

Neural correlates of admiration and compassion

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Edited by Marcus E. Raichle, Washington University School of Medicine, St. Louis, MO, and approved March 10, 2009 (received for review October 21, 2008)

In an fMRI experiment, participants were exposed to narratives based on true stories designed to evoke admiration and compassion in 4 distinct categories: admiration for virtue (AV), admiration for skill (AS), compassion for social/psychological pain (CSP), and compassion for physical pain (CPP). The goal was to test hypotheses about recruitment of homeostatic, somatosensory, and consciousness-related neural systems during the processing of pain-related (compassion) and non-pain-related (admiration) social emotions along 2 dimensions: emotions about other peoples' social/psychological conditions (AV, CSP) and emotions about others' physical conditions (AS, CPP). Consistent with theoretical accounts, the experience of all 4 emotions engaged brain regions involved in interoceptive representation and homeostatic regulation, including anterior insula, anterior cingulate, hypothalamus, and mesencephalon. However, the study also revealed a previously undescribed pattern within the posteromedial cortices (the ensemble of precuneus, posterior cingulate cortex, and retrosplenial region), an intriguing territory currently known for its involvement in the default mode of brain operation and in self-related/consciousness processes: emotions pertaining to social/psychological and physical situations engaged different networks aligned, respectively, with interoceptive and exteroceptive neural systems. Finally, within the anterior insula, activity correlated with AV and CSP peaked later and was more sustained than that associated with CPP. Our findings contribute insights on the functions of the posteromedial cortices and on the recruitment of the anterior insula in social emotions concerned with physical versus psychological pain.

fMRI | insula | morality | posteromedial cortices | social emotions

Social emotions such as admiration and compassion play a critical role in interpersonal relationships and moral behavior (1, 2). They motivate us to either reward (in the case of admiration) or remedy (in the case of compassion) the circumstances of another person (3). The experience of these emotions may also produce a sense of heightened self-awareness that incites our own desire to be virtuous or skillful, or else gratitude for our own good circumstances (4–6).

Admiration can be evoked by witnessing virtuous behavior aimed at reducing the suffering of others [known also as “elevation” (4)] or by displays of virtuous skill; compassion can be evoked by witnessing situations of personal loss and social deprivation (hereafter, social pain) or by witnessing bodily injury. Notably, each of these emotions pertains to another person's immediate physical circumstances (admiration for skill, compassion for physical pain) or social/psychological circumstances (admiration for virtue, compassion for social pain); and each is either related to pain processing (compassion for physical and for social/psychological pain) or not (admiration for skill and for virtue).

Although understanding the neural underpinnings of these emotions is important to the effort of elucidating the neurobiology of social behavior, the neural basis of admiration has not been investigated and the neural correlates of compassion states, in particular the relationship between compassion for physical pain and social pain, has been studied mainly from the perspective of recognizing someone else's social pain or sadness (e.g., ref. 7) rather than experiencing these emotions. In this study, we

induce strong states of admiration and compassion in our participants to investigate the neural underpinnings of feeling these emotion states.

Critical to this argument is the distinction between recognizing another's social or physical situation and emotionally reacting to it. It is well known that basic emotions such as fear, sadness, and happiness and limited social emotions such as moral indignation engage neural systems concerned with sensing and regulating body function (hereafter homeostasis) with varying patterns, and it has been hypothesized that among those systems, the insula plays an especially prominent role (8–13). It is also known that engagement of social emotions and the consequent feeling for another's social/psychological situation are described by poets and lay people alike in visceral and bodily terms and in terms of their heightening effect on one's own self-awareness or consciousness. However, the extent to which we use neural systems related to sensing and regulating our own body and consciousness to react emotionally to the psychological and physical situations of others has not been investigated comprehensively (14), and there is especially little known about how these systems may be involved in positive, approach-oriented emotions such as admiration. If recruitment of body regulation and consciousness systems does occur, how might it differ across varieties of admiration and compassion and between social emotions about others' physical versus social/psychological situations?

Interestingly, neural mechanisms of physical pain (involving especially the dorsal anterior cingulate) have been suggested to underlie the experience of social exclusion or loss (15–18), and recent research has established important shared neural mechanisms between the direct experience of pleasant and unpleasant physical sensations such as pain, noxious odors, and pleasant tastes and the ability to recognize these experiences in others (e.g., 19, 20–28). It has not been established, however, how neural mechanisms used in empathy for another's physical situation may be involved in emotional reactions to another person's psychological state, either admirable or painful. Also, should we find that both compassion for physical pain (CPP) and compassion for social pain (CSP) involve the anterior insula, an important follow-up question relates to the timing of the neural activity in this region. Because CPP is evolutionarily well established (see ref. 29) and develops earlier in children (see ref. 30), it is likely to require minimal cognitive processing before induction, whereas CSP would require more substantial cognitive processing related to cultural factors. We therefore hypothesized that activation in the anterior insula would be induced and dissipated more quickly for CPP than for the other emotions tested, most notably CSP.

Author contributions: M.H.I.-Y., A.M., H.D., and A.D. designed research; M.H.I.-Y. and A.M. performed research; M.H.I.-Y., A.M., H.D., and A.D. analyzed data; and M.H.I.-Y., H.D., and A.D. wrote the paper.

The authors declare no conflict of interest.

This article is a PNAS Direct Submission.

Freely available online through the PNAS open access option.

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This article contains supporting information online at www.pnas.org/cgi/content/full/0810363106/DCSupplemental.

In addition to research on physical and social pain, a rich body of literature from the last decade has converged on the involvement of several brain regions in the making of inferences about the mental states of others, prominently the temporoparietal junction (TPJ), the mesial prefrontal cortex, and a territory encompassing 3 contiguous cortical areas—the posterior cingulate cortex, the retrosplenial, area, and the precuneus—which together comprise the posteromedial cortices (PMC). Prefrontal activations have been linked to the process of generating inferences about another person's mental state and psychological characteristics (see ref. 31 for review, and ref. 32), and activations in TPJ have been related to attributing beliefs to another person (e.g., ref. 33, see ref. 34 for review). However, the consistent engagement of the PMC in social tasks (35) and episodic memory (36) has not been clarified. In a parallel line of research drawing on evidence from focal damage and from neuroanatomical and neurophysiological studies, it has been suggested that this region is involved in consciousness, specifically in the construction of the self (see ref. 37 for review). In light of evidence that simulation on one's own self is an important means to understand others (see ref. 38 for review and refs. 39–41), this raises the possibility that the experience of admiration or compassion would differentially engage the PMC. For this reason, we wished to explore patterns of activation in the PMC during feelings of admiration and compassion.

In brief, although the past decade has seen a remarkable effort to elucidate the neural correlates of social cognition, here, we specifically set out to test whether and how areas of the brain involved in homeostatic regulation and consciousness would be engaged during the feeling of different varieties of admiration and compassion, presumably with different patterns. Specifically, we hypothesized:

1. that admiration and compassion would engage subcortical nuclei in brainstem and hypothalamus, and somatosensory cortices in interoceptive (anterior insula) and exteroceptive sectors (somatosensory association areas including the superior parietal lobule and supramarginal gyrus);
2. that admiration and compassion would engage the PMC (posterior cingulate, retrosplenial cortex and precuneus);
3. that activation in the anterior insula would peak and dissipate more quickly for CPP than for CSP or varieties of admiration.

We used fMRI and behavioral methods in 13 participants (6 women and 7 men) to compare and contrast the neural correlates of experiencing admiration and compassion in 4 distinct conditions: admiration for virtue (AV), admiration for skill (AS), compassion for social pain (CSP), and compassion for physical pain (CPP). For each condition, the experiences were experimentally induced by narratives based on episodes from the lives of real people (none were celebrities; see *Methods*). Narratives consisted of an experimenter's scripted verbal account supplemented by combinations of audio/video/still images that involved social pain (to induce CSP in participants); bodily injury without social consequences (to induce CPP); virtuous acts (to induce AV); or virtuous skill without virtuous implications (to induce AS). The control condition required equivalent processing of narratives that were engaging, social, and active but not emotional. Before the imaging experiment, narratives were developed and tested through an extensive piloting procedure. Participants were introduced to the narratives in a prescanning one-on-one interview but were told neither the categories of emotion in the study nor which emotion each particular narrative was meant to elicit. In the scanner, blood-oxygen-level-dependent (BOLD) signal, respiration rate, and heart rate data were collected while participants viewed short reminder versions and were asked to think about the complete narrative that they had been told earlier, to become as emotional as possible, and

to report the strength of their emotion via button press. Participants' verbal descriptions of their feelings during pre- and postscan interviews, and strength ratings from button presses during the scan, were used to ensure that only data from trials in which the participant became genuinely consumed with the target emotion were contrasted with data from unequivocally nonemotional control trials. Any emotional narrative that produced mixed emotions in a participant or to which a participant did not react emotionally in the scanner was removed from the analysis for that participant.

Emotional states are constituted by bodily changes in internal milieu (e.g., hormonal), autonomic function (e.g., heart rate), smooth as well as striated musculature, and the expression of specific behaviors (e.g., freezing or flight). Accordingly, psychophysiological data were used in the BOLD analysis to identify the time window of the emotional reaction and to ensure our effects were not explainable solely by arousal. Because emotions include psychophysiological changes, which are thus present in all instances in which an emotion is felt, we did not remove the portion of the BOLD signal that correlates with psychophysiological changes. Within the time window identified by the psychophysiological results, ANCOVA random-effects analysis was used to contrast BOLD data from each target condition with control and emotions about psychological circumstances (AV, CSP) with those about physical circumstances (AS, CPP). Event-related averages (ERAs) and a bootstrap procedure were used to statistically compare time-to-peak and duration of BOLD response among conditions in the anterior insula.

Results

Behavioral and Psychophysiological Results. All participants reported feeling appropriately emotional both in the preparation session and in the scanner (as judged by button presses during scanning and by interviews) and indicated that the fixation time in the scanner was sufficient to clear their minds between trials. All subjects but 1 attained each of the target emotions in the scanner. Among qualified emotional trials, average reported emotional strength during scanning differed among conditions ($F = 16.94$, $df = 3$, $P < 0.001$); post hoc comparison at $\alpha = 0.05$ revealed that CSP and CPP had the highest values and were not distinguishable from each other. AV was lower than CSP but not distinguishable from CPP. AS scored lower than the other conditions [for additional details, see *Methods* and *Behavioral Data Analysis* in [supporting information \(SI\) Text](#) and [Table S1](#) for a summary of behavioral results]. Average respiration rate (RR) for each condition showed a rise corresponding to trial onset and a return to baseline after ≈ 12 s. During the 10-s time window used for the BOLD contrasts, average RR was not different between conditions ($F = 0.84$, $df = 4$, $P < 0.51$); average heart rate (HR) was higher than control for AV and CSP, there was a trend for CPP, and AS was indistinguishable from control ($F = 3.49$, $df = 4$, $P < 0.02$; Dunnett t for emotion $>$ control: AV, $P < 0.02$; AS, $P < 0.79$; CSP, $P < 0.02$; CPP, $P < 0.13$) (for additional details see *Image Processing* and *Psychophysiology* in *Methods* and *Psychophysiology* in *SI Text*; see [Fig. S1 A and B](#) for RR and HR time courses). These psychophysiological results make it unlikely that the results of BOLD contrasts could be explained solely by differences in arousal between conditions. In particular, the BOLD contrast between AS and control shows significant results in all hypothesized areas, although there are no differences between arousal levels as measured by psychophysiology in these 2 conditions. Furthermore, RR and HR results from AV, CSP, and CPP are highly comparable, yet patterns of brain activation differ among these conditions.

BOLD Results by Condition Compared with Control. In accord with our prediction that admiration and compassion would engage

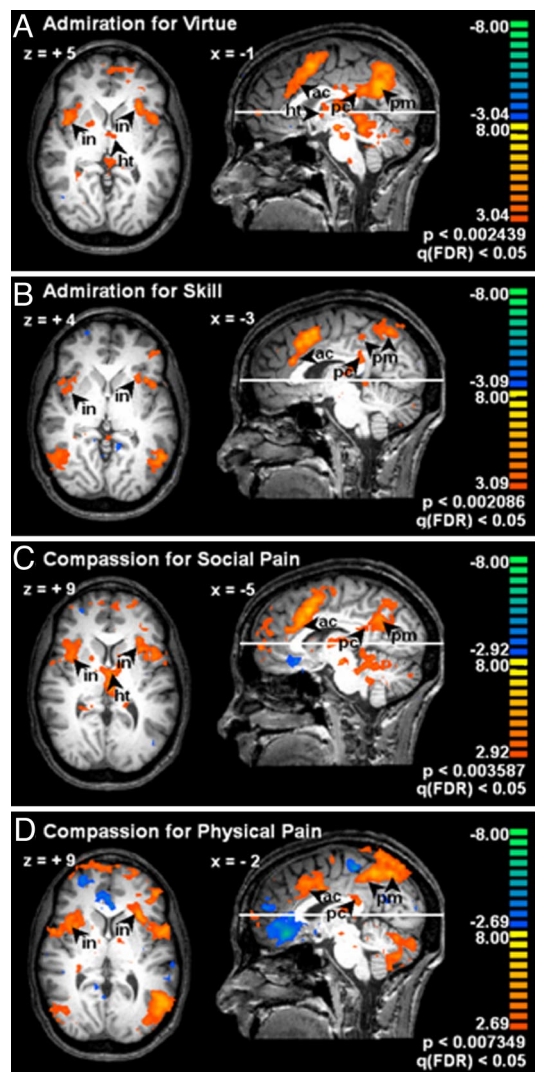


Fig. 1. Neural correlates of admiration for virtue (A) and skill (B) and compassion for social (C) and physical (D) pain. fMRI data are from 13 subjects, displayed on the brain of 1 subject. Each image shows a target emotion contrasted with control. The position of each transverse slice is marked on the parasagittal images; Talairach coordinates of each slice and of the parasagittal view are annotated. Images are thresholded by using the false discovery rate statistic, $q(\text{FDR}) < 0.05$. The bar to the right of each image provides a color code for t statistics of the respective contrast. Note the bilateral activation in the insula (in), anterior cingulate (ac), and dorsal posterior cingulate (pc) for all emotions. Note the activation in the posteroventral posteromedial cortices (pm) in AV (A) and CSP (C) compared with anterosuperior sector in AS (B) and CPP (D). Note brainstem and hypothalamus (ht) in A and C.

subcortical regions related to regulating internal organism states, all conditions produced activation of the hypothalamus, as well as the mesencephalon and pontomedullary junction, which include nuclei involved in autonomic regulation. AV and CSP also engaged the medulla. All conditions activated the anterior middle cingulate cortex. All conditions activated cortical regions involved in sensing the body, including anterior insula and supramarginal gyrus. AS and CPP activated the posterior insula. All conditions strongly activated the PMC, but there was a separation between conditions: AV and CSP activated the inferior/posterior sector, whereas AS and CPP activated the superior/anterior sector (see also Fig. 1; see Table S2 for details).

Of particular interest, relative to the hypothesized regions, there was a partial separation between emotions pertaining to

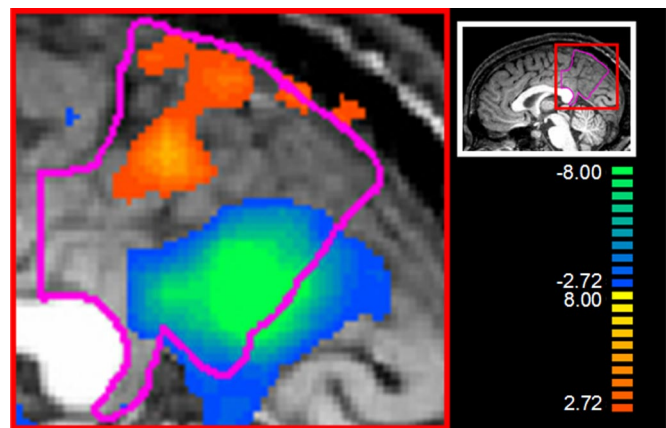


Fig. 2. Relative activation in the posteromedial cortices (PMC, outlined in pink) for admiration for virtue and compassion for social pain (AV/CSP, blue to green) versus admiration for skill and compassion for physical pain (AS/ CPP, orange to yellow). The image is thresholded at $q(\text{FDR}) < 0.05$. The bar to the right provides a color code for t statistics associated with the contrast. The red box frames the location of the magnified view. Note the clear separation between the anterosuperior sector activated by AS/ CPP, and the posteroventral activated by AV/CSP.

physical circumstances (AS and CPP) versus those pertaining to social/psychological circumstances (AV and CSP). This finding is explored below.

BOLD Results Comparing AV/CSP Versus AS/ CPP. Because of the findings mentioned in the previous section and growing interest in the function of the PMC, we calculated a contrast of AV/CSP (combined) versus AS/ CPP (combined). This allowed us to contrast effects of social processing about others' social/psychological situations versus physical situations. This contrast confirmed the functional subdivision in the PMC mentioned above, in that AV/CSP produced more activation in the posterior/ inferior portion of the PMC (the sector most related to interoceptive processing), whereas AS/ CPP produced more activation in the anterior/ superior portion of the PMC (the sector most related to musculoskeletal processing; see Fig. 2). In addition, AV/CSP produced more activation in the anterior cingulate, anterior insula, and hypothalamus, all regions involved in homeostatic regulation. By contrast, AS/ CPP produced more activation in the posterior insula and lateral parietal cortices, including the supramarginal gyrus and superior parietal lobule, all regions related to the musculoskeletal system (see Table S3 for more details).

Event-Related Averaging: Comparison of Time Courses. To test the hypothesis that the activity correlated with CPP would peak earlier and extinguish more quickly than the other emotions, we used double-gamma curve fitting to compare the ERA time courses of the BOLD effects associated with each of the conditions in the anterior insula (see Fig. 3). Duration was calculated from the width of the curves at half-height. Tests for significance were performed in terms of the Z scores of the difference between conditions at a criterion level of 0.05 after correction for multiple comparisons (Bonferroni). CPP peaked more quickly than each of the other emotions and had a shorter duration (see Table S4 for details).

Discussion

The ability to empathize with another person's psychological and physical circumstances is a foundation of sociality and moral behavior (42). In most circumstances, empathy is likely to begin with a cognitive appraisal of another's situation, which leads to

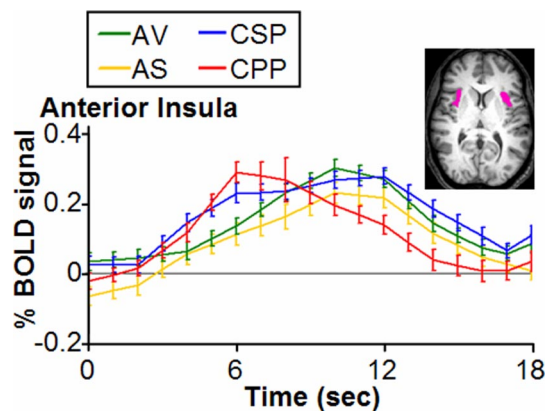


Fig. 3. Event-related averages for the time courses of admiration and compassion in the anterior insula, with standard errors. Units are percentage change in BOLD signal and time in seconds; time courses are not corrected for hemodynamic delay. For display purposes, BOLD data have been linearly interpolated to 1-s resolution. The volume of interest is displayed in pink. Conditions: AV (green): admiration for virtue; AS (yellow): admiration for skill; CSP (blue): compassion for social pain; CPP (red): compassion for physical pain. Note the rapid rise and dissipation of CPP (red) versus the slower and more sustained rise of CSP (blue), AV (green), and AS (yellow).

the induction of a social emotion. In this study, we aimed at inducing strong emotional experiences, either admiring or compassionate, in the participants of the fMRI experiment. One of our aims was to discern whether feelings of admiration and compassion, which are arguably some of the most refined in the human repertoire, would nonetheless recruit neural systems for sensing and regulating body function, as is known to be the case for basic feelings of emotion. Furthermore, we wished to investigate patterns of activation in the posteromedial cortices, a unique set of convergence–divergence cortices (43) known to be involved in self-related processes and the default mode of brain operation (44). Last, we were interested in knowing whether neural activity in the anterior insula associated with compassion for physical pain, arguably a social emotion that requires limited cognitive processing, would peak and dissipate at a rate different from the other emotions tested, in particular compassion for social/psychological pain.

Overall, the finding that homeostatic regulatory mechanisms are engaged in the experience of admiration and compassion supports the hypothesis that social emotions use some of the same basic devices involved in primary emotions (45) and the salience system (46). Relative to the anterior insula and anterior cingulate cortex, our results replicate those of Singer (22) and others (e.g., refs. 16, 21). Our data do not allow us to compare basic and social emotions in terms of degree or pattern of engagement. However, our findings provide insights into the neural differentiation of the social emotions.

First, a notable difference between the experimental conditions was found in the PMC. AV and CSP were associated with strong activation in the inferior/posterior portion of PMC, unlike AS and CPP. By contrast, AS and CPP showed activation in the superior/anterior portion of the PMC, which AV and CSP also showed but to a lesser degree. This distinction is especially intriguing in light of this region's neural connectivity, revealed in a recent neuroanatomical tracing study in the macaque. Parvizi et al. (47) demonstrated that the superior/anterior portion of the PMC is strongly interconnected with lateral parietal cortices, whereas the inferior/posterior portion is closely associated with the anterior middle cingulate cortex, which is itself strongly connected with the insular cortex. Consistent with the anatomical findings, our data suggest a functional subdivision in the PMC regarding emotional processing. Emotions related to

someone else's "psychological" state, e.g., social pain or virtue, may preferentially recruit a network involving the inferior/posterior PMC and the anterior middle cingulate, which are affiliated with interoceptive information; by contrast, emotions related to someone else's "physical" state, e.g., painful injury or virtuous skill, may recruit the sector of PMC most connected with lateral parietal cortices, suggesting a connection to exteroception and musculoskeletal information. Consistent with this interpretation, all emotions engaged the anterior insula, anterior middle cingulate, and lateral parietal cortices; however, in a contrast of AV/CSP (combined) versus AS/ CPP (combined), AV/CSP showed more activity in the anterior middle cingulate and anterior insula, and AS/ CPP showed more activity in the lateral parietal cortices. AV/CSP also showed more activity in the hypothalamus and mesencephalic reticular formation, both homeostasis-related territories, whereas AS/ CPP showed activity in the posterior insula, which is associated with cognitive/motoric processing. Inspection of the data prompted by these findings revealed an equivalent separation at the level of the cerebellum (see ref. 48): AV/CSP activated the anterior/superior cerebellar lobe [Tal: $-30, -76, -38$, $q(\text{FDR}) < 0.001$], whereas AS/ CPP activated the posterior/inferior lobe [Tal: $-21, -40, -20$, $q(\text{FDR}) < 0.001$]. Overall, these results suggest that the processing of social emotions is organized less around the kind of emotional response, be it compassionate or admiring, than around the contents and context of the situation.

Second, activity in the PMC has also been suggested to underlie the self-processes (37), consistent with its role in processes of consciousness (e.g., refs. 49–51) and its participation in tasks associated with perspective taking and social processing (e.g., refs. 52–54). High levels of activity in the PMC (especially the inferior/posterior sectors) appear to be associated with internally focused attention and introspection (36, 55–57) during resting states (44). Interestingly, compassion for social pain and admiration for virtue, perhaps because they pertain to another's suffering or the alleviation of that suffering, respectively, are often associated with a sense of heightened awareness of one's own condition and its moral implications. For example, several participants volunteered that learning of others' virtue or psychological pain, respectively, incited in them a strong but undifferentiated desire to lead a meaningful life, or gratitude for their own good circumstances. Our participants' report of enhanced self-awareness during AV and CSP may reflect a role for the inferior/posterior PMC in introspecting about someone else's situation related to one's own self. Others have suggested such a process in connection with other brain structures (see ref. 38 for review and ref. 58).

Third, although it is known that the anterior insula is involved in compassion for physical pain, our finding that activity in this region peaked more quickly and for a shorter duration during CPP than during CSP (and AV, AS) suggests that emotions about others' physically painful predicaments co-opt neural mechanisms for personally experienced pain most efficiently and directly, whereas emotions about others' psychological/moral situations build on these same mechanisms but may operate less efficiently and directly. If replicated, this finding could have important implications for the role of culture and education in the development and operation of social and moral systems; in order for emotions about the psychological situations of others to be induced and experienced, additional time may be needed for the introspective processing of culturally shaped social knowledge. The rapidity and parallel processing of attention-requiring information, which hallmark the digital age, might reduce the frequency of full experience of such emotions, with potentially negative consequences.

Taken together, the evidence from neural activity patterns and neural time courses in our experiment suggests a differentiation in the processing of these emotional feelings, in keeping with the

normalized and averaged to 2-s intervals to correspond to TR length (see *Psychophysiology* in *SI Text* for details).

Image Processing. After preprocessing and normalization, we estimated the BOLD signal for each participant using a GLM. Individual TRs for each trial type were separately modeled with 9 independent regressors (δ -functions). ANCOVA random effects was used to compare data from TRs corresponding to the time window of maximal psychophysiological effect (see *Image Acquisition and Processing* in *SI Text*). Statistical maps were thresholded by using the false discovery rate statistic, $q(\text{FDR}) < 0.05$ (see *Localization of Activations* in *SI Text*).

Event-Related Averaging and Analysis of Time Course. To test the hypothesis that CPP is more quickly induced and shorter-lived in the anterior insula than the other emotions tested, we statistically compared the time courses of the

BOLD effects associated with each emotion in this brain region by fitting the ERAs of the z-transformed signal with difference of gamma-functions and implementing a bootstrap procedure to estimate the parameters of interest. See *Event-Related Averaging and Analysis of Time Course* *SI Text* for details.

ACKNOWLEDGMENTS. We thank B. Tjan, J. Kaplan, Z.-L. Lu, D. Pantazis, and J. Zhuang for valuable advice on fMRI methodology. J. Parvizi consulted on neuroanatomical issues; S. Wong consulted on analyses of psychophysiological data; X. Yang, X. Li, G. Xue, J. L. Poletti Soto, and L. Xiao collaborated on data analysis; J. McArdle advised on behavioral questionnaires; M. Miles performed reliability coding; G. Fox, I. Uricaru, M. Borner, C. Webber, A. N. Zhou, R. Essex, F. Dandekar, StoryCorps assisted with experimental preparations; and Z.-L. Lu and K. Meyer provided helpful comments on the manuscript. This research was supported by National Institutes of Health Grant P01 NS19632 (to A.D. and H.D.), by a grant from the Mathers Foundation (to A.D. and H.D.), and by the Brain and Creativity Institute Fund.

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