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How do we perceive the pain of others? A window into the neural processes involved in empathy

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To what extent do we share feelings with others? Neuroimaging investigations of the neural mechanisms involved in the perception of pain in others may cast light on one basic component of human empathy, the interpersonal sharing of affect. In this fMRI study, participants were shown a series of still photographs of hands and feet in situations that are likely to cause pain, and a matched set of control photographs without any painful events. They were asked to assess online the level of pain experienced by the person in the photographs. The results demonstrated that perceiving and assessing painful situations in others was associated with significant bilateral changes in activity in several regions notably, the anterior cingulate, the anterior insula, the cerebellum, and to a lesser extent the thalamus. These regions are known to play a significant role in pain processing. Finally, the activity in the anterior cingulate was strongly correlated with the participants' ratings of the others' pain, suggesting that the activity of this brain region is modulated according to subjects' reactivity to the pain of others. Our findings suggest that there is a partial cerebral commonality between perceiving pain in another individual and experiencing it oneself. This study adds to our understanding of the neurological mechanisms implicated in intersubjectivity and human empathy.
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Introduction

Empathy is a complex form of psychological inference in which observation, memory, knowledge, and reasoning are combined to yield insights into the thoughts and feelings of others (Ickes, 1997). Evolutionary, developmental, social, and neuroscience perspectives stress the importance for survival of investing positively in interpersonal relationships, and understanding one's own as well as others' emotions, desires, and intentions (Batson, 1997; Brothers, 1989; Davis, 1996; Decety and Jackson, in press; Harris, 2000; Meltzoff, 2002; Preston and de Waal, 2002). Various definitions of empathy have been proposed, but two primary components are consistent across numerous conceptualizations: (1) an affective response to another person, which often, but not always, entails sharing that person's emotional state, and (2) a cognitive capacity to take the perspective of the other person while keeping self and other differentiated (e.g., Batson, 1991; Davis, 1996; Decety and Jackson, in press; Goldman, 1993; Hodges and Wegner, 1997; Ickes, 2003).

The ability to detect the immediate affective state of another person (Trevarthen, 1979) is considered a precursor to empathy. This corresponds to a state of emotional arousal that stems from the apprehension or comprehension of another's affective state. This state may be similar to, or congruent with, what the other person is feeling (Eisenberg and Strayer, 1987). Developmental studies have shown that newborns can imitate various body movements performed by adults, for example, mouth opening, tongue protrusion, lip pursing, finger movements, and also emotional expressions (Field et al., 1982; Kugiumutzakis, 1998; Meltzoff and Moore, 1977). This initial connection between self and other may be the foundation for developmentally more sophisticated accomplishments, such as the perception of dispositions and intentions in other individuals (Hobson, 1989; Meltzoff, 1990; Meltzoff and Decety, 2003; Rochat and Striano, 2000).

The automatic mapping between self and other is also supported by an abundant empirical literature in the domain of perception and action, which has been marshaled under the common-coding theory (Prinz, 1997). Its core assumption is that actions are coded in terms of the perceivable effects they should generate, and that perception of a given behavior in another individual automatically activates one's own representations of that behavior (Barsalou et al., 2003; Knoblich and Flach, 2001; Preston and de Waal, 2002). This common coding occurs at the level of single neurons in monkeys: mirror neurons in the ventral premotor and posterior parietal cortices fire both during the execution of a goal directed action and during the observation of action in other individuals (Gallese et al., 2002; Rizzolatti et al., 2001). Although

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the perception–action coupling mechanism occurs at the covert level, its outcome enables the establishment of self–other equivalences that may be used to predict and understand others' behaviors (Decety and Sommerville, 2003; Jackson and Decety, 2004; Jeannerod, 1999; Meltzoff, 2002).

There is evidence that perception of emotion activates mechanisms that are responsible for the generation of emotion (Adolphs, 2003). For instance, viewing facial expressions triggers expressions on one's own face (as measured by electromyography), even in the absence of conscious recognition of the stimulus (Dimberg et al., 2000; Wallbott, 1991). Adolphs et al. (2000) have demonstrated that patients with lesions of the right somatosensory cortex are impaired both in the expression and the recognition of facial emotional expressions. Recently, a number of neuroimaging studies demonstrated that similar networks of brain areas are activated by the perception of facial expression depicting emotions and the overt expression of similar emotions (Carr et al., 2003; Ekman and Davidson, 1993, Leslie et al., 2004), the visual perception of disgust (Phillips et al., 1997; Wicker et al., 2003) and touch (Keysers et al., 2004) in others, and the experience of the same sensations in oneself.

Pain is a special psychological state with great evolutionary significance, and pain can, of course, be experienced by self and perceived in others. Our reaction to someone else's physiological pain can be automatic and even accompanied by avoidance-type motor behaviors. However, to fully appreciate how someone else is suffering, one is likely to either covertly remember how it felt (if it was previously experienced) and/or to take the perspective of the other. Although pain processing is known to be a complex and subjective process that has fueled many debates (Craig, 2003; Treede et al., 1999), the perception and processing of a painful stimulation is known to come from a combination of perceptual/sensory and emotional/affective components (Ploghaus et al., 2003; Price, 1999).

Several brain regions have been consistently found to be associated with pain processing, notably the anterior cingulate cortex, the insula, and with less reliability, the thalamus and the primary somatosensory cortex (Bushnell et al., 1999; Coghill et al., 1999; Peyron et al., 2000; Treede et al., 1999). A number of brain imaging studies support the distinction often drawn in the pain literature between the sensory-discriminative aspect of pain processing and the affective one. For instance, the primary (SI) and secondary (SII) sensory cortices are mainly involved in the sensory-discriminative aspects of pain (Bushnell et al., 1999), while the anterior cingulate, and insula cortices subserve mainly the affective-motivational component (e.g., Rainville et al., 1997). However, as pointed out by Hofbauer et al. (2001), it is difficult within a traditional pain paradigm to dissociate sensory and affective components because they are highly correlated.

Although the neural processing of self-pain perception has been widely studied, less is known about how we perceive pain in others, even though this aspect carries important psychological implications. One single-cell recording study in pre-cingulotomy patients has fortuitously shown that pain-related neurons in the anterior cingulate cortex (ACC) can discharge both during the actual sensation as well as during the observation of the same stimuli applied to another person, which suggest a role of this region in pain perception in others (Hutchison et al., 1999). Another recent study by Singer et al. (2004) has demonstrated that feeling pain and seeing a cue that signals the administration of pain to a partner both produced changes in the hemodynamic response in the anterior insula, the ACC, the brainstem, and the cerebellum. Moreover, Morrison et al. (in press) recently reported results from a similar experiment showing that both feeling a moderately painful pinprick and witnessing another person undergoing a similar stimulation were associated with activity in a common region of the right dorsal ACC.

The general hypothesis driving this study is that perceiving and assessing the pain of others, in the absence of actual noxious stimuli, will lead to neurohemodynamic changes in the cerebral network previously reported to be involved in pain processing. More specifically, it can be predicted from the various studies supporting the shared representations mechanism (e.g., Buccino et al., 2001; Decety and Chaminade, 2003; Keysers et al., 2004; Wicker et al., 2003) that the perception of different body parts such as hands and feet in painful situations should lead to hemodynamic changes in SII, as well as in the corresponding areas of SI. Also, change in cerebral activity was predicted in the neural regions implementing the affective component of pain, such as the anterior cingulate and the anterior insula (e.g., Rainville et al., 1997). Such a prediction is also reinforced by the recent findings of pain perception in self and others showing enhanced activation of ACC (Morrison et al., in press) and ACC and bilateral anterior insula (Singer et al., 2004).

Materials and methods

Subjects

Fifteen healthy right-handed volunteers (7 females, 8 males) aged between 19 and 29 years (mean = 22, SD = 2.6) participated in the study. They gave informed written consent and were paid for their participation. No subject had any history of neurological, major medical, or psychiatric disorder. The study was approved by the local Ethics Committees (University of Washington and University of Oregon) and conducted in accordance with the Declaration of Helsinki.

Picture stimuli

A series of 128 digital color pictures showing *right* hands and *right* feet in painful and non-painful situations (64 each) were shot from angles that promoted first-person perspective (i.e., no mental rotation of the limb required for the observer). All situations depicted familiar events that can happen in everyday life (see Fig. 1 for some examples). Various types of pain (mechanical, thermal and pressure) were represented, and the target persons in the pictures varied in gender and age (between 8 and 56 years). The 64 painful pictures used in this study were selected from a larger sample, on the basis of the pain intensity ratings of 20 independent subjects (Jackson and Decety, unpublished data). For each situation, a neutral picture, which involved the same setting without any painful component, was also obtained. All pictures were edited to the same size (600 × 450 pixels).

Davis' Interpersonal Reactivity Index

After scanning, subjects completed the Davis' Interpersonal Reactivity Index (IRI), a 28-item self-report survey of Likert-type items. The 28 items provide individual scores on four subscales:

Fig. 1. Sample pictures of hands and feet in painful (Pain) and neutral (No-Pain) conditions. Note that only right limbs were presented, and for each painful stimulus, a corresponding neutral (No-Pain) one was provided.

perspective taking, fantasy, empathic concern, and personal distress (Davis, 1996).

Scanning method and procedure

Subjects took part in four sequential fMRI sessions. Each session consisted of 10 blocks, two of each of the five following conditions in which subjects had to watch and assess: (1) right hands in painful situations, (2) right hands in neutral situations, (3) right feet in painful situations, (4) right feet in neutral situations, or (5) baseline trials showing static crosses. Each block consisted of four 8-s trials of the same condition (picture = 3.5 s, blank screen = 0.5 s, rating scale = 3.0 s, blank screen = 1.0 s), and each picture was followed by a visual analogue rating scale ranging from "No Pain" to "Worst Possible Pain", except for the baseline trials where the scale values were "Left" and "Right". In the first four conditions, subjects were instructed to rate the intensity of pain they thought the person would feel in each situation. In the baseline trials, subjects were asked to move the cursor in order to reproduce the intersection of the two lines, which was not symmetrical and varied randomly in terms of the position at which the vertical and horizontal lines crossed. Thus, at the end of each trial, they used a two-button response box under their left hand to move a cursor horizontally on the visual scale (index = left, middle finger = right). For each trial, the cursor was placed in the middle of the scale so that every trial in every condition required moving the cursor along the scale by pressing and holding down either of two keys, thereby controlling for the motor output involved in the rating process across all conditions. Subjects were provided with several training trials prior to the scanning sessions in order to learn to use the rating scale and perform the task accurately, and within the allotted time. The visual analogue scales were subsequently divided into 100 equal intervals for analyses. A blank screen of 3 s was inserted between each block of trials. The order of conditions was randomized within a half session (i.e., each condition was presented once before any were repeated). No picture was presented more than once throughout the whole experiment.

After the scanning sessions, participants were debriefed about how they felt during the experiment, and asked specific questions concerning what strategy they used during the task. They were also given a scale (0–10) to rate, in general, their own sensitivity to pain.

Data acquisition and analyses

MRI data were acquired on a 3-T head-only Siemens Magnetom Allegra System equipped with a standard quadrature head coil. Changes in blood oxygenation level-dependent (BOLD) T2* weighted MR signal were measured using a gradient echo-planar imaging (EPI) sequence (repetition time TR = 2000 ms, echo time TE = 30 ms, FoV = 192 mm, flip angle 80°, 64 × 64 matrix, 32 slices/slab, slice thickness 4.5 mm, no gap, voxel size = 3.0 × 3.0 × 4.5 mm). For each scan, a total of 183 EPI volume images were acquired along the AC-PC plane. Structural MR images were acquired with a MPRAGE sequence (TR = 2500, TE = 4.38, fov = 256 mm, flip angle = 8°, 256 × 256 matrix, 160 slices/slab, slice thickness = 1 mm, no gap).

Image processing was carried out using SPM2 (Wellcome Department of Imaging Neuroscience, London, UK), implemented in MATLAB 6.1 (Mathworks Inc. Sherborn, MA). Images were realigned and normalized using standard SPM procedures. The normalized images of 2 × 2 × 2 mm were smoothed by a FWHM 6 × 6 × 6 Gaussian kernel. A first fixed level of analysis was computed subject-wise using the general linear model with hemodynamic response function modeled as a boxcar function whose length covered the four successive pictures of the same type. First-level contrasts were introduced in second-level random-effect analysis to allow for population inferences. Main effects were computed using one-sample *t* tests, including all subjects for each of the contrasts of interest, which yielded a statistical parametric map of the *t* statistic (SPM *t*), subsequently transformed to the unit normal distribution (SPM Z). A voxel-level threshold of $P < 0.0001$ uncorrected for multiple comparisons ($t = 4.99$), and a cluster-level spatial extent threshold of $P < 0.05$ corrected, were used to identify pain-related regions based on a priori hypotheses.

Given that this study did not include an actual pain condition, a region of interest analysis was conducted by taking into account previous neuroimaging studies that have examined both self pain experience and pain perception in others. Specifically, regions of interest for the anterior cingulate cortex and anterior insula were based on the stereotaxic coordinates from Singer et al. (2004) in the "Pain–No pain in Others" contrast (ACC: [0, 27, 33], [−3, 12, 42]; Anterior Insula: [33, 21, −9], [39, 12, −3], [−36, 12, 0]). For the

pain-related EPIs, contrasts were made between the pain conditions taken together and the neutral conditions, between the pain condition of each limb and its respective neutral condition, as well as between all conditions involving a body part and the baseline.

Results

Behavioral measures

Ratings of the pictures presented during the fMRI sessions indicate that participants rated the painful stimuli significantly higher on the analogue scale (Mean = 68, SD = 10) than the neutral ones (Mean = 3, SD = 2), validating their affective content. There were no statistical differences between the scores of each limb, either for the painful (Mean Hand = 68, SD = 9 vs. Mean Foot = 67, SD = 12; $t_{14} = -0.064$, $P > 2.0$), or the neutral stimuli (Mean Hand = 3, SD = 2 vs. Mean Foot = 2, SD = 2; $t_{14} = -0.455$, $P > 2.0$). Post-scan structured interviews confirmed that most participants (13/15) reported imagining the painful situations occurring to others. Assessment of participants' own pain sensitivity, on a 0 to 10 scale, ranged from 2 to 8 (Mean = 4.5, SD 1.8). Note that the mean rating of subjects for the pain scenarios was not correlated with their self-report of pain sensitivity ($r = 0.10$).

Representation of someone else's pain

Contrasts between painful and neutral stimulus conditions revealed several pain-related regions that were more activated during perception of painful stimuli (see Table 1), namely, the anterior insula, the caudal portion of the anterior cingulate (Brodmann area 24), and the cerebellum bilaterally (see Fig. 2A). Additionally, a significant cluster was located in the rostral part of the posterior parietal cortex in both hemispheres (Brodmann areas 5–7). At the subcortical level, the anterior thalamus nucleus was also found to be more activated during pain-related conditions.

Other peaks of significant changes in activity were found bilaterally in the precuneus ([12, −70, 58], [−26, −72, 38]), inferior ([58, 16, 24], [−64, 16, 14]) and middle frontal gyri ([42, 44, 26], [−44, 42, 10]), and also in the right supplementary motor area (8, 18, 52), right occipito-temporal junction (56, −54, −14), as well as additional peaks in the left middle frontal gyrus ([−52, 8, 32], [−28, 0, 52]).

In order to tease out possible predictability issues due to the block nature of the design, which could explain some of the differences between the Pain and No pain conditions, we also conducted an analysis involving the first trial of each block only. Although this inspection does not meet all the requirements of an event-related design, it does extract the data for randomized trials across the experiment, thereby removing any issues of predictability. Using a more liberal threshold ($P < 0.001$ uncorrected), this analysis yielded almost identical peaks of activation within the posterior parietal cortex, anterior cingulate and insula cortices, and cerebellum bilaterally.

Table 1
Pain-related regions of significant activation when the participants watched painful stimuli versus neutral stimuli voxel threshold $P < 0.0001$ uncorrected [$t = 4.99$], extend threshold, $P < 0.05$ corrected [$k > 25$]

Region	L/R	Voxel coordinates			Z score
		x	y	z	
Posterior parietal cortex	L	−42	−44	56	5.31
Posterior parietal cortex	R	40	−50	56	5.22
Anterior cingulate cortex	R	8	26	40	4.68**
Anterior cingulate cortex	L	−10	18	44	4.65**
Anterior thalamus	R	18	2	6	3.38*
Anterior thalamus	L	−18	2	4	4.21*
Anterior insula	L	−42	14	−4	4.58**
Anterior insula	R	32	18	6	4.50**
Cerebellum	L	−24	−72	−28	4.64**
Cerebellum	R	42	−66	−34	4.33*

* $P < 0.001$.
** $P < 0.05$ corrected; 10 mm sphere ROI analyses based on the coordinates from the Pain–No Pain in Others contrast in Singer et al. (2004).

Correlation between brain activity and pain ratings

In an attempt to investigate whether the neural activations found in the contrast between painful and neutral stimuli were related to each individual's average subjective intensity of pain ratings (reactivity to pain), a regression analysis was computed between this neural contrast and a behavioral index of pain intensity. This index was obtained by subtracting the rating from each neutral stimulus from the rating of its corresponding painful stimuli. A significant cluster of activation was detected in the right ACC (14, 20, 44; threshold extend $k = 11$). The plot between the neural activity at these coordinates and the subjective rating shows the significant linear correlation ($r = 0.83$; see Fig. 2B).

Correlation between brain activity and Davis' IRI

No single peak of changes in activity came out significant at $P < 0.001$ in pain-related regions of interest when the Pain vs. No Pain contrast was correlated with the score of the different subscales as well as the total score of the IRI.

Body part-related contrasts

Contrast between all conditions involving body parts (hands and feet in painful and non painful situation collapsed) versus the baseline condition revealed significant activation in several clusters in the occipital lobe in both hemispheres, as well as the medial prefrontal and lateral orbitofrontal cortex. Notably, a bilateral-activated focus ([56, −70, 4], [−56, −68, 2]) was found in the occipito-temporal region (see Fig. 3). There was no significant difference in activation maps between the contrasts examining each limb in painful situations separately against the baseline condition.

In order to examine more closely whether the perception of human body parts activates related cortices following a somatotopic distribution, we contrasted neural responses to painful versus non-painful stimuli for each limb separately. These comparisons resulted in the activation of similar networks irrespective of which body part was perceived. Thus, the neural response to the pain of others was similar regardless of whether the pain was inflicted on the foot or the hand. However, it is noteworthy that there was activation of a cluster located in the middle frontal gyrus in both hemispheres for the conditions involving a right hand. No signal change was observed in the participants' right hand and right foot cortical representations. Interestingly, significant activity was found bilaterally for the foot ([58, 64, 10], [54, − 68, 6]) and in

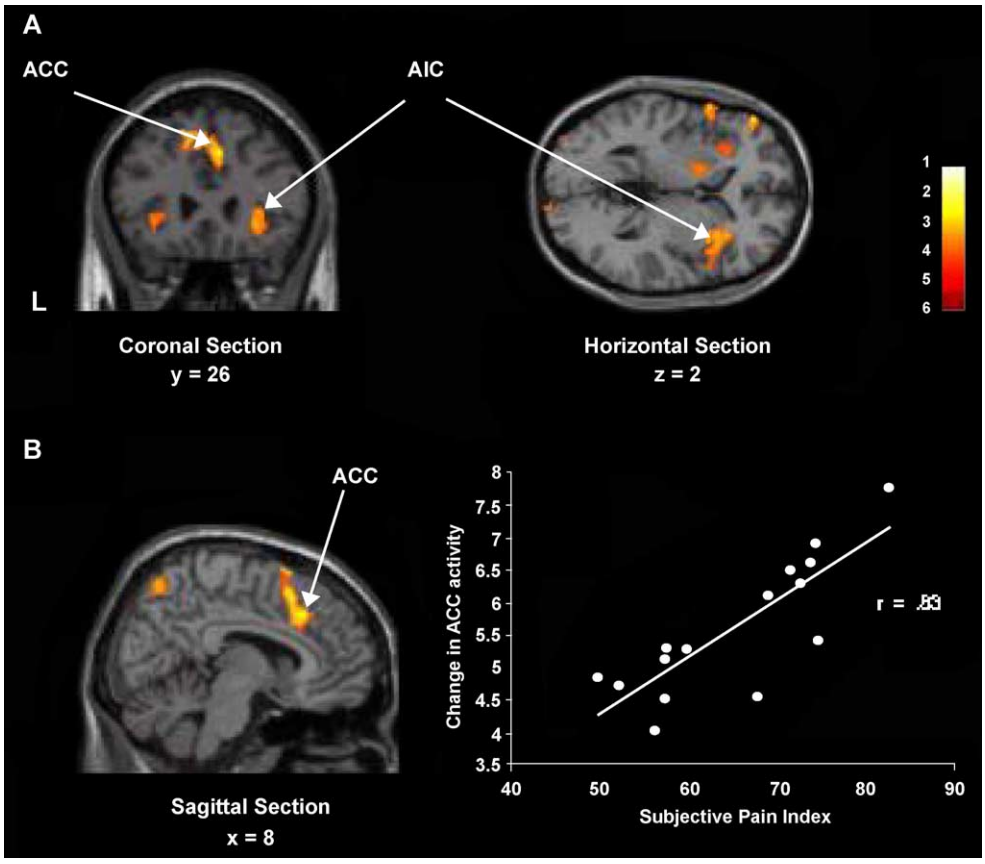

Fig. 2. (A) Anterior insular cortex AIC, thalamus and posterior part of the anterior cingulate ACC activation during the observation and assessment of someone else in painful situations contrasted with neutral (No-Pain) situations. Results are superimposed on the MNI MRI template. (B) ACC cluster superimposed onto a sagittal section and scatter plot showing the positive correlation between the indexed ratings and the level of activity in this region $x = 14$, $y = 20$, $z = 44$.

the right hemisphere for the hand (56, 62, 14) in the posterior temporal cortex corresponding to the MT region, only in the contrasts involving painful stimuli versus non-painful ones.

Discussion

Our study investigated the hemodynamic response during the perception of pain in others, which is a way to address the process involved in empathy (Decety and Jackson, in press; Hodges and Wegner, 1997; Ickes, 2003). Here, we consider perception of pain in others as a social stimulus that triggers a specific mental (affective) state in the perceiver from which empathic processing may stem. Note that our intention was not to investigate self-pain-processing as such, rather we were interested in the hemodynamic changes stemming from the sight of others in potentially painful situations. The results demonstrate that watching other individuals in pain-inducing situations triggers a specific part of a neural network known to be involved in self-pain processing.

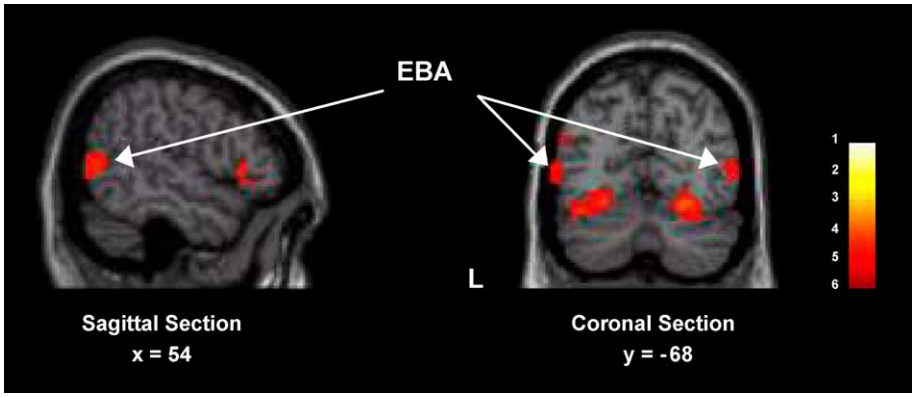

Fig. 3. Clusters of bilateral activation found in the lateral occipito-temporal cortex corresponding to the body selective region EBA; see Downing et al., 2001. Results from the contrast between all the conditions depicting right hands and right feet and the baseline condition are superimposed on the MNI template.

Our first hypothesis that perception of hands and feet in painful situations would be associated with specific changes in the somatosensory cortices (SI–SII) was not confirmed. Although the absence of significant hemodynamic change in these cortical regions could be related to the specificity of our design, it remains consistent with two recent studies that examined both pain in self and in others (Morrison et al., in press; Singer et al., 2004). These studies did not report any activation of SI or SII in conditions of pain in others, even though activations in these regions were observed when the same subject received actual pain. Moreover, the role of the primary somatosensory cortex in pain perception is still debated, and several studies did not report its contribution (see Table 1 of Bushnell et al., 1999; Peyron et al., 2000). In addition, the somatosensory cortex is most often associated with sensory aspects of pain rather than the affective aspects (Bushnell et al., 1999; Craig, 2003), and the former aspect is less likely to be present since there was no actual nociceptive stimulation. Finally, one possible explanation for the lack of involvement of SI and SII could be that the intensity or depth of the induced process was not sufficient to prime the whole sensory-affective pain continuum. In fact, involvement of MI in motor imagery has been found inconsistently in the literature probably for similar reasons (see Grèzes and Decety, 2001; Jackson et al., 2001). Thus, it is possible that an experiment that uses more shocking or more intense stimuli would lead to SI and/or SII activation during observation of pain in others, but such a design would also tap into other related processes such as discomfort and personal distress.

The main finding of this study showing activation in the ACC and in the anterior insula during the perception and assessment of someone else's pain is consistent with previous imaging studies of pain processing that have demonstrated their role in the affective aspect of pain processing (Coghill et al., 1999; Hofbauer et al., 2001; Ploghaus et al., 1999; Rainville et al., 1997; Sawamoto et al., 2000), as well as with recent fMRI studies of empathy for pain (Morrison et al., in press; Singer et al., 2004). In fact, the peaks of activation in the ACC [(8, 26, 40) and (−10, 18, 44)] and anterior insula [(32, 18, 6) and (−42, 14, −4)] for the Pain–No pain contrast in this study are very close, within 1 cm, to those reported by Singer et al. (2004) in the Pain–No pain Others contrast [ACC: (0, 27, 33) and (−3, 12, 42); anterior insula: (39, 12, −3) and (−36, 12, −3)]. These regions are considered as key cortical areas involved in regulating the subjective feelings of pain-related unpleasantness in humans (Bush et al., 2000; Rainville, 2002). Even though the subjects in this study were asked to rate the level of pain intensity after each stimulus, they had to extract this value in the absence of its related sensation in the self. Interestingly, post-scanning interviews and questionnaires indicate that the subjects imagined the level of pain the situation would produce to the other person, which draws on affective and even cognitive/evaluative processes (Bush et al., 2000). Further support for the role of ACC in the affective dimension of pain also comes from a recent fMRI study that demonstrated activation of this region ([−8, 16, 44], [10, 26, 28]) when participants listen to Japanese pain-evoking words as compared to nonsense syllables (Osaka et al., 2004).

Furthermore, the strong correlation between the ratings and the level of activity within the posterior ACC (see Fig. 2B) supports the pivotal role of this region in interrelating attentional and evaluative functions associated with pain-evoking situations (Price, 2000). Our results suggest that such a mechanism is also involved in the evaluation of pain in others, and support the interesting discovery by Hutchison et al. (1999) who identified neurons in the ACC of neurological patients that responded both to painful stimulation and to the anticipation or the observation of the same stimulation applied to another person.

An alternate interpretation would be that the perception and assessment of pain in others leads to an unspecific state of arousal such as personal distress and anxiety (Critchley, 2004; Eisenberg, 2000). In such a case, however, changes in activity should be observed not only in the ACC and anterior insula but also in emotion-related systems, notably the amygdala. Indeed, a number of studies of negative emotions suggest that distress is related to activity in the amygdala (e.g., Irwin et al., 1996; see Davidson, 2002; Posner and Rothbart, 1998 for reviews). Interestingly, a recent review has argued that the amygdala could, however, play a role in persistent pain (Neugebauer et al., 2004). None of these components (distress and persistent pain) were elicited by our paradigm.

Another complementary interpretation of our results is that watching painful stimuli in such daily living contexts prompts anticipatory mechanisms. Several neuroimaging studies have indeed demonstrated that anticipation of painful stimuli being administered to the self increases the hemodynamic signal in pain-related neural regions (Peyron et al., 1999; Ploghaus et al., 1999; Porro et al., 2002, 2003; Sawamoto et al., 2000). However, in our study, participants were not inflicted pain nor were they led to believe that they could receive a nociceptive stimulus during the course of our experiment. Nevertheless, one cannot exclude that such a mechanism is involved because it may be argued that watching pain in others prompts anticipation of pain in oneself. These two interpretations are not mutually exclusive in the light of the shared representation model, considering that anticipatory mechanisms are crucial for one's own survival.

Other results also suggest that the feeling of pain is not restricted to its physical sensation, but occurs within the individual as a result of observing another's emotional state. This result fits well with recent findings that there is a neural realization of the idea that social relationships can sometimes be 'painful'. This latter aspect was demonstrated in an fMRI study showing that the neural circuit involved in pain processing, including the anterior insula and the ACC, was activated when the participants were socially excluded from an on-line computer game (Eisenberger et al., 2003). Interestingly, the ACC was more active during exclusion and its activity correlated positively with self-reported distress. The authors argued that "social pain" is analogous in its neurocognitive function to physical pain.

Contrary to the study by Singer et al. (2004), we did not find any significant correlation between the empathy questionnaire and the hemodynamic changes. Moreover, no correlation was found between self-report of pain sensitivity and pain intensity ratings. These results may not be that surprising considering that self measures of empathy are poor predictors of actual empathic behavior (Davis and Kraus, 1997).

Representation of body parts

No specific activation was detected in association with the visual perception of hands and feet in the somatosensory and

motor/premotor cortex. This does not support the somatotopic prediction that was made based on an fMRI study that showed involvement of differential premotor and parietal somatosensory areas when subjects observed object-related actions made with different effectors including hand and foot (Buccino et al., 2001). However, the neurons exhibiting mirror properties have been mainly discovered in monkeys and humans during observation of goal directed actions, and not during non-directed actions when watching static pictures (Rizzolatti et al., 2001), as were used in the current study. In addition, our stimuli depicted actions for which the subjects were acted upon, not acting. This may represent an important functional difference in the way mirror neurons are triggered, and, if so, it constrains their involvement in many everyday empathic situations.

Activation of area MT is consistent with its involvement in implied or imagined visual motion (Stevens et al., 2000). An fMRI study by Kourtzi and Kanwisher (2000) found stronger activation in MT during viewing of static photographs with implied motion (e.g., a basket ball player about to shoot the ball) compared to viewing photographs without implied motion (e.g., a person sitting in a chair). It is possible that the painful photographs in this experiment imply motion to the observer because each painful event is likely caused by the motion of the body toward an object or the opposite (e.g., door closing on a foot).

It is well recognized that visual stimuli are processed in specialized cortical areas (Allison et al., 2000), and more specifically, there is a region in the occipito-temporal cortex that responds selectively to images of human bodies and body parts (Downing et al., 2001). Examination of the conditions involving body parts versus the baseline condition revealed activation of several clusters in the occipital lobe in both hemispheres, as well as the medial prefrontal and lateral obitofrontal cortex. Notably, a bilateral activated focus was found in the occipito-temporal region ([56, 70, 4], [−56, 68, 2]). This fits very well with the finding that some neurons in the posterior temporal cortex respond selectively to the visual appearance of the body. For example, electrophysiological recordings by Jellema et al. (2002) have identified neurons in the superior temporal sulcus of the monkey brain that discharge selectively at the sight of the body. Recently, Downing et al. (2001) have extended this finding by discovering a body-selective region in the lateral occipito-temporal cortex, which produced a significantly stronger response when subjects viewed still photographs of human bodies and body parts than when they viewed various inanimate objects. As suggested by Downing et al. (2001), this region might not be exclusive to visual stimuli but could relay general amodal semantic knowledge about the body (Chaminade, Meltzoff, and Decety, 2004). Moreover, this region (in the posterior STS) has reciprocal connection with the amygdala and orbitofrontal cortex, and is part of a circuit involved in the elaboration of the affective aspects of social behavior (Adolphs, 2003; Puce and Perrett, 2003).

Conclusion

One of the evolutionary benefits of shared neural representations for self and other is that they can be used to learn from and to understand others. The observation of positive experiences in others may have a reinforcing value. Conversely, through watching negative consequences of other people's behavior, individuals learn to avoid situations that are potentially hazardous and likely to injure themselves, without having to experience them. Here, we investigated the neural response elicited by the assessment of painful situations experienced by others as a means of exploring this important aspect of interpersonal behavior. Our results demonstrate that the anterior cingulate and anterior insula cortices, regions often reported as being part of the pain affective system, are recruited when watching someone else's pain. These findings offer one plausible explanation of how one is affected by another person's state and feelings.

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References

Adolphs, R., 2003. Cognitive neuroscience of human social behavior. Nat. Rev., Neurosci. 4, 165–178.

Adolphs, R., Damasio, H., Tranel, D., Cooper, G., Damasio, A.R., 2000. A role for somatosensory cortices in the visual recognition of emotion as revealed by three-dimensional lesion mapping. J. Neurosci. 20, 2683–2690.

Allison, T., Puce, A., McCarty, G., 2000. Social perception from visual cues: role of the STS region. TICS 4, 267–278.

Barsalou, L.W., Niedenthal, P.M., Barbey, A., Ruppert, J., 2003. Social embodiment. In: Ross, B.H. (Ed.), The Psychology of Learning and Motivation, vol. 43. Academic Press, San Diego, CA, pp. 43–92.

Batson, C.D., 1991. The Altruism Question: Toward a Social-Psychological Answer. Erlbaum, Hillsdale, NJ.

Batson, C.D., 1997. Self-other merging and the empathy altruism hypothesis: reply to Neuberg et al. J. Pers. Soc. Psychol. 73, 517–522.

Brothers, L., 1989. A biological perspective on empathy. Am. J. Psych. 146, 10–19.

Buccino, G., Binkofski, F., Fink, G.R., Fadiga, L., Fogassi, L., Gallese, V., Seitz, R.J., Zilles, K., Rizzolatti, G., Freund, H.J., 2001. Action observation activates premotor and parietal areas in a somatotopic manner: an fMRI study. Eur. J. Neurosci. 13, 400–404.

Bush, G., Luu, P., Posner, M.I., 2000. Cognitive and emotional influences in anterior cingulate cortex. TICS 4, 215–222.

Bushnell, M.C., Duncan, G.H., Hofbauer, R.K., Ha, B., Chen, J.-I., Carrier, B., 1999. Pain perception: is there a role for primary somatosensory cortex? Proc. Natl. Acad. Sci. 96, 7705–7709.

Carr, L., Iacoboni, M., Dubeau, M.C., Mazziotta, J.C., Lenzi, G.L., 2003. Neural mechanisms of empathy in humans: a relay from neural systems for imitation to limbic areas. Proc. Natl. Acad. Sci. 100, 5497–5502.

Chaminade, T., Meltzoff, A.N., Decety, J., 2004. An fMRI study of imitation: action representation and body schema. Neuropsychologia (in press).

Coghill, R.C., Sang, C.N., Maisog, J.M., Iadarola, M., 1999. Pain intensity processing within the human brain: a bilateral, distributed mechanism. J. Neurophysiol. 82, 1934–1943.

Craig, A.D., 2003. A new view of pain as a homeostatic emotion. TINS 26, 303–307.

Critchley, H.D., 2004. The human cortex responds to an interoceptive challenge. Proc. Natl. Acad. Sci. 101, 6333–6334.
Davidson, R.J., 2002. Anxiety and affective style: role of prefrontal cortex and amygdale. Biol. Psychiatry 51, 68–80.
Davis, M.H., 1996. Empathy: A Social Psychological Approach. Westview Press, Madison, WI.
Davis, M.H., Kraus, L.A., 1997. Personality and empathic accuracy. In: Ickes, W. (Ed.), Empathic Accuracy. The Guilford Press, New York, pp. 144–168.
Decety, J., Chaminade, T., 2003. Neural correlates of feeling sympathy. Neuropsychologia 41, 127–138.
Decety, J., Jackson, P.L., 2004. The functional architecture of human empathy. Behav. Cogn. Neurosci. Rev. (in press).
Decety, J., Sommerville, J.A., 2003. Shared representations between self and other: a social cognitive neuroscience view. TICS 7, 527–533.
Dimberg, U., Thunberg, M., Elmehed, K., 2000. Unconscious facial reactions to emotional facial expressions. Psychol. Sci. 11, 86–89.
Downing, P.E., Jiang, Y., Shuman, M., Kanwisher, N., 2001. A cortical area selective for visual processing of the human body. Science 293, 2470–2474.
Eisenberg, N., 2000. Emotion, regulation, and moral development. Annu. Rev. Psychol. 51, 665–697.
Eisenberg, N., Strayer, J., 1987. Critical issues in the study of empathy. In: Eisenberg, N., Strayer, J. (Eds.), Empathy and its development. Cambridge Univ. Press, Cambridge, pp. 3–13.
Eisenberger, N.I., Lieberman, M.D., Williams, K.D., 2003. Does rejection hurt? An fMRI study of social exclusion. Science 302, 290–292.
Ekman, P., Davidson, R.J., 1993. Voluntary smiling changes regional brain activity. Psychol. Sci. 4, 342–345.
Field, T.M., Woodson, R., Greenberg, R., Cohen, D., 1982. Discrimination and imitation of facial expressions by neonates. Science 218, 179–181.
Gallese, V., Fadiga, L., Fogassi, L., Rizzolatti, G., 2002. Action representation and the inferior parietal lobule. In: Prinz, W., Hommel, B. (Eds.), Common Mechanisms in Perception and Action: Attention and Performance XIX. Oxford Univ. Press, New York, pp. 334–355.
Goldman, A.I., 1993. Ethics and cognitive science. Ethics 103, 337–360.
Grèzes, J., Decety, J., 2001. Functional anatomy of execution, mental simulation, observation, and verb generation of actions: a meta-analysis. Hum. Brain Mapp. 12, 1–19.
Harris, P.L., 2000. The Work of the Imagination. Blackwell, Oxford.
Hobson, R.P., 1989. On sharing experiences. Dev. Psychopathol. 1, 197–203.
Hodges, S.D., Wegner, D.M., 1997. Automatic and controlled empathy. In: Ickes, W. (Ed.), Empathic Accuracy, pp. 311–339.
Hofbauer, R.K., Rainville, P., Duncan, G.H., Bushnell, C., 2001. Cortical representation of sensory dimension of pain. J. Neurophysiol. 86, 402–411.
Hutchison, W.D., Davis, K.D., Lozano, A.M., Tasker, R.R., Dostrovsky, J.O., 1999. Pain-related neurons in the human cingulate cortex. Nat. Neurosci. 2, 403–405.
Ickes, W., 1997. Empathic Accuracy. The Guilford Press, New York.
Ickes, W., 2003. Everyday Mind Reading. Prometheus Books, New York.
Irwin, W., Davidson, R.J., Lowe, M.J., Mock, B.J., Sorenson, J.A., Turski, P.A., 1996. Human amygdala activation detected with echo-planar functional magnetic resonance imaging. NeuroReport 7, 1765–1769.
Jackson, P.L., Decety, J., 2004. Motor cognition: a new paradigm to study self other interactions. Curr. Opin. Neurobiol. 14, 259–263.
Jackson, P.L., Lafleur, M.F., Malouin, F., Richards, C., Doyon, J., 2001. Potential role of mental practice using motor imagery in neurologic rehabilitation. Arch. Phys. Med. Rehabil. 82, 1133–1141.
Jeannerod, M., 1999. To act or not to act: perspectives on the representation of actions. Q. J. Exp. Psychol. 52A, 1–29.
Jellema, T., Baker, C.I., Oram, M.W., Perrett, D.I., 2002. Cell populations in the banks of the superior temporal sulcus of the macaque and imitation. In: Meltzoff, A.N., Prinz, W. (Eds.), The Imitative Mind: Development, Evolution, and Brain Bases. Cambridge Univ. Press, New York, pp. 267–290.
Keysers, C., Wicker, B., Gazzola, V., Anton, J.L., Fogassi, L., Gallese, V., 2004. A touching sight: SII/PV activation during the observation and experience of touch. Neuron 42, 335–346.
Knoblich, G., Flach, R., 2001. Predicting the effects of actions. Psychol. Sci. 12, 467–472.
Kourtzi, Z., Kanwisher, N., 2000. Activation in human MT/MST by static images with implied motion. J. Cogn. Neurosci. 12, 48–55.
Kugiumutzakis, G., 1998. Neonatal imitation in the intersubjective companion space. In: Braten, S. (Ed.), Intersubjective communication and emotion in early ontogeny. Cambridge Univ. Press, Cambridge, pp. 63–88.
Leslie, K.R., Johnson-Frey, S.H., Grafton, S.T., 2004. Functional imaging of face and hand imitation: towards a motor theory of empathy. NeuroImage 21, 601–607.
Meltzoff, A.N., 1990. Foundations for developing a concept of self: the role of imitation in relating self to other and the value of social mirroring, social modeling, and self practice in infancy. In: Cicchetti, D., Beeghly, M. (Eds.), The Self in Transition: Infancy to Childhood. Chicago Univ. Press, Chicago, pp. 139–164.
Meltzoff, A.N., 2002. Imitation as a mechanism of social cognition: origins of empathy, theory of mind, and the representation of action. In: Goswami, U. (Ed.), Blackwell Handbook of Childhood Cognitive Development. Blackwell Publishers, Oxford, pp. 6–25.
Meltzoff, A.N., Decety, J., 2003. What imitation tells us about social cognition: a rapprochement between developmental psychology and cognitive neuroscience. Philos. Trans. R. Soc. Lond., B 358, 491–500.
Meltzoff, A.N., Moore, M.K., 1977. Imitation of facial and manual gestures by human neonates. Science 198, 75–78.
Morrison, I., Lloyd, D., di Pellegrino, G., Robets, N., 2004. Vicarious responses to pain in anterior cingulate cortex is empathy a multisensory issue? Cogn. Affect. Behav. Neurosc. (in press).
Neugebauer, V., Li, W., Bird, G.C., Han, J.S., 2004. The amygdala and persistent pain. Neuroscientist 10, 221–234.
Osaka, N., Osaka, M., Morishita, M., Kondo, H., Fukuyama, H., 2004. A word expressing affective pain activates the anterior cingulate cortex in the human brain: an fMRI study. Behav. Brain Res. 153, 123–127.
Peyron, R., Garcia-Larrea, L., Grégroire, M.-C., Costes, N., Convers, P., Lavenne, F., Mauguière, F., Michel, D., Laurent, B., 1999. Haemodynamic brain responses to acute pain in humans. Brain 122, 1765–1779.
Peyron, R., Laurent, B., Garcia-Larrea, L., 2000. Functional imaging of brain responses to pain. A review and meta-analysis. Clin. Neurophysiol. 30, 263–288.
Phillips, M.L., Young, A.W., Senior, C., Brammer, M., Andrew, C., Calder, A.J., Bullmore, E.T., Perrett, D.I., Rowland, D., Williams, S.C., Gray, J.A., David, A.S., 1997. A specific neural substrate for perceiving facial expressions of disgust. Nature 389, 495–498.
Ploghaus, A., Tracey, I., Gati, J.S., Clare, S., Menon, R.S., Matthews, P.M., Rawlins, J.N., 1999. Dissociating pain from its anticipation in the human brain. Science 284, 1979–1981.
Ploghaus, A., Becerra, L., Borras, C., Borsook, D., 2003. Neural circuitry underlying pain modulation: expectation, hypnosis, placebo. TICS 7, 197–200.
Porro, C.A., Baraldi, P., Pagnoni, G., Serafini, M., Facchin, P., Maieron, M., Nichelli, P., 2002. Does anticipation of pain affect cortical nociceptive systems? J. Neurosci. 22, 3206–3214.
Porro, C.A., Cettolo, V., Francescato, M.P., Baraldi, P., 2003. Functional activity mapping of the mesial hemispheric wall during anticipation of pain. NeuroImage 19, 1738–1747.
Posner, M.I., Rothbart, M.K., 1998. Attention, self-regulation and consciousness. Philos. Trans. R. Soc. Lond., Biol. Sci. 353, 1915–1927.
Preston, S.D., de Waal, F.B.M., 2002. Empathy: its ultimate and proximate bases. Behav. Brain Sci. 25, 1–72.
Price, D.D., 1999. Psychological Mechanisms of Pain and Analgesia. IASP Press, Seattle, WA.
Price, D.D., 2000. Psychological and neural mechanisms of the affective dimension of pain. Science 288, 1769–1772.
Prinz, W., 1997. Perception and action planning. Eur. J. Cogn. Psychol. 9, 129–154.

Puce, A., Perrett, D., 2003. Electrophysiology and brain imaging of biological motion. Philos. Trans. R. Soc. Lond., B 358, 435–445.

Rainville, P., 2002. Brain mechanisms of pain affect and pain modulation. Curr. Opin. Neurobiol. 12, 195–204.

Rainville, P., Duncan, G.H., Price, D.D., Carrier, B., Bushnell, M.C., 1997. Pain affect encoded in human anterior cingulate but not in somatosensory cortex. Science 277, 968–971.

Rizzolatti, G., Fogassi, L., Gallese, V., 2001. Neurophysiological mechanisms underlying the understanding and imitation of action. Nat. Rev. Neurosci. 2, 661–670.

Rochat, P., Striano, T., 2000. Perceived self in infancy. Infant Behav. Dev. 23, 513–530.

Sawamoto, N., Honda, M., Okado, T., Hanakawa, T., Kanda, M., Fukuyama, H., Konishi, J., Shibasaki, H., 2000. Expectation of pain enhances responses to nonpainful somatosensory stimulation in the anterior cingulate cortex and parietal operculum/posterior insula: an event-related functional magnetic resonance imaging study. J. Neurosci. 20, 7438–7445.

Singer, T., Seymour, B., O'Doherty, J., Kaube, H., Dolan, R.J., Frith, C.D., 2004. Empathy for pain involves the affective but not sensory components of pain. Science 303, 1157–1162.

Stevens, J.A., Fonlupt, P., Shiffrar, M., Decety, J., 2000. New aspects of motion perception: selective neural encoding of apparent human movements. NeuroReport 11, 109–115.

Treede, R.D., Kenshalo, D.R., Gracely, R.H., Jones, A.K.P., 1999. The cortical representation of pain. Pain 79, 105–111.

Trevarthen, C., 1979. Communication and cooperation in early infancy. In: Bullowa, M. (Ed.), Before Speech: The Beginning of Interpersonal Communication. Cambridge Univ. Press, London, pp. 321–347.

Wallbott, H.G., 1991. Recognition of emotion from facial expression via imitation? Some indirect evidence for an old theory. Br. J. Soc. Psychol. 30, 207–219.

Wicker, B., Keysers, C., Plailly, J., Royet, J.P., Gallese, V., Rizzolatti, G., 2003. Both of us disgusted in *My* insula: the common neural basis of seeing and feeling disgust. Neuron 40, 655–664.