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Imagining being the agent of actions that carry different moral consequences: An fMRI study

Jean Decety^{a,b,*}, Eric C. Porges^a

^a Department of Psychology and Center for Cognitive and Social Neuroscience, The University of Chicago, 5848 S. University Avenue, Chicago, IL 60637, United States

^b Department of Psychiatry and Behavioral Neuroscience, The University of Chicago, 5848 S. University Avenue, Chicago, IL 60637, United States

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ABSTRACT

To investigate the contribution of agency to neural processing involved in aggression and morality, participants viewed in the MRI scanner a series of short visual scenarios in which an individual was either intentionally harming another person or easing the other's pain. They were required to mentally simulate being the perpetrator or the recipient of those actions. Functional connectivity analyses demonstrate that positive agency (easing the pain of another) was associated with increased activity in ventral striatum, while negative agency (harming the other) resulted in a strong signal decrease in the ventromedial prefrontal cortex and activation in the amygdala. Overall, our data show that explicit perspective taking strategy has profound impact on the neural recruitment associated with distinct behaviors as well as their moral consequences. Results from this study can inform new strategies both for therapeutic interventions for patients with socioemotional disorders and the education of medical practitioners.

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1. Introduction

While the domain of moral psychology is quite old, the past decade has seen an explosion of empirical research of the neural bases of morality, building on advances in functional neuroimaging in healthy subjects as well as on brain lesions in neurological patients. The diverse literature on the neural mechanisms of moral cognition can be divided into three domains: moral emotions, theory of mind, and abstract reasoning. The link between these different domains is becoming increasingly clear. Converging results from lesion (Bramham, Norris, Hornak, Bullock, & Polkey, 2009; Eslinger et al., 2009; Mendez, Anderson, & Shapira, 2005; Young et al., 2010) and functional neuroimaging studies (Decety, Michalska, & Kinzler, in press; Greene, Sommerville, Nystrom, Daley, and Cohen, 2001; Moll et al., 2007; Moll, de Oliveira-Souza, Bramati, & Grafman, 2002) indicate the specific roles for the ventromedial prefrontal cortex (vmPFC), anterior cingulate cortex (ACC), anterior insular cortex (AIC), amygdala, and posterior part of the superior temporal sulcus (pSTS) in moral cognition (see Moll, Zahn, de Oliveira-Souza, Krueger, & Grafman, 2005; Young, 2011, for

reviews). Notably, an emotional learning system (mediated by the amygdala) and a system for decision making on via reinforcement expectations (mediated by the vmPFC) are crucial for cueing morally appropriate behavior and the acquisition of moral knowledge during childhood (Blair & Blair, 2009). Moral reasoning is thus underpinned by specific neural circuitry, but these circuits are not unique to morality, rather, they involve regions and systems underlying specific states of feelings, cognitive, and motivational processes.

Most of the past functional neuroimaging studies have used paradigms contrasting putatively moral to non-moral visual stimuli or written scenarios (e.g., moral dilemmas) in which the participants were required to make a judgment (right or wrong) or to imagine what they would feel if they were in these situations. An important, yet less explored, component of the moral calculus is the role of agency. Clearly society and law require that people are responsible for their actions. The subjective experience of agency tells us when we are responsible and when we are not. The sense of agency is thus a major dimension to be appreciated in relation to morality in that people can be held responsible for their actions and are expected to pay for their consequences. The sense of agency refers to the subjective awareness that one is initiating, executing, and controlling one's own volitional actions in the world (Gallagher, 2000). It is the pre-reflective awareness or implicit sense that it is 'me' who is presently executing bodily movements or thinking thoughts. In normal, non-pathological experience, the sense of

* Corresponding author at: Department of Psychology and Center for Cognitive and Social Neuroscience, The University of Chicago, 5848 S. University Avenue, Chicago, IL 60637, United States.

E-mail address: decety@uchicago.edu (J. Decety).

agency is tightly integrated with one's sense of ownership, which is the pre-reflective awareness or implicit sense that one is the owner of an action, movement or thought (Jeannerod, 2003).

The purpose of the present study was to explore the influence of agency upon moral cognition by contrasting intentions and actions that have opposite moral consequences (harming vs. helping another), based on a combination of two well-established and validated paradigms of pain empathy and mental simulation of action, respectively.

A large number of studies have reliably demonstrated that perceiving or imagining people in pain is associated with the activation of a restricted number of regions which are similarly recruited during the first-person experience of pain. These regions include the AIC, anterior midcingulate cortex (aMCC), dorsal anterior cingulate cortex (dACC), supplementary motor area (SMA), periaqueductal gray (PAG), and less consistently the somatosensory cortex (Jackson, Rainville, & Decety, 2006; Lamm, Decety, & Singer, 2011 for meta-analyses). Activation of these regions reflects a general aversive arousal response coupled with motor preparation of defensive actions, which is not specific to nociception (Decety, 2011; Yamada & Decety, 2009). It is important to note that studies investigating pain empathy have not yet addressed the contribution of the sense of agency. In most of these past studies, participants were asked to passively view facial expression of pain, body parts in pain, people being harmed, or view a cognitive cue indicating that someone is hurt or harmed.

Mental simulation is an effective means to investigate the neural underpinnings of action representation, both in terms of computational and neural mechanisms. In the domain of motor cognition, theoretical and empirical arguments support a model that actions involve a covert stage (Jeannerod, 2001). This covert stage is a representation of the future, which includes the goal of the action, the means to reach it, and its consequences on the organism and the external world. Covert and overt stages thus represent a continuum, such that every overtly executed action implies the existence of a covert stage, although a covert action does not necessarily become an overt action (Jeannerod, 1994). The simulation theory developed by Jeannerod and colleagues postulates that covert actions are in fact actions, except for the fact that they are not executed (Jackson & Decety, 2004; Jeannerod & Decety, 1995; Jeannerod & Frak, 1999; Jeannerod & Pacherie, 2004). The theory therefore predicts a similarity, in neural computations, between the state where an action is simulated and the state of execution of that action (Hesslow, 2002). Support for this theory comes from neuroimaging studies which have shown that when participants mentally simulate actions (e.g., Decety et al., 1994; Roth et al., 1996; Ruby & Decety, 2001), imagine experiencing emotions (Preston et al., 2007; Ruby & Decety, 2004), or imagine being in pain (Jackson, Brunet, Meltzoff, & Decety, 2006; Lamm, Batson, & Decety, 2007), neural responses are similar to those seen during the authentic experience of acting, feeling, or experiencing pain. Imagining oneself involved in an action or a situation can thus be used to elicit neural activity that closely parallels that of the actual situation (Decety & Grèzes, 2006).

In the domain of moral agency, the perception of an action as intentional (as opposed to accidental) has been shown to determine the perceived "wrongness" of the action (Cushman, 2008), which has various consequences. We feel less responsible for our own actions when we do not feel they were carried out intentionally, and we do not blame others as harshly when they commit an infraction unintentionally (Kahn, 1992). This view is confirmed in the empirical research and also in the laws of our legal systems, where even an offense serious enough to result in the death of another has explicitly different categories of crime to account for agency or intentionality. The concept of agency is closely intertwined with intentionality, requiring intentionality as well as forethought and self-reactiveness (Bandura, 2006). Within this concept, action can-

not be reflexive, but rather a self-initiated behavior emanating from the individual.

In the present study, we investigated the impact of perspective taking on moral agency by contrasting the mental simulation of actions that lead to opposite consequences (harming vs. helping). In the scanner, participants were presented with short video clips depicting two individuals interacting and were asked to adopt the perspective of one of the actors in the clip. The actions depicted in the clips involved either an individual intentionally harming another or an individual helping another. By comparing neuro-hemodynamic responses and more importantly changes in functional connectivity to different perspectives, we can identify patterns of communication between regions involved in simulation of action and determine how the moral consequences of an action might modulate such networks. It is predicted that taking the perspective of an individual harming another will be associated with reduced activation of the vmPFC compared to taking the perspective of the victim. Taking the perspective of a victim is likely to produce a strong hemodynamic response in the pain matrix and areas involved in defensive behaviors. Finally, drawing on studies showing that doing good makes us feel good (Brown, Nesse, Vonokur, & Smith, 2003; Post, 2005), we predicted a statistical association between the amygdala and activity in the ventral striatum when participants imagined being the agent of benevolent actions.

2. Materials and methods

2.1. Participants

Twenty-two right-handed male participants aged 19–26 years were recruited for this experiment via a study pool. They provided informed written consent and were paid for their participation. All participants reported no history of neurological, psychiatric, or major medical disorder, and no current use of psychoactive medications at the time of the study. The study was approved by the local Ethics Committees (University of Chicago and University of Oregon, where scanning was performed), and conducted in accordance with the Declaration of Helsinki.

2.2. Dispositional measures

To exclude atypical subjects, a series of self-report questionnaires evaluating emotional awareness, empathy, and pain were completed several weeks before the functional MRI experiment. These questionnaires included the Toronto alexithymia scale (TAS-20), the interpersonal reactivity index (IRI) (Davis, 1994), the emotional contagion questionnaire (Doherty, 1997). The TAS-20 measures emotional self-awareness. The IRI is the most widely used self-report measure of dispositional empathy. Its four subscales (empathic concern, perspective taking, fantasy scale and personal distress) assess different aspects of interpersonal affective responses. The emotional contagion questionnaire (ECQ) assesses the susceptibility to other's emotions from afferent feedback generated by mimicry. Only individuals in the typical range for these tests were recruited for the present study.

2.3. Stimuli and experimental design

The stimuli consisted of a series of 72 animated visual sequences comprised of photographs depicting two human actors, whose torsos and limbs were visible but not their face. All stimuli showed two individuals interacting, where one individual was either intentionally harming the other or alleviating their pain. Baseline trials consisted of two actors executing actions that were matched to the helping and hurting stimuli, but differed in that the actors did not physically interact with one another. The animated stimuli were created and validated for this study: validation was conducted by 222 participants who were shown the dynamic stimuli and asked to estimate how painful the situations were and whether they believed that pain had been inflicted or alleviated and in cases where there was an interaction between the actors, was it intentional (Estabrook, 2007). Each animation consisted of three digital color pictures, which were edited to the same size (600 × 480 pixels). The durations of the first, second, and third pictures were 1000 ms, 200 ms and 1000 ms, respectively. Six sessions were run, each consisting of a unique condition with 24 animated stimuli of a single class, presented in a block design.

Prior to the scanning session, participants were familiarized with the stimuli and trained with the perspective-taking instructions with stimuli for each perspective-taking task. Those stimuli were not used in the scanning session. Before each functional MRI run of a given type of perspective taking, participants were given verbal instructions to insure understanding and compliance with the task. In addition, prior to each block, participants were presented with a brief instruction screen describing the type of perspective that they had to take for the given condition, i.e.,

“imagine you are harming the other”; “imagine you are being harmed by the other”; “imagine you are alleviating the pain of the other”; “imagine you are being helped by the other”; “imagine you are the one who is moving”; “imagine you are the one who is still”.

2.4. MRI scanning

Stimuli and instructions were presented with the E-prime software (Psychology Software Tools, Inc., Pittsburgh, PA) via a back projection system. Subjects' responses were recorded with a button box. A block design was used with 7 baseline blocks (duration 8 s each) during which a fixation cross was presented, interleaved with 6 stimulation blocks of a single condition. Each block included of 4 animations with an inter-stimulus interval of 18 s, followed by one question about the difficulty/ease with a visual analogue scale (VAS), and then an inter block interval of 8 s. These questions were asked to ensure that participants were actively participating in the task.

Eye-tracking was continuously monitored and recorded during scanning with the ASL system (Applied Science Laboratories, Bedford, MA, USA) to insure that participants were alert during the entire scanning session.

MRI data were acquired on a 3 Tesla Siemens Magnetom Allegra equipped with a standard quadrature head coil. Changes in blood-oxygenation-level-dependent (BOLD) signal were measured using a T2*-weighted single-shot echoplanar imaging (EPI) sequence (repetition time TR = 1810 ms, echo time TE = 30 ms, flip angle = 80°, 30 axial slices/volume with 45 mm slice thickness, no gap, in-plane resolution = 328 mm × 328 mm, 64 × 64 matrix, FOV 210 mm × 210 mm). Each run was preceded by several dummy scans ensuring steady state magnetization conditions.

2.5. Functional MRI data analyses

Image processing was performed with SPM5 (Wellcome Department of Imaging Neuroscience, London, UK), implemented in MATLAB 7 (Mathworks Inc., Sherborn, MA, USA). Preprocessing included correction for head motion (realignment to mean image volume, using the default unwarp and realign function to account for susceptibility-movement interactions in orbitofrontal regions), normalization from the mean realigned and unwrapped EPI image to the EPI template provided in SPM5 (normalization performed using default SPM parameters), and smoothing using a 6 mm FWHM isotropic Gaussian kernel. Event-related responses were assessed by setting up fixed effects general linear models (GLM) for each subject. Regressors of interest modeling the experimental conditions, the instruction display and fixation epochs were defined and convolved with the canonical hemodynamic response function (HRF). All models included a high-pass filter with a cut-off at 128 s in order to remove scanner drifts. Region of interest (ROI) parameter estimates were extracted using *rfxplot* (Gläscher, 2009) and predefined anatomical masks from the Anatomical Automatic Labeling toolbox (Tzourio-Mazoyer et al., 2002).

2.6. Analyses of functional segregation

Following model estimation, contrasts were calculated for each subject to assess differences between conditions and in relation to the implicitly modeled fixation baseline were assessed. The resulting first-level contrast images were entered into second-level random effects (RFX) analyses to assess differences between conditions with population inference. Activation differences against baseline were interpreted using a voxel-level threshold of $p = 0.01$ and a spatial extent threshold of $k = 10$, corrected for multiple comparisons across the whole volume using the false discovery rate (FDR, $p < 0.05$) approach (Genovese, Lazar, & Nichols, 2002). The more subtle activation differences between conditions (main effects and interactions) were assessed using a voxel-level threshold of $p = 0.001$ and $k = 10$ continuous voxels, uncorrected for multiple comparisons on a priori defined regions of interest. The choice of these thresholds was based upon exploratory data analyses and upon effect size considerations derived from similar experiments of pain empathy using similar stimuli (Akitsuki & Decety, 2009; Decety & Michalska, 2010; Decety, Michalska, & Akitsuki, 2008; Jackson, Brunet, et al., 2006; Jackson, Meltzoff, & Decety, 2005; Jackson, Rainville, et al., 2006; Lamm, Batson, et al., 2007; Lamm, Nusbaum, Meltzoff, & Decety, 2007).

Significant clusters were anatomically labeled using structural neuroanatomy information and probabilistic cytoarchitectonic maps provided in the anatomy toolbox, version 14 (Eickhoff et al., 2005). For brain regions not covered by the toolboxes, the Duvernoy brain atlas was used (Duvernoy, 1991).

2.7. Effective connectivity analyses

Psychophysiological interaction (PPI) analyses (Friston et al., 1997) were performed to identify the brain regions that showed stronger covariation with left amygdala in the context of taking the perspective of the actor or victim in both the helping and harming conditions. This region was selected upon an *a priori* hypotheses based on two meta-analyses of neuroimaging studies on the amygdala and its role in emotion processing. One analysis found differences in temporal dynamics and habituation rates, specifically a shorter duration responses in the right amygdala to emotional-laden stimuli and more sustained ones in the left amygdala (Sergeier, Chochol, & Armony, 2008). The other meta-analysis showed a significantly greater

proportion of studies reporting left amygdala activation in emotion processing (Baas, Aleman, & Kahn, 2004). Further it is known that the amygdala has feed-forward and feed-back connections with many regions brain thought to be involved in perspective taking, pain representation and moral reasoning (Hoistad & Barabas, 2008).

Individual volumes of interest (ROIs) were defined as a 3-mm radius sphere. The center of this sphere was the local maximum nearest to the respective cluster maximum determined by the main effect of the segregation analysis (i.e., Passive Helping trials > baseline). The significance threshold for ROI extraction was set to $p = 0.05$, $k = 10$. PPI analyses were performed in the following way: (1) extraction of the time-series data of the first eigenvariate of the seed ROI (low-pass filtered and mean corrected, BOLD-deconvolved) to get an estimate of the actual neural response; (2) generating a vector contrasting the time-series of the estimated neural response for the targeted conditions (representing the interaction between the psychological and physiological factors, i.e., the PPI regressor), a second vector representing the main effect of the selected contrast (the psychological variable, i.e., the P regressor), and a third vector representing the ROI time course (the physiological variable, Y regressor); and (3) forward-convolving these regressors with the canonical hemodynamic response function in order to estimate the effects of the PPI regressor. The resulting statistical parametric maps (SPMs) showed clusters for which connectivity differed in the chosen conditions.

3. Results

3.1. Effect of agency (passive and active)

The main effect of imagining being a passive agent relative to imagining being an active agent resulted in signal increase in the network of brain regions that control attention orienting including the frontal eye fields, superior colliculus, superior parietal lobe, inferior frontal gyrus, and temporal parietal junction (Corbetta & Shulman, 2002; Posner & Rothbart, 2007), as well as regions that belong to the pain neuromatrix, namely the dACC, aMCC, AIC, SMA, and thalamus (Jackson, Brunet, et al., 2006; Jackson, Rainville, et al., 2006; Lamm et al., 2011; Price, 2000) (supplementary Table 1). The reverse contrast, all active conditions versus all passive conditions, showed no significant effects at $p < 0.005$, uncorrected.

3.2. Effect of valence (hurting and helping)

The main effect of all hurting conditions relative to all helping conditions recruited regions involved in visual processing including the frontal eye fields and the lingual gyrus, as well as the periaqueductal gray, ventrolateral prefrontal cortex, and the middle frontal gyrus (supplementary Table 2).

The main effect for the reverse contrast, all helping conditions compared to all hurting conditions showed activation in the dorsolateral prefrontal cortex, somatosensory cortex, SMA, pons, and right TPJ (supplementary Table 3).

3.3. Imagining helping and harming another

When participants imagined helping another relative to imagining harming another individual, signal increase was detected in the right dorsolateral prefrontal cortex, ventral striatum, and right posterior temporal cortex/TPJ (supplementary Table 4). The reverse contrast, comparing imagining harming versus imagining helping another, was associated with increased activity in the left dorsolateral prefrontal cortex, ventrolateral prefrontal cortex and inferior frontal gyrus (supplementary Table 5). Regions significantly more active when participants imagined being the passive agent of neutral actions (neither harming nor helping) versus being an active agent carrying out these actions included the dorsal prefrontal frontal cortex, medial prefrontal cortex, somatosensory cortex and temporal poles. No regions were significantly more active when participants imagined being the active agent versus the passive agent of neutral actions at $p < 0.005$ uncorrected.

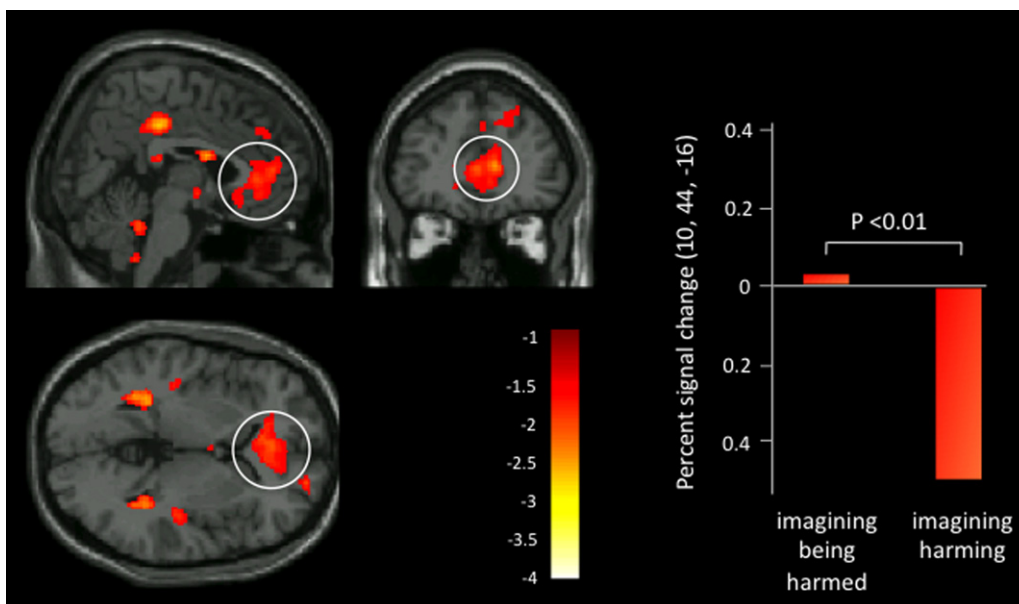


Fig. 1. Neuro-hemodynamic decrease in the medial orbitofrontal cortex when participants imagined harming another vs. imagined being harmed. Bar graph shows % signal change relative baseline ($p < 0.05$).

3.4. Imagining injuring another individual

Consistent with previous research (Pietrini, Guazzelli, Basso, Jaffe, & Grafman, 2000), a deactivation of the medial orbitofrontal cortex was observed across conditions where participants imagined harm occurring (imagine being hurt and imagine hurting another) were collapsed and compared to baseline. This deactivation was still significant ($p < 0.05$) when imagining hurting was contrasted with imagining being hurt (Fig. 1).

3.5. Imagining oneself being injured

Imagining oneself as the victim contrasted with imagining oneself as the aggressor produced a strong hemodynamic response in the pain matrix, including the ACC, anterior and middle insula, somatosensory cortex and the SMA (supplementary Table 6). Activation of areas involved in preparation of defensive behaviors was also found in regions supportive of motor response (motor cortex), autonomic arousal (aMCC), as well as enhanced activity in visual processing regions (cuneus and calcarine sulcus). In addition, for this contrast an anatomically defined region of interest (ROI) analysis for bilateral amygdala showed a relative increase in percent signal change (psc) when subjects imagined being harmed and a relative decrease in the same region when they imagined themselves harming another individual (Fig. 2).

3.6. Imagining helping and imagining being helped

When participants were imagining helping another versus being helped, activation was detected in the parietal cortex, septal nuclei and temporal poles (supplementary Table 7). The reverse contrast, imagining being helped versus imagining helping another individual was associated with signal increase in the anterior cingulate cortex, dorsomedial and ventromedial prefrontal cortex, and in the SMA (supplementary Table 8).

3.7. Functional connectivity

Functional connectivity for all contrasts were assessed with a PPI analysis seeded from the left amygdala. The selection of the

left amygdala was based on the results of two meta-analyses that demonstrated a more reliable (Baas et al., 2004) and longer duration response to emotional-laden stimuli (Sergerie et al., 2008). When subjects imagined being harmed contrasted with imagining harming another PPI analysis indicated a co-activation of neural networks involved in attention orientation (frontal eye fields, superior colliculus, interparietal sulcus), as well as areas involved in representation of physiological state (somatosensory cortex), physiological arousal (medial ACC) (Critchley et al., 2003), representation of negative emotion (temporal poles) (Jimura, Koniski, & Miyashita, 2009) and multisensory integration (right medial temporal lobe) (Hoistad & Barabas, 2008) (supplementary Table 9).

When subjects imagined alleviating the pain of another (contrasted with imagining having their pain alleviated), increased

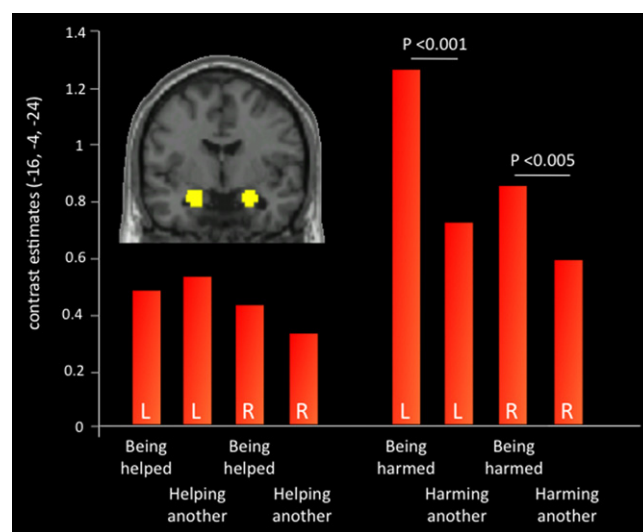


Fig. 2. Region of interest analysis (ROI) showed that in both the left and right amygdala activation was observed when participants imagined being harmed compared to when they imagined harming another ($p < 0.005$, FDR corrected). No significant signal change difference was observed in the left and right amygdala for the condition where participants imagined having their pain alleviated compared to imagining alleviating another's pain.

functional connectivity with the left amygdala was observed in areas involved in monitoring cognitive conflict and decision making (anterior cingulate cortex, ventrolateral prefrontal cortex, ventromedial prefrontal cortex and dorsolateral prefrontal cortex), areas associated with motor preparation and proprioception (supplementary motor area and posterior insula), regions responsive to aversive stimuli and visceral disgust (insula) and structures that are recruited for behavioral reinforcement (ventral striatum, $x = -12$, $y = 6$, $z = -10$) (see [supplementary Table 10](#)).

When participants imagined having their pain alleviated (contrasted with imagining alleviating the pain of another), functional connectivity revealed covariance with left amygdala in areas involved in pain representation, motor preparation and autonomic arousal (periaqueductal gray, primary somatosensory cortex and medial cingulate cortex), regions involved in visual processing and attention (precuneus, calcarine fissure, superior colliculus, bilateral inferior parietal lobule and right superior parietal lobule), and structures utilized in cognitive reasoning and decision making (dorsolateral PFC and ventromedial PFC) ([supplementary Table 11](#)).

3.8. Dispositional measures and relationship to brain activation

No significant correlation was found between the self-report measures (IRI, TAS-20, SPQ, and EC) and the hemodynamic response at the whole brain level or in the ROIs, except for an association between the emotion contagion sub-scale of the IRI and activity in the ACC ($r = .44$, $p < 0.05$) and the SMA ($r = .50$, $p < .02$) when participants imagined having their pain alleviated.

4. Discussion

This study was designed to examine the impact of perspective taking on neural networks underpinning simulation of actions with different moral consequences. The findings support our hypothesis, showing distinctly different patterns of hemodynamic response as a function of agency and consequences of actions, in brain circuits previously implicated in aggression, nociception, orienting-attention and mobilization.

Not surprisingly, neural regions of the pain matrix were activated during the imagination of being harmed by another. These regions include the aMCC, dorsal ACC, SMA, PAG, insula and the somatosensory cortex. This finding is consistent with previous work, using similar visual stimuli, which has shown that the observation or even the imagination of people in pain is sufficient to elicit activation in neural circuits implicated in the processing of a nociceptive experience (Akitsuki & Decety, 2009; Decety et al., 2008; Decety & Michalska, 2010; Decety, Michalska, Akitsuki, & Lahey, 2009). In addition to brain regions involved in nociception, it was also predicted that subjects would have greater activation in areas involved in orienting attention, including the superior parietal cortex, frontal eye fields, and the superior colliculus (Corbetta, Kincade, & Shulman, 2002; Posner & Rothbart, 2007). As predicted, when the perspective of the injured person was taken, greater activation was detected in this network. This may be explained because identification of the source of injury would be a necessary step in escaping from current danger or preventing similar future injury. Interestingly, the parahippocampal region also was activated, providing a potential mechanism for the avoidance of similar risks in the future (Axmacher, Schmitz, Weinreich, Elger, & Fell, 2008).

Results from the functional connectivity analyses, seeded in the left amygdala, further support and extended these results. Connectivity analyses in the present study identify regions whose activity co-varies with activity in amygdala during different conditions, helping to create a dynamic model of circuits underlying each type of agency condition. Amygdala-modulated responses to the per-

spective of being harmed, increased connectivity with brain regions that have been previously implicated in negative emotion processing such as the lateral OFC and temporal poles (Olson, Plotzker, & Ezzyat, 2007). In concert with these regions, activation was also seen in areas involved in autonomic arousal, including the medial ACC and the pons (Critchley et al., 2003). The attention-orienting network was also activated, including frontal eye fields, superior parietal and superior colliculus.

A very different pattern of connectivity was detected when participants imagined harming another individual compared with imagining helping another. A strong decrease was found in the vmPFC, in conjunction with an increase in activation in the secondary visual cortex, inferior frontal gyrus, posterior thalamus, and head of the caudate. The decrease in the vmPFC is consistent with previous data from a positron emission tomography study that found reduced activation in that region during imagined aggression (Pietrini et al., 2000). The vmPFC has reciprocal connections with regions associated with emotion processing such as the amygdala, temporal poles and reward processing areas, and has long been known to play a crucial role in the modulation of the expression of social and emotional behavior (Grafman & Litvan, 1999), and plays a key role in influencing the evaluation of affective information in the regulation of the amygdalar response (van Reekum et al., 2007). Ventromedial prefrontal cortex impairments are a well-replicated finding in the imaging literature associated with violent and antisocial behavior (e.g., Raine et al., 1998; Soderstrom, Tullberg, Wikkelsoe, Ekholm, & Forsman, 2000). Lesions to the medial orbitofrontal cortex are known to disrupt inhibitory and emotional mechanisms and lead to impulsive and socially inappropriate behavior (Anderson, Bechara, Damasio, Tranel, & Damasio, 1999). Patients with vmPFC lesions may exhibit blunted affect, diminished empathy and difficulty with moral reasoning (Eslinger et al., 2009; Moll et al., 2005). The deactivation of the vmPFC together with a heightened signal in the thalamus and the head of the caudate nucleus—a region highly innervated by dopamine neurons, may be indicative of a diminished control of aggression in conjunction with an enjoyment of aggression. Interestingly, a study of youth with aggressive conduct disorder found selective increase of the amygdala and ventral striatum when they viewed video clips depicting people being hurt, and this pattern was strongly correlated with behavioral ratings of their sadistic tendencies (Decety et al., 2009).

It should be noted that by necessity, all trials in which participants imagined having their pain alleviated began with the subject imagining being in a painful situation which was then alleviated by an imagined individual over the course of the trial's duration. In this contrast, the activated network that covaried with the left amygdala, comprises the parietal attention areas and somatosensory regions, as well as large portions of the visual cortex. This is indicative that participants were engaged in the task, and as a result focused their attention on the somatosensory information conveyed by the stimuli and the mental simulation of their pain being alleviated. A growing body of research has reliably demonstrated that the perception, anticipation and imagination of bodily pain is associated with activation of the somatosensory cortex (see Benuzzi, Lui, Duzzi, Nichelli, & Porro, 2008; Jackson, Brunet, et al., 2006; Jackson, Rainville, et al., 2006; Lamm et al., 2011; Porro et al., 2002). Appropriately, regions of the pain matrix, such as the anterior insula, were activated in all conditions except for trials in which participants imagined harming another.

The inverse contrast, imagining alleviating the pain of another vs. imagining having one's own pain alleviated, was associated with increased connectivity with neural regions implicated in decision making, motor engagement, and behavioral reinforcement (ventral striatum, see [Fig. 3](#)). Greater functional connectivity was found with the prefrontal cortex (ACC, SMA, vmPFC, middle frontal

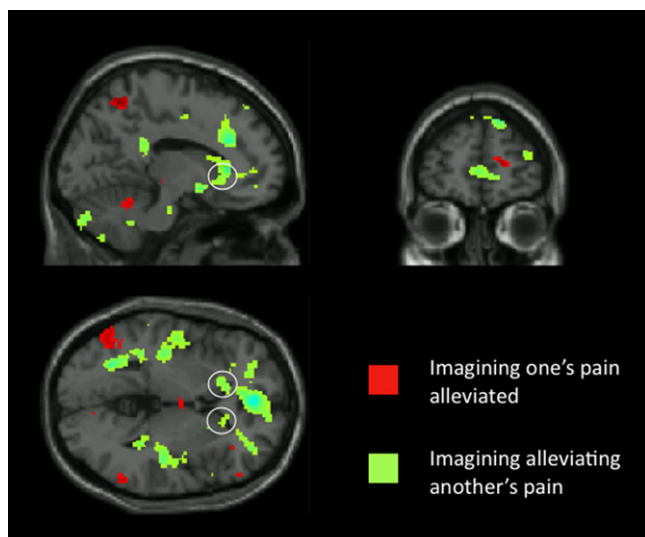


Fig. 3. Functional connectivity analysis, seeded from the left amygdala revealed different activation patterns when participants imagined having their pain alleviated (red) or imagined alleviating the pain of another (green). Note the increase in the ventral striatum (white circles) when participants imagined alleviating the pain of another. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of the article.)

gyrus, dorsolateral PFC and orbitofrontal cortex), which support processing needed to evaluate and determine the appropriate, empathetic and decision processing, motor planning necessary to carry out that response. In addition, significant increase in connectivity between the amygdala and the ventral striatum was found when participants imagined alleviating the pain of another. This is a very interesting and new finding that provides support for the motivational aspect of prosocial behavior. A handful of previous neuroimaging studies have reported a mesolimbic reward circuit is engaged by giving monetary donations (e.g., Moll et al., 2006), as well as by allocating monetary and social rewards (Izuma, Saito, & S, 2008). Another functional MRI study reported that the mere presence of observers increased donation rates and significantly affected activity in the striatal regions (Izuma, Saito, & Sadato, 2010). The fact that imagining helping is associated with ventral striatum activation is consistent with the idea that prosocial behaviors can be motivated by a plurality of motives, including reducing one's own discomfort, feeling good about oneself, or feelings of sympathy for the other (Decety, *in press*).

Finally, it should be noted that the contrast “imagining being harmed vs. imagining harming” produced a pattern of activation very similar to previous results, found when participants observed an individual being harmed with no explicit instruction about the perspective to take (Decety et al., 2008; Decety & Michalska, 2010). In the current study, regions of the pain matrix were found in response to stimuli depicting one individual harming another only when the participant imagined being the victim, but not the perpetrator. This implies that without explicit instruction, normal individuals may automatically take the perspective of the individual being injured. In light of this, future research would be well served to explicitly instruct their participants which perspective to take. Conversely, inference about the perspective an individual has taken (without explicit instruction) may be drawn from the pattern of neural response to such scenarios, and this could have an interesting diagnostic utility in clinical neurology and psychiatry.

One limitation of our study is that all data are based on a limited sample of male participants. As there are gender differences in physical aggression and helping behavior favoring males and

females, respectively, future studies may want to include both genders.

5. Conclusion

The findings of our study suggest that imagining actions that have different moral consequences, whether helping, being helped, harming or being harmed, call upon different, yet interacting neural networks, as documented by the functional connectivity analyses. Furthermore, since the present study used an elegant design where a single set of visual stimuli were used for both pain-alleviated conditions (imagine helping and imagine being helped), and a different set of stimuli used for both harming conditions, modulation of neural activity can be attributed to the agency participants were instructed to take in each condition with a great degree of confidence. Thus, an explicit perspective taking strategy can have profound impact on the neural recruitment associated with distinct behaviors as well as their moral consequences.

These findings may have a variety of therapeutic and research implications. For clinicians, the implications are manifold. For instance, on the therapeutic end it becomes a possible intervention for individuals who find themselves problematically distressed or oversensitive to the sight of another in pain. Perspective taking manipulation, through a strategy where they explicitly took the perspective of someone other than the injured, would allow the patient to modulate their response to the aversive situation, by recruiting partly different neural networks. From a medical practitioner's point of view it is always a struggle to find an appropriate balance between empathic detachment and empathic sensitivity to patients' suffering (Halpern, 2011). In the context of care giving environments, medical practitioners such as physicians, nurses, emergency workers and therapists have no choice but to interact with people suffering or traumatized as part of their everyday activities (Gleichgerricht & Decety, 2011). This painful reality may, however, take its toll on these people, and can lead to compassion fatigue, burn out, professional distress, and result in a low sense of accomplishment and severe emotional exhaustion. It is clear within certain medical contexts (e.g., an accident scene where an emergency worker must provide cardiopulmonary support) that above other considerations, the rapid execution of the procedure is paramount, and personal distress of the practitioner could be detrimental to its success. In training for similar situations, explicit instruction to avoid focusing on the experience of the patient could be beneficial. Conversely, in the absence of imminent danger, explicitly taking the perspective of the patient may enhance clinicians' ability to evaluate the distress and pain of their patients. Work by Cheng et al. (2007) as well as Decety, Yang, and Cheng (2010) demonstrated that when observing needle insertions into a patient's face, hands or feet, healthy controls exhibit signal increase in regions of the pain matrix (anterior insula, somatosensory cortex, periaqueductal gray and anterior cingulate cortex), and a N100 ERPs response. However, experienced physicians do not, and instead recruit regions of the prefrontal cortex associated with cognitive control and emotional regulation. The findings of the present study suggest that activation in these regions can be intentionally modulated in one way or the other by an explicit perspective taking strategy. In fact, it may be the case that in the fMRI study by Cheng et al. (2007), physicians are natively taking a clinician's perspective, as opposed to the controls who take the patient's perspective. This may suggest that a physician, who deliberately takes the perspective of a patient, may exhibit typical neurological hallmarks of pain observation, and thus have a better understanding of the patients' distress. It has been argued that a modicum of negative arousal is necessary to help physicians attune to and empathically understand patient's emotions (Halpern, 2001). Further research is

essential to investigate and validate an optimal perspective taking strategy that can be associated with a more “control-like” neural recruitment for people are regularly exposed to the distress and suffering of others and who are vulnerable to compassion fatigue and burnout. The goal is to find an appropriate balance between paying attention to the details of a patient’s painful experience without becoming emotionally over-involved in a way that can preclude effective medical management and impact the well-being of medical practitioners.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.neuropsychologia.2011.06.024.

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