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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 tstraint 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.

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 pro-

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

	Left						Right					
Brain region	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						

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

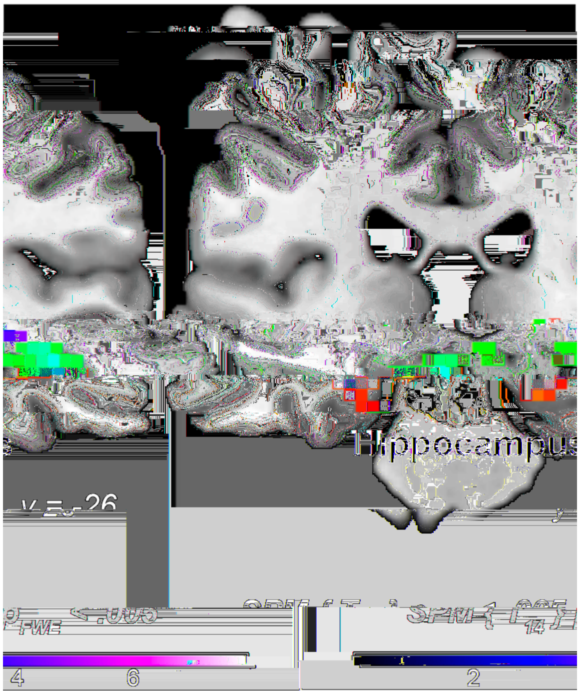

Figure 2 Neurofunctional correlates of 3- vs 1PP moral judgments.

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.

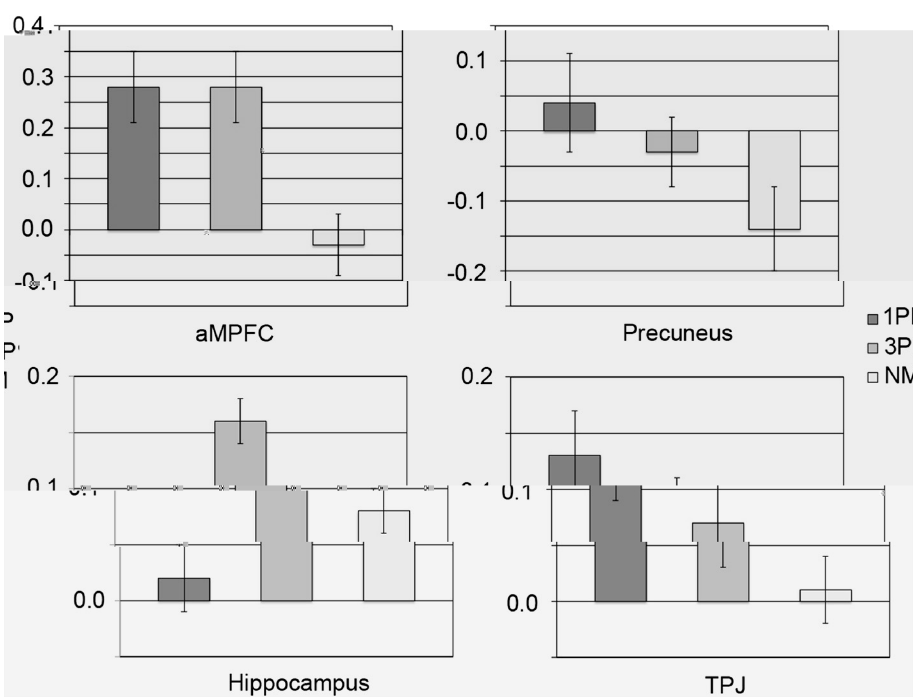

Figure 3 Region of interest analysis: anterior medial prefrontal cortex (aMPFC), precuneus, hippocampus, and temporoparietal junction (TPJ). Error bars denote standard error of the mean.

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].

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References

1. Roskies A: Neuroethics for the new millenium. *Neuron* 2002, 35(1):21–23.
2. Giordano J: Neuroethics: interacting 'traditions' as a viable meta-ethics. *AJOB Neurosci* 2011, 2(2):17–19.
3. Giordano J: Neuroethics: traditions, tasks and values. *Hum Prospect* 2011, 1(1):2–8.
4. Giordano J, Benedikter R: An early - and necessary - flight of the owl of Minerva: Neuroscience, neurotechnology, human socio-cultural boundaries, and the importance of neuroethics. *J Evol Technol* 2012, 22(1):14–25.
5. Giordano J, Benedikter R: Toward a systems' continuum: on the use of neuroscience and neurotechnology to assess and affect aggression, cognition and behavior. In *Topics in Neurobiology of Aggression: Implications for Deterrence. Strategic Multilayer Assessment Group.* Washington, DC: SMA Publications; 2013:69–85.
6. Uttal WR: *The New Phrenology: The limits of localizing cognitive processes in the brain.* Cambridge, MA: MIT Press; 2001.
7. Bao Y, Pöppel E: Anthropological universals and cultural specifics: Conceptual and methodological challenges in cultural neuroscience. *Neurosci Biobehav Rev* 2012, 36:2143–2146.
8. Giordano J: Integrative convergence in neuroscience: trajectories, problems and the need for a progressive neurobioethics. In *Technological Innovation in Sensing and Detecting Chemical, Biological, Radiological, Nuclear Threats and Ecological Terrorism. (NATO Science for Peace and Security Series).* Edited by Vaseashta A, Braman E. NY: Springer; 2012.
9. Giordano J: Neurotechnology as deimurgical force: avoiding Icarus folly. In *Neurotechnology: Premises, Potential and Problems. Edited Giordano J.* Boca Raton: CRC Press; 2012:1–14.
10. Greene JD, Sommerville RB, Nystrom LE, Darley JM, Cohen JD: An fMRI investigation of emotional engagement in moral judgment. *Science* 2001, 293:2105–2108.
11. Greene J, Haidt J: How (and where) does moral judgment work? *Trends Cogn Sci* 2002, 6:517–523.
12. Zaidel DW, Nadal M: Brain Intersections of Aesthetics and Morals: Perspectives from Biology, Neuroscience, and Evolution. *Perspect Biol Med* 2011, 54:367–380.
13. Tsukiura T, Cabeza R: Shared brain activity for aesthetic and moral judgments: implications for the Beauty-is-Good stereotype. *Soc Cogn Affect Neurosci* 2010. doi:10.1093/scan/nsy025.
14. Avram M, Gutyrchik E, Bao Y, Pöppel E, Reiser M, Blautzik J: Neurofunctional correlates of aesthetic and moral judgments. *Neurosci Lett* 2013, 534:128–132. doi:10.1016/j.neulet.2012.11.053.
15. Moll J, Zahn R, de Oliveira-Souza R, Krueger F, Grafman J: Opinion: the neural basis of human moral cognition. *Nature Rev Neurosci* 2005, 6:799–809.
16. Casebeer WD: The Neural mechanisms of moral cognition: a multiple-aspect approach to moral judgment and decision-making. *BiolPhilos* 2003, 18:169–194.
17. Verplaetse J, DeSchrijver J, Vanneste S, Braeckman J: *(Eds.). The Moral Brain.* Heidelberg: Springer Verlag; 2009.
18. Young L, Dungan J: Where in the brain is morality? Everywhere and maybe nowhere. *Soc Neurosci* 2012, 7(1):1.
19. Monin B, Pizarro D, Beer JS: Deciding versus reacting: conceptions of moral judgment and the reason- affect debate. *Rev Gen Psychol* 2007, 11:99–111.
20. Vogeley K, Fink G: Neural correlates of the first-person perspective. *Trends Cogn Sci* 2003, 7:38–42.
21. Ruby P, Decety J: Effect of subjective perspective taking during simulation of action: a PET investigation of agency. *Nat Neurosci* 2001, 4:546–550.
22. Ruby P, Decety J: What you believe versus what you think they believe: a neuroimaging study of conceptual perspective-taking. *Eur J Neurosci* 2003, 17:2475–2480. doi:10.1046/J.1460-9568.2003.02673.X.
23. Ruby P, Decety J: How would you feel versus how do you think she would feel? A neuroimaging study of perspective-taking with social emotions. *J Cogn Neurosci* 2004, 16:988–999. doi:10.1162/0898929041502661.
24. Ramsey R, Hansen P, Apperly I, Samson D: Seeing it my way or your way: frontoparietal brain areas sustain viewpoint-independent perspective selection processes. *J Cogn Neurosci* 2013, 25(5):670–684.
25. Ochsner KN, Knierim K, Ludlow DH, Hanelin J, Ramachandran T, Glover G: Reflecting upon feelings: An fMRI study of neural systems supporting the attribution of emotion to self and other. *J Cog Neurosci* 2004, 16:1746–1772.
26. Jones EE, Nisbett RE: *The actor and the observer: Divergent perceptions of the causes of behavior.* New York: General Learning Press; 1971.
27. Nadelhoffer T, Feltz A: The Actor–Observer Bias and moral intuitions: Adding fuel to Sinnott-Armstrong's fire. *Neuroethics* 2008, 1(2):133–144.
28. Takahashi H, Yahata N, Koeda M, Matsuda T, Asai K, Okubo Y: Brain activation associated with evaluative processes of guilt and embarrassment: an fMRI study. *Neuroimage* 2004, 23:967–974.
29. Foot P: The Problem of abortion and the Doctrine of the Double Effect in virtues and vices. *Oxford Rev* 1967, 5:5–15.
30. Thomson JJ: Killing, letting die, and the trolley problem. *The Monist* 1976, 59:204–217.
31. Greene JD: The secret joke of Kant's soul. In *Moral Psychology, Vol. 3: The Neuroscience of Morality.* Edited by Sinnott-Armstrong W. Cambridge, MA: MIT Press; 2008.
32. Lewicki MS, Sejnowksi TJ: Bayesian unsupervised learning of higher order structure. In *Advances in Neural Information Processing Systems 9.* Edited by Mozer M, Jordan M, Petsche T. Cambridge, MA: MIT Press; 1997:529–535.
33. Rao RN: Bayesian computation in recurrent neural circuits. *Neural Comput* 2004, 16(1):1–38.
34. Boyd JR: Destruction and creation. *Lecture presented to the U.S. Army Command and General Staff College.* 3 September, 1976.
35. Grossberg S: Linking attention to learning, expectation, competition, and consciousness. In *Neurobiology of Attention.* Edited by Itti L, Rees G, Tsotsos JK. San Diego: Elsevier; 2005:652–662.
36. Shadlen M, Gold JI: The neurophysiology of decision-making as a window on cognition. In *The Cognitive Neurosciences.* 3rd edition. Edited by Gazzaniga MS. Cambridge: MIT Press; 2004:1229–1441.
37. Fumagalli M, Prior A: Functional and clinical neuroanatomy of morality. *Brain* 2012, 135(7):2006–20021.
38. Raine A, Yang Y: Neural foundations to moral reasoning and anti-social behavior. *Soc Cogn Affect Neurosci* 2006, 3:203–213.
39. Immordino-Yang MH, Singh V: Hippocampal contributions to the processing of social emotions. *Hum Brain Mapp* 2011. doi:10.1002/hbm.21485.
40. Perry D, Hendler T, Shamay-Tsoory SG: Projecting memories: the role of the hippocampus in emotional mentalizing. *Neuroimage* 2011, 54:1669–1676.
41. Tzourio-Mazoyer N, Landeau B, Papathanassiou D, Crivello F, Etard O, Delcroix N: Automated anatomical labeling of activations in SPM using a macroscopic anatomical parcellation of the MNI MRI single-subject brain. *Neuroimage* 2002, 15(1):273–289.
42. Amodio DM, Frith CD: Meeting of the minds: The medial frontal cortex and social cognition. *Nature Re Neurosci* 2006, 7:268–277.
43. Brett M, Johnsrude I, Owen A: The problem of functional localization in the human brain. *Nature Rev Neurosci* 2002, 3:243–249.
44. Gallagher HL, Frith CD: Functional imaging of 'theory of mind'. *Trends Cog Sci* 2003, 7(2):77–83.
45. Burgess PW, Simons JS, Dumontheil I, Gilbert SJ: The gateway hypothesis of rostral prefrontal cortex (area 10) function. In *Measuring the Mind: Speed, Control, and Age.* Edited by Duncan J, McLeod P, Phillips L. Oxford: Oxford University Press; 2005:215–246.

46. Koenigsberg HW, Fan J, Ochsner KN, Liu X, Guise K, Pizzarello S, Dorantes C, Tecuta L, Guerreri S, Goodman M, New A, Flory J, Siever LJ: Neural correlates of using distancing to regulate emotional responses to social situations. *Neuropsychologia* 2010, 48(6):1813–1822. doi: 10.1016/j.neuropsychologia.2010.03.002
47. Ramnani N, Owen AM: Anterior prefrontal cortex: insights into function from anatomy and neuroimaging. *Nature Revs Neurosci* 2004, 5(3):184–194.
48. Cavanna AE, Trimble MR: The precuneus: a review of its functional anatomy and behavioural correlates. *Brain* 2006, 129:564–583.
49. Decety J, Sommerville JA: Shared representations between self and others: a social cognitive neuroscience view. *Trends Cog Sci* 2003, 7:527–533.
50. Phan K, Wager T, Taylor S, Liberzon I: Functional neuroanatomy of emotion: a meta-analysis of emotion activation studies in PET and fMRI. *Neuroimage* 2002, 16:331–348.
51. Sparing R, Mottaghy FM, Ganis G, Thompson WL, Töpper R, Kosslyn SM, Pascual-Leone A: Visual cortex excitability increases during visual mental imagery – a TMS study in healthy human subjects. *Brain Res* 2002, 938:92–97.
52. Morris JS, Ohman A, Dolan RJ: Conscious and unconscious emotional learning in the human amygdala. *Nature* 1998, 393:467–470.
53. Croft KE, Duff MC, Anderson SW, Adolphs R, Tranel D: *Bilateral amygdala damage is associated with reduced updating of character judgments.* Chicago, IL: Paper presented at the annual conference of the Society for Neuroscience; 2009.
54. Rosenbaum RS, Stuss DT, Levine B, Tulving E: Theory of mind is independent of episodic memory. *Science* 2007, 318:1257.
55. Manns JR, Hopkins RO, Reed JM, Kitchener EG, Squire LR: Recognition memory and the human hippocampus. *Neuron* 2003, 37:171–180.
56. Strange BA, Fletcher PC, Henson RNA, Friston KJ, Dolan RJ: Segregating the functions of human hippocampus. *PNAS USA* 1999, 96:4034–4039.
57. Wood ER, Dudchenko PA, Robitsek RJ, Eichenbaum H: Hippocampal neurons encode information about different types of memory episodes occurring in the same location. *Neuron* 2000, 27:623–633.
58. Croft KE, Duff MC, Kovach CK, Anderson SW, Adolphs R, Tranel D: Detestable or marvelous? Neuroanatomical correlates of character judgments. *Neuropsychologia* 2010, 48(6):1789–1801.
59. Quirk GJ, Russo GK, Barron JL, Lebron K: The role of ventromedial prefrontal cortex in the recovery of extinguished fear. *J Neurosci* 2000, 20(16):6225–6231.
60. Urry HL, van Reekum CM, Johnstone T, Kalin NH, Thurow ME, Schaefer HS, Jackson CA, Frye CJ, Greischar LL, Alexander AL, Davidson RJ: Amygdala and ventromedial prefrontal cortex are inversely coupled during regulation of negative affect and predict the diurnal pattern of cortisol secretion among older adults. *J Neurosci* 2006, 26:4415–4425.
61. Pöppel E: Pre-semantically defined temporal windows for cognitive processing. *Phil Trans Royal Soc B* 1887–1896, 2009:364.
62. Pöppel E, Bao Y: Temporal windows as bridge from objective to subjective time. In *Subjective Time.* Edited by Lloyd D, Arstila V. Cambridge, MA: MIT Press. in Press.
63. Moll J, de Oliveira-Souza R, Garrido GJ, Bramati IE, Caparelli-Daquer EM, Paiva ML, Zahn R, Grafman J: The self as a moral agent: linking the neural bases of social agency and moral sensitivity. *Social Neurosci* 2007, 2(3-4):336-352. doi:10.1080/17470910701392024.
64. MacMurray J: *Persons in Relation.* London: Faber and Faber; 1961.
65. Pöppel E: Perceptual identity and personal self: neurobiological reflections. In *Personality from Biological, Cognitive, and Social Perspectives.* Edited by Maruszewski T, Malgorzata Fajkowska M, Eysenck MM. New York: Eliot Werner Publications, Clinton Corners; 2010:75–82.
66. Shaver R: *Rational Egoism: A Selective and Critical History.* Cambridge: Cambridge University Press; 1998.
67. Trivers RL: The evolution of reciprocal altruism. *Quarterly Review of Biology* 1971, 46:35–57.
68. Schino G, Aureli F: A few misunderstandings about reciprocal altruism. *Commun Integr Biol* 2010, 3(6):561–563.
69. Stephens C: Modeling reciprocal altruism. *Br J Phil Sci* 1996, 47(4):533–551.
70. Segaert K, Weber K, De Lange F, Petersson KM, Hagoort P: The suppression of repetition enhancement: A review of fMRI studies. *Neuropsychologia* 2013, 51:59–66.
71. VanMeter J: Neuroimaging. In *Scientific and Philosophical Perspectives in Neuroethics.* Edited by Giordano J, Gordijn B. Cambridge: Cambridge University Press; 2010:230–239.

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