development of the social intuitionist model (SIM). SIM is based on moral sense theory, in which moral judgments are defined as intuitive evaluations of actions or character (good or bad), regarding the values or virtues held by a culture or subculture (Haidt, 2001). The two approaches influenced not only theories in philosophy and psychology, but also the way in which researchers designed and planned their experiments (Haidt, 2001; Monin, Pizarro, & Beer, 2007). In other words, different types of stimuli were used according to the researchers' approach. Thus, there are two issues, which could be clarified by the employment of neuroscientific measuring techniques (neuroimaging – e.g. fMRI): (1) does the brain differentiate between esthetic and moral judgments, and what sort of structures are involved in moral decision-making processes – structures related to higher cognitive functions or emotional processes, or both? (2) The two major paradigms of research in moral judgment (rationalist versus emotionalist) use different stimuli in their experiments, is it possible that these approaches lead to different results?

2.1.1. Esthetic and moral judgments: a common denominator

There are several plausible arguments that suggest that esthetic and moral judgments are similar in nature. First, they are considered value judgments (Came, 2012), where each value can be either positive or negative: beauty and ugliness, and rightness and wrongness. Second, both judgment modalities seem to rely on common cognitive processes: cognitive control, reward-seeking behavior, representation of actions and sensory imagery (Cupchik, Vartanian, Crawley, & Mikulis, 2009; J. D. Greene, Sommerville, Nystrom, Darley, & Cohen, 2001). Third, in some cases it is difficult to differentiate between the two, since certain aspects of esthetic assessment allow moral evaluation (moral assessment of works of art) and vice versa (esthetic judgments of moral conduct or character). Nevertheless, certain aspects separate the two: on the one hand, esthetic judgments require a direct confrontation with the evaluated object/ situation, demand no consistency, and are intrinsic; on the other hand, moral judgments often involve other people and/ or action, imply a ranking of alternatives, and are more preferential (Came, 2012; Carritt, 1955).

Both esthetic and moral judgments have elicited strong research interest in neuroscience, however almost all studies consider them separately (J. Greene & Haidt, 2002; Jacobsen, Schubotz, Hofel, & Cramon, 2006). Only a few number of papers connected the two judgment modalities (Tsukiura & Cabeza, 2011; Zaidel & Nadal, 2011).

A psychological process that supports both esthetic and moral evaluation seems possible, although unclear. Relatively recent neuroscientific findings strengthen the hypothesis that these evaluations may rely on similar neural foundations (J. D. Greene et al., 2001). A number of brain regions involved in the processing of beauty and morality have been identified (Tsukiura & Cabeza, 2011; Zaidel & Nadal, 2011). Furthermore, the neural correlates found by most studies on morality, revealed the involvement of both cognitive and emotional networks (J. D. Greene et al., 2001; Moll, de Oliveira-Souza, Bramati, & Grafman,

2002; Moll, Zahn, de Oliveira-Souza, Krueger, & Grafman, 2005). Thus, both esthetic and moral judgments may rely on networks supporting both cognitive and emotional processes.

2.1.2. Perspectives in moral research

As mentioned earlier, there are two major approaches in moral research, related to how the nature of morality is defined: emotional/ intuitive or rational. Monin and colleagues (2007) provide a summary of the way in which the approaches may influence experimental paradigms. First, the “rationalists” use moral dilemmas to study moral judgments, while the “emotionalists” use strong emotionally laden statements or pictures (moral reactions). Second, the psychological processes involved may be different: the focus of moral dilemmas is on the decision making process - a conflict between two moral principles, whereas moral reactions focus on the emotional reactions of the subjects. Third, moral dilemmas are typically presented in a first person perspective (1PP), while moral reactions are presented in a third-person perspective (3PP). The perspectives alone (1PP versus 3PP) seem to be supported by different brain structures, at least in non-moral contexts. For instance, different neural activations were observed for stimuli presented in either 1- or 3PP in *non-moral visuospatial tasks* (Vogel & Fink, 2003). Furthermore, differences have also been found in *social non-moral tasks* or Theory of Mind – ToM - (Ames, Jenkins, Banaji, & Mitchell, 2008; Ochsner et al., 2004; Otsuka, Osaka, Yaoi, & Osaka, 2011).

Additionally, different psychological and neural processes may support the decider’s perspective alone (1PP/ 3PP). In this sense, studies in social psychology have repeatedly shown that in *negative situations* there is a tendency to attribute one's own actions (1PP) to external causes, while attributing other people's (3PP) behaviors to internal ones, the so-called "actor-observer bias" (Jones & Nisbett, 1971; Nadelhoffer & Feltz, 2008). This bias may present itself as a crucial issue in moral research, since moral studies generally use

negative situations (Takahashi et al., 2008). Thus, the nature of moral judgment may not only be very complex and somewhat covert to our research methods, but our own paradigms of study may in fact alter the findings.

2.2. Experimental findings

2.2.1. Neural correlates of esthetic judgments

Although fMRI methodology has helped us separate even very close-related judgment types such as beauty and symmetry (Jacobsen et al., 2006), the neuroscientific literature on esthetics seems to be defined by lack of consistency - in other words the results appear to be quite heterogeneous. This may be linked to the subjective nature of esthetic evaluation, in which cultural norms, education, exposure, but also individual differences play a crucial role. Furthermore, personality can act as a predictor as well (Park et al., 2013). In a recent study, individual and personal differences of the participants were taken into account (Vessel, Starr, & Rubin, 2012). Activation in sensory regions - occipital-temporal - and striatum increased linearly with the personal esthetic appreciation, and only for the most moving stimuli (according to each subject), did activation in the default-mode network (DMN) - i.e. anterior medial prefrontal cortex (aMPFC), and posterior cingulate cortex (PCC) - emerge. Activation in these regions has been found by other studies as well, although independent of individual differences or personal preferences (Cela-Conde et al., 2013).

2.2.2. Neural correlates of moral judgments

The biological underpinnings of moral judgments have been studied from several angles including, but not limited to, the usage of moral dilemmas in both normal and pathological populations (J. D. Greene et al., 2001; Pujol et al., 2011), the usage of strong emotionally-laden moral stimuli in video or picture form, and even the comparison of moral judgments

with legal judgments (Schleim, Spranger, Erk, & Walter, 2011). Most researchers on neuromorality would concur that there is no such things as a "moral brain", rather moral activation encompasses circuitry now classified as part of both the "emotional" and the "social brain" (J. Greene & Haidt, 2002; Young & Dungan, 2012). Nevertheless, "typical" moral activation has been found in the following structures: orbitofrontal cortex (OFC), MPFC, anterior cingulate cortex (ACC), PCC, precuneus, temporo-parietal junction (TPJ), insula, and amygdala (J. Greene & Haidt, 2002; Moll et al., 2005).

2.2.3. Neural correlates of first- and third-person perspective

Different patterns of neural activity were observed for stimuli presented in either 1- or 3PP in *non-moral visuospatial tasks* (Vogeley & Fink, 2003). During the 1PP situation, neural activity was increased in the medial prefrontal cortex (MPFC), posterior cingulate cortex (PCC), and temporoparietal cortex, bilaterally, whereas in the 3PP situation, neural activity was increased in the medial superior parietal and right premotor cortex. Furthermore, differences have also been found in *social non-moral tasks* (which appear to reflect theory of mind, ToM), although these results are somewhat less clear. For example, in a study of the influence of the person's perspective on ToM, 1- and 3PP-type sentences elicited different patterns of neural activation: 1PP-based stimuli yielded greater activation in the caudate nucleus, while 3PP-based stimuli evoked increased neural activity in the dorsolateral prefrontal cortex (DLPFC). The authors related activity in the caudate nucleus to self-focal cognition, and DLPFC-activity to ToM (Otsuka et al., 2011). Ames et al. (2008) investigated neural processing for 1- and 3PP-based decision-making, and demonstrated that while the ventromedial prefrontal cortex (vmPFC) was activated in both conditions, 1PP-based stimuli elicited higher levels of vmPFC activity. The study concluded that consciously adopting another person's perspective could prompt neural activity in those networks involved in self-

referential cognitive processing. Thus, some degree of overlap between 1- and 3PP is possible.

2.3. The present work

The main focus of my doctoral research intended to elucidate the specific involvement of mental processes and their neural underpinnings in moral decision-making. The thesis is composed of two sections: (1) Addressing the possible shared neural circuitry of esthetic and moral judgments, which could in turn clarify what kind of psychological processes support both judgment modalities, and (2) Investigating whether different paradigms of study in moral research can lead to different results.

However, our findings have to be interpreted with care, since the limitations of fMRI, like any neurotechnology, must be appreciated (Bao & Pöppel, 2012).

2.3.1. Brief introduction of the thesis: Part I

In a first study, published as Avram et al. (2013), functional magnetic resonance imaging (fMRI) was employed in order to study, in a within-subjects design, the potential equivalence of esthetic and moral judgments. One-line verses from poems and short moral statements were used as stimuli. These types of stimuli represent a new methodological approach, at least for esthetic research. Sixteen right-handed subjects (9 female; mean age 28.25) with normal or corrected to normal vision participated. The main result suggests a common basis for the two judgment categories, revealing comparable neural networks mainly the orbitomedial prefrontal cortex. However, additional activations were found in the moral judgment condition, that is, in the posterior cingulate cortex, the precuneus, and the temporoparietal junction. These regions have been related to understanding the minds of others. The common network found suggests that up to a point the brain may not differentiate

between esthetic and moral evaluations. In order to make judgments the cognitive machinery relies on functions that include emotional, cognitive, and social processes, as well as their integration. It is possible that the differences appear after the integration. A possible mechanism through which this is possible on a neural level is discussed.

2.3.2. Brief introduction of the thesis: Part II

In the second section, published as Avram et al. (2014), the fMRI methodology was used in order to investigate, whether moral judgments in either a first- or third-person perspective are supported by different neural substrates. Sixteen right-handed subjects (9 female; mean age 28.25) with normal or corrected to normal vision participated. The results indicate that different neural mechanisms appear to be involved in these perspectives. Although conjunction analysis revealed common activation in the anterior medial prefrontal cortex, the third-person perspective elicited unique activations in hippocampus and visual cortex. The common activation can be explained by the role the anterior medial prefrontal cortex may play in integrating different information types and also by its involvement in theory of mind. Our results also indicate that the so-called "actor-observer bias" affects moral evaluation in the third-person perspective, possibly due to the involvement of the hippocampus. We suggest two possible ways in which the hippocampus may support the process of moral judgment: by the engagement of episodic memory and its role in understanding the behaviors and emotions of others.

3. Published scientific works

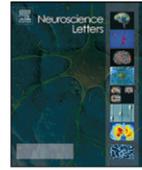
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Neurofunctional correlates of esthetic and moral judgments

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HIGHLIGHTS

- ▶ Our study compares the neurofunctional correlates of esthetic and moral judgments.
- ▶ Our results suggest similar functionality in comparable neural networks (OMPFC).
- ▶ Unique activation was found in the moral judgment condition (PCC/Precuneus, TPJ).
- ▶ These regions have been related to self-processing and theory of mind.

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ABSTRACT

Recent neuroimaging studies indicate that there may be common ground for esthetic and moral judgments. However, because previous studies focused on either esthetic or moral judgments and did not compare the two directly, the issue remains open whether a common ground actually exists. We employed functional magnetic resonance imaging in order to study, in a within-subjects design, the potential equivalence of esthetic and moral judgments. One-line verses from poems and short moral statements were used as stimuli. Our results suggest a common basis for the two judgment categories, revealing comparable neural networks mainly the orbitomedial prefrontal cortex. However, additional activations were found in the moral judgment condition, that is, in the posterior cingulate cortex, the precuneus, and the temporoparietal junction. These regions have been related to understanding the minds of others.

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1. Introduction

There is an old debate on the possibility of a common ground for esthetic (EJ) and moral judgments (MJ). David Hume, a promoter of moral sense theory, defined EJ as subjective evaluations relying on feelings of pleasure or displeasure [42], further extending this to hold true for MJ [15]. Regarding EJ, Immanuel Kant accepted Hume's view, while promoting a pure rational notion of morality. This generated a debate on the nature of MJ: are they reason-based, or emotion-based [15,25]? In psychology, rationalists had dominated until the social intuitionist model (SIM) was developed. SIM,

based on moral sense theory, defines MJ as intuitive evaluations of actions or character (good or bad) [15].

EJ and MJ similarities seem to depend upon the nature of these judgments. Both are considered value judgments [2], where each value can be either positive or negative: beauty and ugliness, and rightness and wrongness. Furthermore, several cognitive processes seem shared: cognitive control, reward-seeking behavior, representation of actions and sensory imagery [3,11]. The boundaries between EJ and MJ seem rather unclear, since certain subjects of esthetic assessment can be morally evaluated (moral assessment of works of art) and vice versa (esthetic judgments of moral conduct or character). Although several attributes distinguish the two: EJs are intrinsic, demand no consistency, but require a direct confrontation with the stimuli; MJs are more preferential, imply a ranking of alternatives, involve others and require action [2,7].

Although the neuroscientific literature has shown strong interest in EJ [19,20,22] and MJ [12,24], only few papers have connected the judgment modalities [40,41].

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We consider a psychological process supporting both evaluations of esthetic and moral stimuli [15] likely, yet unclear. Are EJ and MJ similar or the same, processed by equivalent brain structures? A number of regions involved in processing beauty and morality were identified [40,41]. The question arises whether a universal network for judgments is involved or whether – independent of such a network – EJ and MJ are processed in the same brain regions. The former appears unlikely, as research suggests that different judgments have different neural correlates [18]. Even when comparing akin judgments, that is, esthetic and symmetry judgments, different regions are activated [20].

Based on previous literature, we expect to find common activation in several areas: orbitofrontal cortex (OFC) and insula [40], medial prefrontal cortex (MPFC), precuneus, middle temporal gyrus (MTG), and temporal pole [13,19,41]. However, some areas may have an extra functional role for MJ: the default mode network (DMN) may be more active in MJ due to a convergence of its components and typical MJ structures [14,17]. It was speculated that this convergence results from introspection or inflated personal ruminations [12]. Parts of the DMN – temporoparietal junction (TPJ) and MPFC – were related to theory of mind (ToM), which has also been related to MJ [26]. We are unaware of any reported direct link between DMN, or ToM, and EJ. Thus, we expect a stronger engagement in MPFC, posterior cingulate cortex (PCC), precuneus and TPJ for the MJ. We do not include anterior cingulate cortex (ACC) since this structure has been shown to be active during cognitive conflict [16], which could be generated by both experimental conditions.

2. Method

2.1. Participants

Sixteen right-handed subjects (9 female; mean age 28.25) with normal or corrected to normal vision participated. The study was conducted in accordance with the Declaration of Helsinki and approved by the local ethics committee. All participants provided written informed consent prior to participation and received financial reward.

2.2. Stimulus material

Forty-five subjects evaluated 42 one-line verses from German poems (i.e. “Wer reitet so spät durch Nacht und Wind” from Goethe’s Erlkönig/“Who’s riding so late through th’ endless wild”) and moral statements (i.e. “It is false to wage war”) for valence and arousal in a pre-study. A five-point Likert scale was used, with scores ranging between -2 (unpleasant/agitating) and 2 (pleasant/calming), to ensure a comparison on a similar level. Extreme values were excluded on an $[-1, 1]$ interval; only 24 stimuli remained in each category similar in valence (-0.37 esthetic, and 0.38 moral) and arousal (-0.12 esthetics, and -0.12 moral). A paired *t*-test was used in order to control for stimuli sentence length. There was no statistically significant difference between esthetic ($M = 7.00$, $SD = 1.25$) and moral stimuli ($M = 6.96$, $SD = 2.76$), $t(23) = 0.0641$, $p = 0.94$. A control condition was also used in the fMRI study. Participants were asked judge if sentences comprised of randomized letters make up real words. This particular control condition was used in order to insure unbiased semantic and syntactic processing of esthetic and moral stimuli, thus preventing linguistic representation, and to control for optical input.

2.3. Procedure

Functional magnetic resonance imaging was used to examine the two judgments. A block design was used with 8 blocks per condition, each block comprising 3 stimuli on a black background.

The order of stimuli and blocks was pseudo-randomized (Presentation, Neurobehavioral Systems, USA). Subjects viewed the stimuli via a mirror attached to the head-coil on a LCD screen behind the scanner. Stimuli were presented for 3500 ms, followed by 1000 ms displaying a black screen with a white question mark while subjects decided whether the stimuli could be considered either beautiful (poems), or right (moral statements) by pressing a button (Cedrus Lumina response box, Cambridge Research Systems Ltd.). After each block, a fixation asterisk appeared on screen for 6000 ms.

The study was conducted with a 3T system (Philips ACHIEVA, Germany) at the University Hospital LMU Munich. For anatomical reference T1-weighted MPRAGE sequence was performed (TR = 7.4 ms, TE = 3.4 ms, FA = 8°, 301 sagittal slices, FOV = 240 × 256 mm, matrix = 227 × 227, inter-slice gap = 0.6 mm). For BOLD imaging T2*-weighted EPI sequence was used (TR = 3000 ms, TE = 35 ms, FA = 90°, 36 axial slices, slice thickness = 3.5 mm, inter-slice gap = 0 mm, ascending acquisition, FOV = 230 × 230 mm, matrix = 76 × 77, in-plane resolution = 3 × 3 mm). In total 177 functional volumes were acquired.

2.4. Data processing and analysis

Preprocessing and statistical analyses for all data were performed using SPM8 (Wellcome Department of Cognitive Neurology, London, UK). Motion correction, realignment and spatial normalization were performed in the preprocessing analysis.

Smoothing was executed using a Gaussian kernel of 8 mm FWHM. The experimental conditions (Esthetic – EJ, Moral – MJ, and Control – C) were modeled by a boxcar function convolved with a hemodynamic response function. Several single-tailed *t*-contrasts were calculated for each subject (EJ > C, C > EJ, MJ < C, C > MJ, EJ > MJ, MJ > EJ) in the first level. The individual contrast images were used for a random effect analysis in SPM second level. A conjunction analysis [9] was performed to identify positive changes in BOLD signal intensity commonly seen in EJ and MJ by using contrast images of each condition compared with the control condition. Group activation contrasts ($p < 0.0001$) were cluster-level corrected by family wise error (FWE) < 0.05.

3. Results

3.1. Behavioral data

The subjects rated 48% of the esthetic stimuli as beautiful and 43% of the moral stimuli as right. A *t*-test revealed no differences between esthetic ($M = 0.48$, $SD = 0.13$) and moral stimuli ($M = 0.43$, $SD = 0.1$); $t(15) = 0.892$, $p = 0.38$. Thus a similar number of positive and negative evaluations of EJ and MJ were used. There was no significant difference in reaction time ($F(2, 42) = 2.98$; $p = 0.06$) in EJ ($M = 481$, $SD = 57$ ms) compared to MJ ($M = 523$, $SD = 65$ ms) and control ($M = 477$, $SD = 48$ ms).

3.2. fMRI data

A conjunction analysis was used in order to find common activations between EJ and MJ. Common activation for the judgment modalities (compared to control) was found in: OFC (Brodmann Area, BA - 47), inferior frontal gyrus (BA 45), MPFC (BA 32), ACC (BA 32), premotor area (BA 6), supplementary motor area (SMA/BA 6), MTG (BA 22), insula (BA 13), substantia nigra, and visual cortex (BA 18) (Table 1, Fig. 1).

In order to find the unique brain activations for the two judgment modalities a direct comparison was done. No regions were found activated for EJ in the EJ > MJ comparison. However, MJ seem to elicit more activation in the middle frontal gyrus (MFG/BA 8),

Table 1
Conjunction analysis: esthetic and moral judgments.

Brain region	BA	x	y	z	t	mm ³
<i>Bilateral</i>						
MPFC	8	0	26	41	11.20	3780
ACC	32	-7	27	31	11.20	468
Supplementary motor area	6	3	14	49	11.20	8937
Substantia nigra		-13	-22	-13	5.73	208
<i>Left</i>						
Orbitofrontal cortex	47	-39	26	-5	11.12	3105
Inferior frontal gyrus	45	-51	23	7	10.13	9324
Premotor area	6	-42	5	49	10.14	5508
Middle temporal gyrus	21	-60	-28	1	7.84	5184
<i>Right</i>						
Orbitofrontal cortex	47	39	26	-8	8.34	1377
Insular lobe	13	36	26	1	8.01	2565
Visual cortex	18	24	-91	-2	10.81	1647

Note: BA, Brodmann area; x, y, z, MNI coordinates.

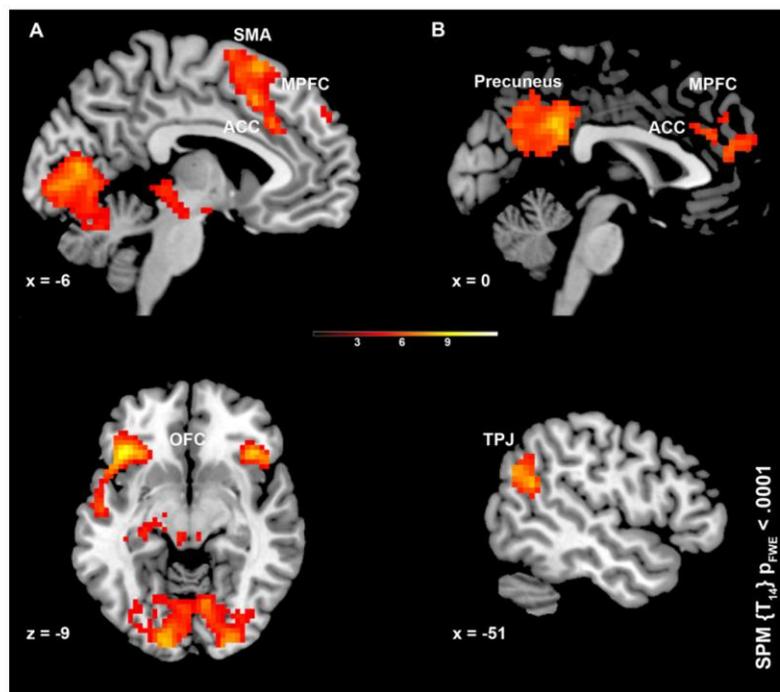


Fig. 1. Neurofunctional correlates of esthetic and moral judgments (A) Conjunction analysis (esthetic and moral judgments), (B) Moral versus esthetic judgments. Orbitofrontal Cortex (OFC), Anterior Cingulate Cortex (ACC), Medial Prefrontal Cortex (MPFC), Supplementary Motor Area (SMA), Temporoparietal Junction (TPJ).

MPFC (BA 9), ACC (BA 10), PCC (BA 31), precuneus (BA 7), TPJ (BA 39), MTG (BA 22), and visual cortex (BA 17) (Table 2, Fig. 1).

4. Discussion

We have demonstrated that esthetic (EJ) and moral judgments (MJ) rely on comparable neural networks. Our results confirm our first hypothesis on a common ground between the judgment modalities and are in line with other studies that have found activation in these areas: OFC, insula, MPFC, MTG, and precuneus [40,41]. Our second hypothesis was also confirmed, a stronger engagement being found for MPFC, PCC, precuneus and TPJ in the MJ condition.

OFC has been related to processing of esthetic beauty [22], MJ [12], and moral beauty or regard for positive outcome [38]. MPFC is related to emotional processing [30], cognitive control,

decision-making in relation to reward, punishment, and self-processing [41]. This area's involvement in ToM is consistent across the literature [10] and could explain the greater engagement for MJ in the direct comparison analysis. Another common activation was found in ACC. Although we hypothesized little difference between the experimental conditions, a stronger engagement was found for MJ. We did not control for conflict or problem difficulty, however, this greater involvement could be interpreted through the nature of the conflict (beautiful – not beautiful versus rightness – wrongness) and/or additional consequences that MJ may bear. Due to strong connections among OFC, MPFC and ACC a network was suggested – the orbital medial prefrontal cortex (OMPFC) – related to emotion processing and social cognition [4,30].

Insula has been related to both EJ and MJ, although a common function is not clear. Activation in the right anterior insula has been

Table 2
Moral versus esthetic judgment.

Brain region	BA	x	y	z	t	mm ³
<i>Bilateral</i>						
MPPFC	9	–6	47	21	5.46	3024
Anterior cingulate cortex	32	–6	47	16	10.49	3159
Posterior cingulate cortex	31	3	–43	28	8.42	3267
Precuneus	7	–1	–62	41	6.33	7857
<i>Left</i>						
Middle frontal gyrus	9	–33	20	52	8.65	2011
Temporoparietal junction	39	–45	–64	34	12.30	5728
Middle temporal gyrus	22	–48	–52	22	8.01	3488
Visual cortex	17	–3	–64	19	8.75	378

Note: BA, Brodmann area; x, y, z, MNI coordinates.

interpreted as: hedonic response during esthetic experience [6], norm violation [34], emotional processing [30], and empathy [36].

MJ also elicited unique activation. All activation found in the direct comparison analysis is considered typical for moral evaluations [12]. MFG is considered to be an area implicated in conscious down-regulation of negative emotion [29]. PCC and precuneus seem to be involved in the recall of emotional memories, experience of emotion, self-referencing, and integration of the stimuli in the person's extended moral context [16,21,23]. Precuneus has also been related to ToM – especially during judgments requiring empathy [8]. TPJ has been related to several mental processes including ToM [35]. Lesion studies on the left TPJ suggest that damage in this region leads to impairments in cognitive processes involved in the inferences of someone's belief [33]. PCC, precuneus, and TPJ are part of DMN [1,32], and have also been related to processing intentions related to the self. When the causal link between one's own intentions and actions was studied, activations were found in the following regions: precuneus, PCC, prefrontal cortex, TPJ, and temporal pole [5]. Thus, the stronger activation in some brain structures by MJ may be explained by the fact that these judgments require an action more often than EJ.

The activation in the visual cortex may be explained by the emotionally salient stimuli [31,39]. Due to dense interconnections between the visual cortex and the amygdala, a modulating effect from the amygdala seems possible and has been also noted by previous studies [27]. It is also possible that the moral stimuli were more easily imagined, while mental imagery is known for activating parts of the visual cortex [37].

Our results suggest that EJ and MJ share activation in the OMPFC network. This common frontal activation appears to be in line with the psychological functionality of this network (processing emotional and social stimuli, but also in finding the most desirable and rewarding outcomes for the organism [28]), and may suggest similar psychological processes. Alternatively, the common activations could be elicited by the processing of similar stimuli (e.g. semantic or syntactic processing). However, through the extra activations found for MJ, activations related to MJ irrelevant of stimuli type [24], the processing cannot be limited to semantic or syntactic processing. Furthermore, our results seem to be in line with the psychological and cognitive unique characteristics of MJ: the demand for action and the involvement of others. These characteristics seem to be the key features in making a clear distinction between EJ and MJ, not only on a psychological, but also on a neural level.

Since the two judgments elicit different subjective experiences and share activation in the OMPFC, the question arises how the brain differentiates between the two judgment modalities. This differentiation may be clarified by the unique brain activations found for MJ. Almost all activated regions are part of the ToM network, regions related to an external point of view, or understanding the minds of others. We suggest that the moral stimuli elicited more

mental challenge than the esthetic stimuli (as observed in the increased activity of the ACC), possibly due to the consequences these judgments may have either for oneself and/or for others. Perhaps, in processing this higher cognitive interference, the OMPFC network recruits further ToM-related neural components, thus insuring multiple modalities of stimulus processing like emotional, social or self-referencing. The activation in some of these areas may also suggest a readiness for action, which MJ often require.

In conclusion, although EJ and MJ do share several neural and psychological processes involved in handling emotional and social appreciations and finding desirable outcomes for the organism, the involvement of others as well as the demand for action sharply separates the two judgments of value.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at <http://dx.doi.org/10.1016/j.neulet.2012.11.053>.

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3.2. Neural correlates of moral judgments in first- and third-person perspectives: implications for neuroethics and beyond

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Neural correlates of moral judgments in first- and third-person perspectives: implications for neuroethics and beyond

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Abstract

Background: There appears to be an inconsistency in experimental paradigms used in fMRI research on moral judgments. As stimuli, moral dilemmas or moral statements/ pictures that induce emotional reactions are usually employed; a main difference between these stimuli is the perspective of the participants reflecting first-person (moral dilemmas) or third-person perspective (moral reactions). The present study employed functional magnetic resonance imaging (fMRI) in order to investigate the neural correlates of moral judgments in either first- or third-person perspective.

Results: Our results indicate that different neural mechanisms appear to be involved in these perspectives. Although conjunction analysis revealed common activation in the anterior medial prefrontal cortex, third person-perspective elicited unique activations in hippocampus and visual cortex. The common activation can be explained by the role the anterior medial prefrontal cortex may play in integrating different information types and also by its involvement in theory of mind. Our results also indicate that the so-called "actor-observer bias" affects moral evaluation in the third-person perspective, possibly due to the involvement of the hippocampus. We suggest two possible ways in which the hippocampus may support the process of moral judgment: by the engagement of episodic memory and its role in understanding the behaviors and emotions of others.

Conclusion: We posit that these findings demonstrate that first or third person perspectives in moral cognition involve distinct neural processes, that are important to different aspects of moral judgments. These results are important to a deepened understanding of neural correlates of moral cognition—the so-called "first tradition" of neuroethics, with the caveat that any results must be interpreted and employed with prudence, so as to heed neuroethics "second tradition" that sustains the pragmatic evaluation of outcomes, capabilities and limitations of neuroscientific techniques and technologies.

Keywords: fMRI, Moral judgment, Perspective, "actor-observer bias", Anterior medial prefrontal cortex, Precuneus, Hippocampus, Theory of mind, Neuroethics

Background

Studies of moral decision-making have been the focus of philosophy, psychology, and more recently, the brain sciences. Examination of the ways that humans (and perhaps other organisms) engage intent, memory, emotion, and reasoning processes relevant to their execution and constraint of conduct toward others, acquisition and use of

various resources, survival, and flourishing have become the emphases of sub-disciplines of the cognitive neurosciences, such as neuroeconomics and more specifically, neuroethics. Developing from the older fields of moral philosophy and moral psychology, neuroethics obtains two primary orientations (or so-called "traditions"). The first can be somewhat colloquially described as "...the neuroscience of ethics" [1]. Rather, we offer that a more apt definition of this branch of neuroethics would be: studies of the putative neural substrates and mechanisms involved in proto-moral and moral cognition and behaviors [2-5]. The second

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“tradition” addresses the ethico-legal and social issues fostered by the use of neuroscience and neurotechnologies in research, medical practice, or public life.

In this latter regard, particular interest has centered upon the use of neuroimaging techniques and technologies to depict, and define neural bases of moral decision-making, if not “morality”, writ-large—as constituent to ongoing criticism of neuroimaging, in general [6]. Still, by recognizing and compensating inherent technical and conceptual limitations [7] iterative progress in neuroimaging technology and method have yielded improvement in outcomes, which sustain this approach as both valid and valuable to elucidating the relative activity of various neural networks in certain types of cognitive tasks and behaviors, including those involved in moral judgments and behaviors - with certain caveats noted and acknowledged [8,9].

Such studies have revealed the complexity of these types of decisions. In the main, focus has shifted from defining moral judgments as purely cognitive processes (i.e. - reason) to revealing more emotion-based processes, and recent results suggest the involvement of both processes in those decisions that are (both subjectively and objectively evaluated as being) morally sensitive and/or responsive [10-15]. What has also become clear is that moral decisions are not uniformly processed by a particular locus, region or network [16,17], but rather are more widely distributed in and across neural fields that are involved in memory, reward, reinforcement, and punishment, rationalization, interoception (e.g.- provocation of and response to various emotions, self-referentiality, etc.), and behavior. For example, Young and Dungan [18] suggest that such brain areas include the medial prefrontal cortex (MPFC) – involved in emotional processing; posterior cingulate cortex (PCC) and precuneus – both involved in self-referential processing, the temporo-parietal junction (TPJ) and/or somewhat larger fields of Brodmann’s area 39 – that are involved in aspects of social processing and/ or theory of mind (ToM).

As well, it is likely that different patterns of neural network activation may be involved in particular types of moral decisions, based upon the nature of the evocative stimuli, situations, and relative involvement of the subject. In this light, a methodological question has recently been raised regarding the viability of the rational and emotional/intuitionist theories of moral cognition and judgments [19]. These research approaches to moral judgment use different experimental stimuli: “rationalist” protocols use moral dilemmas to study moral judgments, while “emotionalist” protocols employ emotionally-laden statements or pictures to assess what appear to be moral reactions. Is it possible that these approaches elicit distinct processes of moral cognition and lead to different results? Monin and colleagues [19] argue that the focus of reasoning in moral dilemmas is on the decision-making process - a conflict between

two moral constructs and/or principles, whereas moral reactions reflect subjects’ emotional responses to particular stimuli and situations that have moral relevance. Of note is that moral dilemma protocols are typically presented in a first person perspective (1PP), while moral reaction protocols are characteristically presented in a third-person perspective (3PP). Thus, we question whether the perspective of the subject(s) toward the moral stimuli is sufficient to evoke differing effects, and elicit distinct patterns of neural network activity.

We opine that using stimuli presented in either 1- or 3PP may elucidate a number of potentially interactive variables that may shed new light on studies of neural mechanisms and processes of moral cognition. To wit, it has been shown that different patterns of neural activity were observed for stimuli presented in either 1- or 3-PP in *non-moral visuospatial tasks* [20]. During the 1-PP situation, neural activity was increased in the medial prefrontal cortex (MPFC), posterior cingulate cortex (PCC), and temporoparietal junction (TPJ) bilaterally, whereas in the 3-PP situation, neural activity was increased in the medial superior parietal and right premotor cortex.

Furthermore, differences have also been found in social non-moral tasks (which appear to reflect theory of mind, ToM), although these results are somewhat less clear. In a study on the influence of the person’s perspective on ToM, 1- and 3-PP-type sentences elicited different patterns of neural activation: 1PP-based stimuli yielded greater activation in the caudate nucleus, while 3PP-based stimuli evoked increased neural activity in the dorsolateral prefrontal cortex (DLPFC). The authors related activity in the caudate nucleus to self-focal cognition, and DLPFC-activity to ToM. Other studies report stronger 3PP activation in the TPJ and dorsal MPFC [21-24] which are regarded as parts of the ToM network.

On the other hand, many of these studies have reported greater activation for the 1PP compared to 3PP in the MPFC and PCC/ precuneus. Ochsner and colleagues compared neural processes involved in inferences about one’s own and others emotional states. Concomitant activation was demonstrated in the MPFC, left inferior PFC, PCC/ precuneus and STS/ TPJ [25]. This appeared to reflect recruitment of specific sub-regions in the MPFC, and additional activation in the medial temporal cortex for processing self-emotionality, while the lateral PFC and medial occipital activation appeared to be involved in processing emotional inferences of/about others. We posit that these results suggest that “self-judgments” seem to activate more medial networks, while judgments about others appear to engage more lateral networks. As well, components of both networks have some degree of overlap.

Social psychological studies have repeatedly shown that negative situations elicit a tendency to attribute one’s own

actions (1PP) to external causes, while attributing other people's (3PP) behaviors to internal causes, a phenomenon referred to as the "actor- observer bias" [26,27]. This may affect results in studies of moral decision-making, given that many such studies have employed negative situations as stimuli [28]. Nadelhoffer and Feltz [27] conducted a behavioral study of the actor-observer bias using a version of Philippa Foot's [29] iconic "trolley problem" as the moral dilemma stimulus, viz.- a trolley is running out of control toward five people who are on the track and unaware of the looming danger. You have the opportunity to save these five people by throwing a switch and sending the trolley down a different track. However, if you do this, you will then kill one individual who is on the second track (for overview, see also Thomson [30] and for discussion of relevance to neural bases of moral decision-making, see Green [31]). The dilemma was presented either in a 1PP (i.e. - the subject was the actor, actively engaged in throwing the switch to divert the trolley), or in a 3PP (i.e. - the subject was a passive observer who could tell an actor to throw the switch). In the actor condition, 65% of the participants found the action (throwing the switch) to be permissible, whereas 90% of the participants in the observer condition found the action to be morally acceptable. These results imply different psychological processes involved in the two perspectives.

Thus, differential activation of distinct neural networks in response to 1PP- or 3PP-based stimuli is expected. Based on previous studies activation in the medial parts of the default mode network can be anticipated for the 1PP, and more lateral activation (e.g. DLPFC, TPJ) can be expected for the 3PP. However, since common activation for both perspectives has been found in several studies, and the default mode and ToM networks overlap in several regions, shared activation may also be expected. MPFC and PCC/ precuneus seem to be common denominators for the perspectives. Theoretically, the observer condition (3PP) of the "actor- observer bias" would tend to involve attribution of behaviors to internal causes, thus there is an attempt to understand the mind (i.e. - mental processes, in this case, the perceived "morality") of the "actor". Indeed, ToM has been linked to moral judgments, and may be seen as important to moral evaluations of the actions of others [18].

As well, given that (a) most decisions, inclusive of potentially moral judgments involve some degree of Bayesian processing [32,33]; (b) such processing involves recollection of circumstance, effect and potential consequences in orientation to self, others and situations [2,5,34], and (c) learning and memory have been shown to play significant roles in these processes [35,36], it is likely that neural substrates of memory (e.g.- septo-hippocampal networks) would be involved [37,38]. Studies have fortified this speculation by demonstrating hippocampal activation in

tasks involving perception of the emotions and actions of others [39,40]. Accordingly, we posit that hippocampal activation (for the 3PP-, as well as perhaps 1PP-situations) is to be expected. In sum, we hypothesize that the perspective of the subject (i.e.- as either actor (1PP), or observer (3PP)) will evoke differential activity in distinct neural networks that are putatively involved in the particular cognitive aspects of these orientations to moral judgment(s). To test this hypothesis we employed functional magnetic resonance imaging (fMRI) to compare moral judgments posed in 1- and 3PP-based scenarios.

Method

Participants

Sixteen (16) right-handed subjects (9 female, 7 male; mean age 28.25 years) with normal or corrected to normal vision participated in this study. Participants had no reported history of psychiatric or neurological disorder, and were not using psychoactive drugs at the time of the study. The study was conducted in accordance with the Declaration of Helsinki, and approved by the Ethics Committee and Internal Review Board of the Human Science Center of the Ludwig-Maximilians University. Active, written informed consent for participation in the study was obtained from all participants, and subjects received financial compensation for their time.

Stimulus material

Sixty-nine (69) subjects evaluated 72 moral statements for valence and arousal in a pre-study. Half of the statements were presented in the 1PP ("I am a cruel person because I have aggressive thoughts towards my child"), and half were presented in the 3PP ("A person who has aggressive thoughts toward his/ her child is cruel"). To assure valid comparisons, a five point Likert scale was used to rate the stimuli for valence, with scores ranging between -2 (unpleasant) and 2 (pleasant), and arousal, with scores ranging between -2 (agitating) and 2 (calming). Extreme values were excluded on an [-1, 1] interval in order to obviate the strongly emotion- laden stimuli, and to compare similar emotional reactions. Only 8 stimuli remained in each category after the pre-study. In order to ensure valid statistical comparisons of valence and arousal, two paired *t*-tests were used; there were no statistically significant differences between stimuli presented in 1PP narrative ($M = -0.82$, $SD = 0.35$) and 3PP narrative ($M = -0.82$, $SD = 0.19$), $t(7) = 0.05$, $p > .05$ with respect to valence. There were also no statistically significant differences between stimuli presented in 1PP narrative ($M = -0.76$, $SD = 0.30$) and 3PP narrative ($M = -0.77$, $SD = 0.22$), $t(7) = 0.04$, $p > .05$ with respect to arousal. Another paired *t*-test was used to control for stimulus sentence length. There were no statistically significant differences between stimuli

presented in 1PP narrative ($M = 8.38$, $SD = 3.20$) and 3PP narrative ($M = 10.25$, $SD = 2.71$), $t(7) = 1.34$, $p > .05$.

Subjects had to rate the sentences as "right" or "wrong" by relying upon intuition (i.e. described to them as "a gut-feeling"), and not necessarily their real life experience (s) (e.g. some participants may not have had children), so as to base their answers upon an "as-if" situation (e.g. If I were to have aggressive thoughts towards my child - and, indeed, if I had children - would I be a cruel person?).

Although the stimuli were controlled for length, there may have been differences in sentence construction. For example, in the 1PP narrative, "I am a cruel person because I have aggressive thoughts towards my child", it might seem that the 3PP narrative that would have been the best match would be: "John is a cruel person because he has aggressive thoughts towards his child". However, the actor-observer bias appears to be more prominent in cases where the actor is not known - e.g. a stranger [26]. Therefore, we choose a more abstract expression, namely "a person". Another condition was also used, in which participants were asked to evaluate a non-moral statement based upon their perception of what they believed to be right or wrong (e.g. "There are people who are friendly"). An additional, "scrambled" condition was also used, in which participants had to push a response button when viewing a sentence composed of random letters. This condition was employed to test whether moral judgments activate a similar pattern when compared to scrambled words as in our previous study [14] and is not directly related to this study.

All stimuli were presented twice during the fMRI experiment.

Procedure

Functional magnetic resonance imaging (fMRI) was used in order to study the 1PP and 3PP types of judgments. A block design was used with 4 conditions (1PP, 3PP, non-moral, and scrambled) and 8 blocks per condition, each block comprising 2 stimuli, presented in white, on a black background. The order of stimuli and blocks was pseudo-randomized. Subjects viewed the stimuli via a mirror attached to the head-coil on a LCD screen behind the scanner. Stimuli were presented for 6000 ms (Presentation, Neurobehavioral Systems, USA), followed by 300 ms displaying a black screen, which in turn was followed by a 1000 ms black screen with a white question mark, in which subjects had to decide whether the statements could be considered right or wrong by pressing a button (Cedrus Lumina response box, Cambridge Research Systems Ltd.). After the two stimuli a black screen was presented for 6000 ms as a break between blocks. This method was used to ensure consistent parameters of cognitive processing in each subject for each presented stimuli. Given these protocols, reaction time analyses were not required.

The study was conducted with a 3T system (Philips ACHIEVA, Germany) at the University Hospital LMU Munich. For anatomical reference, a T1-weighted MPRAGE sequence was performed (TR = 7.4 ms, TE = 3.4 ms, FA = 8°, 301 sagittal slices, FOV = 240 × 256 mm, matrix = 227 × 227, inter-slice gap = 0.6 mm). For BOLD imaging, a T2*-weighted EPI sequence was used (TR = 3000 ms, TE = 35 ms, FA = 90°, 36 axial slices, slice thickness = 3.5 mm, inter-slice gap = 0 mm, ascending acquisition, FOV = 230 × 230 mm, matrix = 76 × 77, in-plane resolution = 3 × 3 mm). In total 229 functional volumes were acquired, 5 being discarded.

Data processing and analysis

The preprocessing and statistical analyses were performed using SPM8 (Wellcome Department of Cognitive Neurology, London, UK). Motion correction, realignment and spatial normalization were performed in the preprocessing analysis. Smoothing was executed using a Gaussian kernel of 8 mm FWHM. The four experimental conditions were modeled by a boxcar function convolved with a hemodynamic response function. In the first level, several single-tailed t-contrasts have been calculated for each subject, condition versus baseline. The individual contrast images were used for a random effect analysis in a second level. A conjunction analysis was performed to identify positive changes in BOLD signal intensity commonly seen in 1PP and 3PP presentations by using contrast images of each condition compared with the non-moral condition. Only activations are reported. Group activation contrasts (uncorrected $< .005$) were cluster-level corrected by family wise error (FWE) $< .05$ with a cluster-size threshold of 50 voxels.

Region of interest (ROI) analysis

Parameter estimates of signal intensity were extracted from regions of interest (ROIs) for each subject using MARSeille Boîte À Région d'Intérêt software (MarsBaR v0.42; [43]) in the aMPFC, precuneus, TPJ, and hippocampus, with ROIs defined as spheres with 10mm radius centered at the peaks of the parametric activation. Anatomical description was accomplished by referring to the Automatic Anatomic Labeling (AAL) [41] atlas from the Wake Forest University (WFU) Pickatlas (Advanced Neuroscience Imaging Research Laboratory, Winston-Salem, North Carolina, USA). Repeated measures analyses of variance with mean beta values for each subject were done to determine whether neural activity within these regions differed between 1- and 3PP moral judgments and the non-moral condition. Gaussian distribution, homogeneity of variance and covariance and sphericity could be assumed ($p > .05$). Corrections for multiple comparisons were done by the Bonferroni procedure. Statistical analyses calculated with SPSS Statistics 16.0 (IBM, USA).

Results

Behavioral results

Subjects evaluated the moral statements to be either morally right, or morally wrong.

A chi-square-test revealed a statistically significant difference in yes/ no responses for the two moral conditions, $\chi^2(1) = 28.96, p < 0.01$. The participants found 19% of the 1PP and 51% of the 3PP stimuli to be morally right.

fMRI results

1PP- and 3PP-based judgments were each compared to the non-moral condition (NM). 1PP-based judgments yielded greater activation than NM in the anterior medial prefrontal cortex (aMPFC - BA 10), posterior cingulate cortex (PCC - BA 23) extending in the precuneus (BA 7), and temporoparietal junction (TPJ - BA 39) (Table 1, Figure 1). 3PP-based judgments elicited greater activation in the aMPFC (BA 10), but also in the lingual gyrus (BA 17), middle occipital gyrus (BA 18) and hippocampus (Table 1, Figure 1).

In order to assess overlapping neural activity evoked by the two judgment modalities, a conjunction analysis was used. Common activation for the two judgment modalities (compared to control) was found only in the anterior medial prefrontal cortex $x = 3, y = 59, z = 28$ (BA 10; cluster size = 3078 mm³, $t = 4.93$). Relative activations were generated only by the 3PP > 1PP contrast in: hippocampus bilaterally, and visual cortex - fusiform gyrus (BA 37), middle occipital gyrus (BA 19), and cuneus (BA 18) (Table 2, Figure 2). No activations above threshold were observed in the inversed contrast, 1PP > 3PP.

In order to ensure that the effects were related to the 1PP or 3PP moral conditions, and not due to the subtraction of the NM condition, the aMPFC, precuneus, TPJ, and hippocampus were selected for ROI analyses. Overall main effects were observed for all ROIs. For aMPFC ($F(2, 30) = 13.17, p < .001$, partial $\eta^2 = .468$), differences

were found between 1PP and NM condition ($p < .002$), and between 3PP and NM conditions ($p < .006$), but no difference was found between the two moral conditions ($p = 1$). For precuneus ($F(2, 30) = 5.22, p < .011$, partial $\eta^2 = .258$) differences were found between 1PP and NM condition ($p < .038$), but none between 3PP and the NM condition ($p = .057$) or between the two moral conditions ($p = .544$). For TPJ ($F(2, 30) = 7.29, p < .003$, partial $\eta^2 = .327$) differences were found between 1PP and NM condition ($p < .003$), and between 3PP and NM conditions ($p < .032$). No difference was found between the moral conditions ($p = .262$). For hippocampus ($F(2, 30) = 12.46, p < .0001$, partial $\eta^2 = .453$) differences were observed between 1PP- and 3PP conditions ($p < .0001$), and between 3PP and NM condition ($p < .005$). However, no difference was found between NM and 1PP conditions ($p = .316$) (Figure 3).

Discussion

The findings bring to light both common and distinct activations for moral judgments in 1PP and 3PP. A conjunction analysis revealed common activation in the aMPFC for both perspectives. When compared to the non-moral condition, 1PP moral judgments elicited activation in the aMPFC, PCC extending in the precuneus, and TPJ, whereas 3PP moral judgments elicited activation in the aMPFC, hippocampus and visual cortex.

The behavioral results, which revealed that 19% of the stimuli in 1PP- and 51% of the 3PP- stimuli were evaluated as right, seem to concur with Nadelhoffer and Feltz's study [27] showing involvement of the "actor-observer bias". However, the paucity of imaging research on the "actor-observer bias" makes it challenging to describe the way in which the neurofunctional correlates of the bias may be contributory to, or form moral judgments.

Even though first and third person perspectives (1PP, 3PP) elicited additional activity (except for aMPFC) in

Table 1 Relative activation table: 1- and non 3PP moral judgments versus non-moral judgments

Brain region	Left						Right					
	BA	x	y	z	t	mm ³	BA	x	y	z	t	mm ³
1PP > NM												
aPFC	10	-6	56	22	5.64	3080	10	12	56	22	3.35	1593
Posterior cingulate cortex	23	-3	-52	31	3.94	378						
Precuneus	7	-3	-58	40	4.98	1431						
Temporoparietal junction	39	-42	-55	19	5.22	675						
3PP > NM												
aPFC	10	-15	50	37	4.87	459	10	3	59	28	4.90	1880
Lingual gyrus	18	-33	-85	4	6.69	3726						
Middle occipital gyrus	-22	-25	-8	4.28	378							
Hippocampus	17	6	-82	-5	7.91	4212						

Note. BA - aPFC - anterior prefrontal cortex, Brodmann area, x, y, z - MNI coordinates.

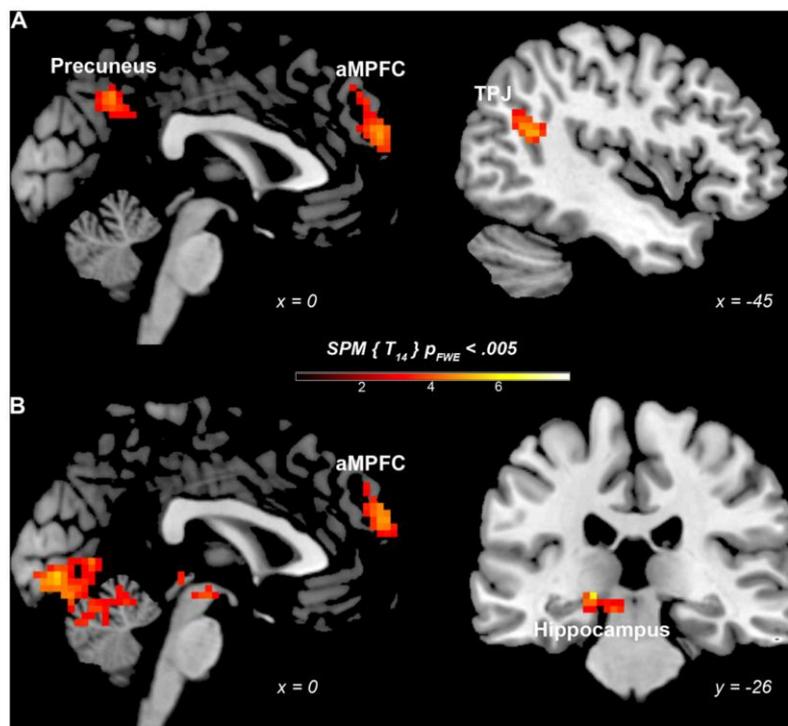


Figure 1 Neurofunctional correlates of 1- and 3PP moral judgments. (A) 1PP moral judgments versus NM condition, (B) 3PP moral judgments versus NM condition. Anterior Medial Prefrontal Cortex (aMPFC), Temporoparietal Junction (TPJ).

comparison with the non-moral condition (NM), these differences did not withstand the threshold-correction (except for hippocampus and visual cortex) in the direct (3PP- vs.1PP; 1PP vs. 3PP-based comparisons). The findings reveal both common and distinct activations for moral judgments in 1PP and 3PP. A conjunction analysis revealed common activation in the aMPFC for both perspectives. When compared to the non-moral condition, 1PP moral judgments elicited activation in the aMPFC, PCC extending in the precuneus, and TPJ, whereas 3PP moral judgments elicited activation in the aMPFC, hippocampus and visual cortex.

No significant statistical differences in signal activation strength were revealed by the ROI analyses between 1- and

3PP-based presentations in the MPFC, precuneus, and TPJ. The aMPFC has been shown to be involved in the explicit representation of both one's own mental state, and also the mental states of others [43]. Furthermore, its activity has been consistently demonstrated in social cognition and ToM tasks [42]. Moreover, the aMPFC seems to function in coordination of external and internal stimuli [44].

Theoretically, 1PP presentation should elicit activation in those areas involved in assessing behavior in a given situation. When compared to the non-moral condition, signal activation was elicited in aMPFC, precuneus and right TPJ. Given that in 81% of the cases the subjects evaluated the moral stimuli as wrong; it seems that subjects may have tried to distance themselves from strong

Table 2 Relative activation table: 3PP versus 1PP moral judgments

Brain region	Left						Right					
	BA	x	y	z	t	mm ³	BA	x	y	z	t	mm ³
Hippocampus		-36	-22	-14	4.08	1688		24	-28	-11	5.24	1836
Fusiform gyrus	37	-33	-52	-17	6.05	2889	19	24	-70	-14	4.43	1832
Middle occipital gyrus	19	-30	-85	16	8.25	2584	19	27	-85	19	4.69	2448
Cuneus	18	12	-88	19	4.90	536						

Note. BA – Brodmann area, x, y, z – MNI coordinates.

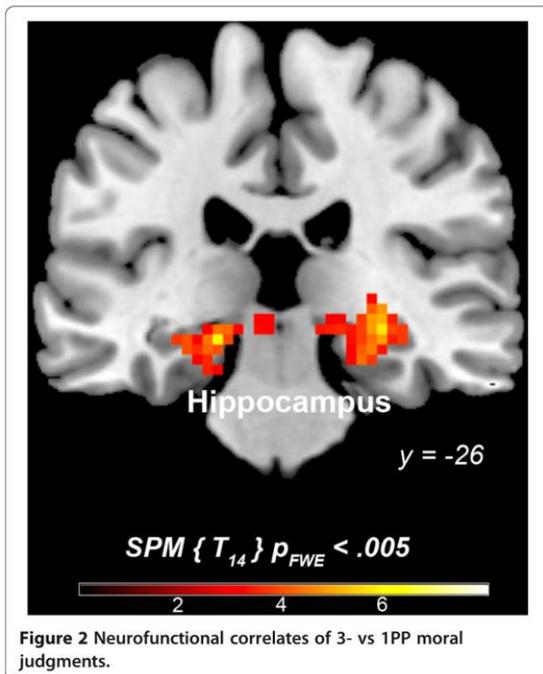


Figure 2 Neurofunctional correlates of 3- vs 1PP moral judgments.

emotional stimuli. Koenigsberg et al. [45] found signal activation in the PCC/ precuneus, TPJ, and middle and superior temporal gyrus during emotional-distancing tasks. Since the aMPFC contributes to the integration of emotion in decision-making and planning [46], activation in this area suggests that the stimuli may have elicited emotional processing. An attempt to relate the stimuli to the self also seems probable, due to activation of the precuneus, which has been shown to be involved in types of self-processing (e.g. mental imagery strategies; [47]). However, these strategies also engage precuneus perspective-based cognition. Perspective-based cognition has also been shown to involve the TPJ [48]. That both the precuneus and TPJ are involved in may suggest that subjects attempted to change their perspective when responding to the moral stimuli.

In the 3PP-based condition, subjects appear to evaluate the behavior of others through the inner characteristics of the actor, in accordance with the “actor-observer bias”. Behavioral data suggest that the evaluating standards were less strict, with 51% of the stimuli being rated as morally right. When compared to the non-moral condition neural activation during presentation of moral conditions was found in aMPFC, hippocampus (bilaterally), and visual cortex. That there was almost equal activation in the aMPFC for both 1PP- and 3PP presentations of moral conditions (as based upon ROI analysis) suggests the involvement of similar processes in these decision events.

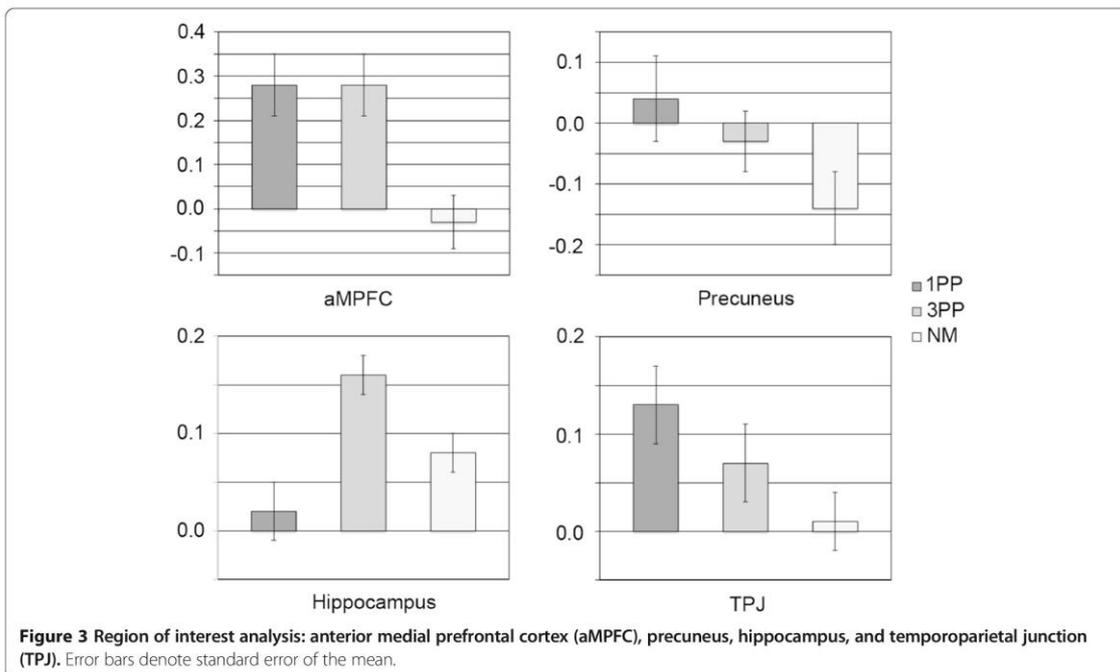


Figure 3 Region of interest analysis: anterior medial prefrontal cortex (aMPFC), precuneus, hippocampus, and temporoparietal junction (TPJ). Error bars denote standard error of the mean.

Activation in the visual cortex may be explained by the visual salience of the emotional stimuli presented. [28,49,50]. Due to dense interconnections between the visual cortex and the amygdala, a modulating effect from the amygdala as noted by previous studies seems possible [51].

Recent neuroimaging studies have related hippocampal activity to ToM in understanding the emotions and behaviors of others [39], specifically as related to the facilitative role of the hippocampus, and its implication in inducing and sustaining emotional reactions. Hippocampal activation may also suggest both a possible role of memories and projection of self-knowledge while making emotional judgments regarding others [40] and the viability of declarative memory to integrate relevant information between different inputs about a given event [52]. However, it has been suggested that ToM may be independent of episodic memory [53]. In the present study, the stimuli were not related to typical daily experiences, but rather, represented extreme violence, blasphemy, and questionable sexual behavior.

Therefore, we argue that activation in the 3PP condition may be dependent upon semantic memory, in that factual or general information about the world may contribute to making sense of perceived deviant behavior. Hippocampal activity has also been shown during tasks of semantic memory [54], in retrieval of relevant memories [55] that allow past events to influence present decisions [56]. Taking this into consideration, the presentation of moral situations may trigger the recollection of memories of related situational and/or contextual information that relates to, and could influence present decision-making through a Bayesian mechanism of ecological observation, orientation and action [2,5,34]. While it might be possible that the observed hippocampal activation could, perhaps partially, be explained by different conditions relying more or less on short-term memory, we find it difficult to explain why the 3PP would rely more on short-term memory than the 1PP, since there were no statistical significant differences in assessments of sentence length, valence, or arousal.

Furthermore, an interaction between the ventromedial prefrontal cortex (vmPFC) and hippocampus has been suggested to mediate cognitive evaluations of the moral character of others [57]. Emotional salience is attributed to moral information by the involvement of the vmPFC, while hippocampal networks involved in memory retrieval enable necessary contextual information in order to make an appropriate character judgment. However, given that the vmPFC includes at least the ventral part of Brodmann's area 10 (BA 10; [58]), and appears to serve a binding function between aMPFC and the amygdala [59], we suggest that BA 10 may have a functional role in integrating emotional information (via enhanced

activation of the visual cortex), and recollective aspects of the decision-process; (possibly through hippocampal connections) that are involved in, and/or subserve moral cognition and judgments.

Thus, we posit that the vmPFC plays a role in emotional salience, while the aMPFC contributes to synthesizing the "moral" information, by integrating emotional and recollective information, thereby enabling appropriate strategies in moral decision-making. To summarize, we claim that the involvement of the hippocampus for the 3PP moral judgment can be explained through the results of recent studies that elucidated its role in understanding emotions and behaviors of others, while somewhat more "classical" hippocampal activity (i.e.- memory) plays a role in the recollection of stored related retrograde situational or contextual information. We consider the role of the hippocampus in 3PP moral judgments of crucial importance due to the psychological implications of these functional roles.

There is also a temporal aspect that may be involved, which would support the "actor-observer bias". If 1PP presentations engage evaluative cognition, then such processing is temporally related to the present [60,61]. The 3PP situation, however, relies on more abstract evaluations, which tend to be more time independent, in which inner characteristics of others may come into play. Moreover, if subjects distance themselves from the stimuli used in 1PP presentations, the time needed to evaluate these stimuli would be shorter than that needed to evaluate the stimuli in the 3PP condition, where memory processing would represent an important function in stimuli assessment.

An important aspect of the present study is the use of novel stimuli. Since moral dilemmas have already been used to study the "actor-observer bias" [27] a different approach, i.e. using moral reactions, may be helpful in extrapolating the findings. For this reason, control of emotional valence and duration of stimuli has been ensured. Such parameters, however, decrease the number of stimuli that were used. This may be problematic; however, due to the novelty of the approach used, a possible limitation in generalization seems suitable in order to gain greater experimental control over the stimuli.

Despite these limitations, the present findings suggest that different neural networks may be involved in, and subserve the perspective one has towards moral situations. A similar case was found for agency in moral judgments, for which different associated emotions were found to rely upon both distinct and overlapping neural substrates [62]. A psychological component, which could explain the neural differences found for moral perspective taking, is the actor-observer bias. Thus, care must be taken when interpreting neuroimaging studies of the neural bases of morality, since the perspective of the participants

towards the moral stimuli may indeed elicit distinct neural activation.

In summary, moral stimuli presented in either 1- or 3PP elicit both distinct (e.g. hippocampus, and visual cortex for 3PP) and common patterns of neural activation (e.g. in the self- or ToM networks). These results suggest that differences may be related to the “actor-observer bias”. In the 1PP presentation the stimuli were evaluated with regard to the situation. Since the participants could not control the situation (although it elicited a strong emotional response), we posit that subjects may have attempted to distance themselves from the stimuli by engaging in perspective shifting. The 3PP moral judgments seem to have been evaluated by considering the inner characteristics of the “actors”, through recollection(s) of relevant information and also by engaging in ToM processes.

The overlap in the self- and ToM networks suggests that self-processing may be a basis through which to experience complex emotions about others' mental state [39]. These findings do not imply identical psychological processes for these different perspectives, and do not contradict the suggested involvement of the “actor-observer bias”. We believe that the most important implication of this study is related to distinct mechanisms and processes of moral cognition. To date, research has posed that networks of the so-called “moral brain” are homogeneously activated, independent of the eliciting stimuli. This also implies that similar psychological processes subserve moral cognition and/or reasoning, irrespective of perception of, or orientation to the situation [15]. The present results, however, contrast this view, and suggest that different types of stimuli may indeed engage distinct types of neural activity and psychological processing, and that both reflect orientation to the situation, which may be influenced by a host of factors affecting cognitive biasing, inclusive of cultural differences and a variety of social effects.

While it has been offered that moral and ethical judgments and actions are “other-based” (see, for example, MacMurray [63]), it is important to note that any and all decisions - inclusive of moral judgments (affecting others) - emanate from, and in many ways are reciprocal to, and reflective of the self [2,3,5,64-66]. In this light, potentially moral situations are perceived differently depending upon one's orientation to, and relative involvement in the situation and circumstance, and its effect upon prior experience, past and present reinforcing and rewarding influences, and predicted outcomes and their impact upon self and others [67-69].

The results presented here suggest that while there appears to be something of a core neural network that is involved in the types of moral decisions rendered in this study, the spatial and temporal engagement of elements of this network are peculiar to distinct types and aspects of situation and circumstances. There are several

limitations of this study. First, the number of stimuli remaining after the pilot study was rather small. Therefore, we suggest that future studies employ a larger number of stimuli. This would also enable non-repetition of stimuli, thereby avoiding possible learning effects that have been shown to decrease BOLD signal - e.g. in visual cortex, PFC etc. [69,70]. Second, it remains somewhat uncertain to what extent participants attributed external causes to the 1PP, and internal causes to the 3PP, since the subjects were not required to describe the way in which they evaluated the stimuli. Future studies could employ a post-scanning interview during which subjects are asked to explain their decision-making processes.

Conclusion

In conclusion, we opine that the present study suggests differential patterns and mechanisms of 1PP and 3PP moral judgments. Such findings have implications for consideration of how moral decisions are made and morally-relevant acts are tendered (e.g.- “Good Samaritan” acts, “by-stander effects”, etc.), and prompt further inquiry to how patterns of neural activity may affect types and extent of behaviors in morally-relevant situations, and if and how such patterns of activity are stable, modifiable, and/or learned. Yet, we also advocate prudence in interpretation of these and related findings [2-4,7-9], as the limitations of fMRI, like any neurotechnology, must be appreciated (see van Meter [71] for overview).

This encourages engagement of neuroethics' second tradition, namely, an analysis of the ways that neuroscience and neurotechnology are, can, and should be employed to gain understanding of cognitions, emotions and behaviors, and how such information is used (in medicine, law and the public sphere). Indeed, while findings such as those presented in this study may be provocative, care must be taken in extrapolating such information to real-world circumstances, so as to avoid over- or under-estimating the role of neurobiology in psychological and social activity, and/or the capabilities of neuroscience and neurotechnology to address and answer perdurable and pressing questions about the “nature” of morality, and other dimensions of cognition, emotion and behavior.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

All authors contributed to study concept. MA was responsible for data collection, data analysis and interpretation, and manuscript preparation. EG and KF were responsible for data analysis and interpretation and critical review of the manuscript, MR and JB were responsible for data collection and preliminary data evaluation. YB, EP and JG made substantial contributions to interpretation of data, have been involved in developing and revising the manuscript for important intellectual content, and have given final approval of the version to be published.

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6. Eidesstattliche Versicherung

Eidesstattliche Versicherung

Avram, Mihai

Name, Vorname

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