The Moral Affiliations of Disgust

A Functional MRI Study

Jorge Moll, MD, Ricardo de Oliveira-Souza, MD,*† Fernanda Tovar Moll, MD,* Fátima Azevedo Ignácio, PhD,‡ Ivanei E. Bramati, PhD,* Egas M. Caparelli-Dáquer, MD,*†§ and Paul J. Eslinger, PhD‖*

Abstract: Recent investigations in cognitive neuroscience have shown that ordinary human behavior is guided by emotions that are uniquely human in their experiential and interpersonal aspects. These "moral emotions" contribute importantly to human social behavior and derive from the neurobehavioral reorganization of the basic plan of emotions that pervade mammalian life. Disgust is one prototypic emotion with multiple domains that include viscerosomatic reaction patterns and subjective experiences linked to (a) the sensory properties of a class of natural stimuli, (b) a set of aversive experiences and (c) a unique mode of experiencing morality. In the current investigation, we tested the hypotheses that (a) the experience of disgust devoid of moral connotations ("pure disgust") can be subjectively and behaviorally differentiated from the experience of disgust disguised in the moral emotion of "indignation" and that (b) pure disgust and indignation may have partially overlapping neural substrates. Thirteen normal adult volunteers were investigated with functional magnetic resonance imaging as they read a series of statements depicting scenarios of pure disgust, indignation, and neutral emotion. After the scanning procedure, they assigned one basic and one moral emotion to each stimulus from an array of six basic and seven moral emotions. Results indicated that (a) emotional stimuli may evoke pure disgust with or without indignation, (b) these different aspects of the experience of disgust could be elicited by a set of written statements, and (c) pure disgust and indignation recruited both overlapping and distinct brain regions, mainly in the frontal and temporal lobes. This work underscores the importance of the prefrontal and orbitofrontal cortices in moral judgment and in the automatic attribution of morality to social events. Human disgust encompasses a variety of emotional experiences that are ingrained in frontal, temporal, and limbic networks.

Key Words: disgust, moral emotions, moral judgment, social cognition, functional magnetic resonance imaging

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Disgust has been featured in most classifications as a domain of emotional behaviors shared by most mammals.[1] At its most elementary level, disgust is the aversive experience associated with responses that act to expel repulsive material from the upper digestive tract. Disgust includes a motivation to avoid, expel, or break off contact with the offending entity, often coupled to the need to wash, purify, or remove residues of physical contact that was made with the entity. These behavioral patterns encompass specific changes in facial and vocal expression, mood, and viscerosomatic integration, such as nausea, gagging, and vomiting.[2]

Although disgust has been well studied as a basic emotion, its presence and influence on social behavior have not as yet been fully appreciated in the field of neuroscience. The diversity of the human disgust experience is grounded in cognitive and emotional mechanisms that give disgust the characteristics of a moral emotion. Moral emotions are distinguished specifically by their linkage to the interests or welfare of society as a whole or of persons other than the judge or agent.[3] The moral emotion of disgust spans a broad spectrum of attitudes, experiences, and behaviors that pervade common sense, politics, religion, art, and philosophy.[4] It is within social and cultural contexts that disgust can be associated more with psychologic aspects than strictly with the sensory properties of the offending sources.[5] Disgust, contempt, and anger are social emotions that are thought to result from violations to the ethics of divinity, community, and autonomy, respectively.[4] Disgust arising in interpersonal situations typically induces behaviors that help break off contact, remove, harm, or destroy the offending agent(s), leading to restoration of a baseline of purity or normality.

Disgust can be subdivided into several levels of specificity (Table 1). The most general and elementary forms of disgust are distaste and core disgust that occur in conjunction with offensive and/or aversive sensory experiences. More specific psychologic forms of disgust are typical of humans and occur principally in the social domain, where they are represented by interpersonal and moral disgust. Interpersonal

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*Neuroimaging and Behavioral Neurology Group (GNNC), LABS-Hospitais D'Or, Rio de Janeiro, Brazil; †Hospital Universitário Gaffrée e Guinle, Universidade do Rio de Janeiro, Rio de Janeiro, Brazil; ‡Instituto Philippe Pinel, Rio de Janeiro, Brazil; §Behavioral Assessment Laboratory, Department of Physiological Sciences, UERJ, Rio de Janeiro, Brazil; and ‖Departments of Neurology, Behavioral Science, and Pediatrics, College of Medicine, Penn State University, Hershey Medical Center, Hershey, Pennsylvania.
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Reprints: Dr. Jorge Moll, Neuroimaging and Behavioral Neurology Group (GNNC), LABS-Hospitais D'Or, Rua Pinheiro Guimarães, 22/4° andar, Botafogo, Rio de Janeiro, RJ 22281-080, Brazil (e-mail: jmoll@neuroimage.com).

TABLE 1. Diverse Experiences of Disgust

Distaste. A general mammalian response to the sensory qualities of materials, which are perceived as "bad tastes."

Core disgust. Elicited by animals and their products as potential foods.
- Food related
- Body waste products
- Animal waste products

Animal nature disgust. Elicited by the reminiscence of the animal nature and mortality of humans.
- Poor hygiene
- Sex related
- Violations of the body envelope (eg, gore, surgery, deformity, accidental exposure of internal organs)
- Death and organic decay

Interpersonal disgust. Contact with individuals belonging to an "inferior nature."
- Strangeness
- Disease
- Misfortune
- Moral taint

Moral disgust. Related to the protection of the self as a spiritual entity from degrading and polluting influences. Elicited by contact with "certain" other people (eg, homosexuals, people of different cultural or ethnic groups, criminals) who committed moral offenses endowed with contamination.

disgust is triggered by circumstances or ideas involving people who violate local cultural norms on the use of their bodies, particularly in issues of sex, drugs, and body modification. Moral disgust relates to the spiritual protection of the self against degrading and polluting influences.[3,6]

Most human lesion and neuroimaging studies have been restricted to the recognition of facial and vocal displays of disgust in others.[8,9] An early positron emission tomography study on the experience of disgust in women used film and recall as emotion-eliciting stimuli. These results showed activation in the medial frontal lobes, temporal poles, thalamus, midbrain, and cerebellar hemispheres.[10] Calder et al[11] reported that a patient with acquired damage to the left putamen and anterior insula experienced a remarkable impairment in the experience of disgust from multiple sensory channels.

In a series of investigations, Moll et al reported the neural correlates of moral judgment and emotion with functional magnetic resonance imaging (fMRI). When normal adult volunteers passively viewed scenes evocative of basic (disgust and fear) and moral (compassion and indignation) emotions, significant bilateral activation occurred in the amygdala, thalamus, midbrain, and visual cortex.[12] Direct comparison between basic and moral emotions revealed that basic emotions activated the right anterior insula and adjacent frontal operculum, while the moral condition activated the medial orbitofrontal (OFC), frontopolar, and medial frontal cortices and the posterior third of the superior temporal sulcus (STS), mainly in the right hemisphere. In another fMRI study, normal adult volunteers were required to judge written statements evocative of either basic or moral emotions.[13] The medial OFC and the posterior STS responded preferentially to judgments about statements evocative of moral emotions (indignation and compassion), while the extended amygdala and the lateral OFC were activated by social judgments associated with basic emotions such as disgust and fear. More recently, we devised a set of 190 written stimuli to evoke moral emotions as a paper-and-pencil instrument for use in fMRI protocols. These stimuli were standardized in normal adults, and the most reliable were assembled in the Moral Emotions Battery (MEB). In this study, these stimuli were presented to normal young adults to elicit emotional experiences and probe the behavioral and fMRI correlates of the experience of disgust and indignation. Given the behavioral affinities between disgust (a basic emotion) and indignation (a moral emotion), we tested the hypotheses that (a) disgust and indignation would share some core psychologic mechanisms, (b) the subjective experience of disgust and indignation would be reflected in partially overlapping brain activation patterns, and (c) there would be differential effects of disgust and indignation on brain activation, mainly in frontolimbic structures.

MATERIALS AND METHODS

Subjects

Thirteen right-handed adults (seven men, six women), aged 25.5 ± 4.5 years (mean ± SD), with 14 ± 2 years of education, without a history of past or current neurologic or psychiatric disorders, were studied (see Table 4 for further details). The fMRI volunteers had not participated in the MEB standardization study and were not paid for their participation. The study was conducted in the Hospital Barra D'Or and approved by the hospital's institutional review board and ethics committees. Written informed consent was obtained from all participants.

Background Measures

Individual Sensitivity to Disgust

Individual sensitivities to disgust were assessed with a Brazilian adaptation of the Disgust Scale (D Scale).[14] Twenty-eight items in this self-administered scale sample seven dimensions of disgust sensitivity: food, animals, body products, sex, envelope violations, death, and hygiene. An addition scale of four items is designed to elicit disgust only if the respondent follows the "magical thinking" laws of similarity and contagion. (Magical thinking is a means of making sense of natural world phenomena originally observed in preagricultural people by 19th and early 20th century anthropologists. It operates through two distinct laws. The law of contagion ["once in contact, always in contact"] refers to the tendency to act as if brief contact causes a permanent transfer of properties from one object to another, even when there is no material substance transferred. Some people, for example, report that they would not drink from a glass that once held dog feces no matter how many times the glass was scrubbed and sterilized. The law of similarity holds that "the image equals the object." For example, a piece of chocolate fudge becomes far less desirable when it is shaped like a piece of dog feces.)[15] Thus, the D Scale offers eight subscale scores in addition to a total score between 0 and 32. Low and high scores indicate correspondingly low and high sensitivities to disgust. Typical adults score in the middle range of the scale. Sample items from the scale include "I never let any part of my body touch the toilet seat in public restrooms" and "You see maggots on a piece of meat in an outdoor garbage pail." (For further information on the D Scale, see http://wsrv.clas.virginia.edu/~jdh6n/disgustscale.html.)

Interpersonal Reactivity Index

The Interpersonal Reactivity Index (IRI) is a multidimensional measure of empathy[16] or "the cognitive and emotional processes that bind people together in various kinds of relationships that permit sharing of experiences and the understanding of others."[17] The IRI has several advantages over other measures of empathy because it taps four dimensions of the empathy construct that are represented in the subscales of perspective taking, fantasy, empathic concern, and personal distress. Each subscale contains seven items scored from 0 ("does not describe me well") to 4 ("describes me very well").

Alexithymia, the inability to recognize and verbally describe emotional experiences,[18] is an important component of introspection. To ascertain that subjects were able to verbally describe their feelings, they were administered the Brief Alexithymia Scale, an abridged version of the Toronto Alexithymia Scale.[19] This scale includes six items related to the ability to identify or describe one's own feelings (eg, "I find it hard to know how I feel," "It's hard for me to describe what I'm feeling") as well as the propensity for externally oriented thinking (eg, "I can feel close to someone even in moments of silence") on 4-point ordinal scales ranging from "never" to "always."

Beck Depression Inventory

We employed a Brazilian adaptation of the 13-item Beck Depression Inventory (BDI) with scores ranging from 0 ("none") to 3 ("extreme"). Typical items include "feelings of sadness" and "feelings of guilt" referred to the last 2 weeks.[20]

We assessed these domains to ascertain that our fMRI volunteers did not differ statistically from an independent sample of normal individuals on emotional and mood characteristics that might modify the main results. Individual scores on each measure were compared with those of a normative database that has been gathered during the past years for use as a local neurobehavioral reference (unpublished results).

Stimuli and Task

MEB

The MEB consists of pairs of statements depicting emotional and neutral scenarios. Stimuli were construed so that subjects were passive witnesses of the situations depicted in the stimuli. The emotional content of the statements was validated in a previous investigation involving 48 normal adults of both genders and from a variety of occupations. Two major categories of emotions are included in the MEB: six basic emotions (category A) and seven moral emotions (category B) that must be rated as independently as possible. There are also neutral statements (no emotional content or valence) for each category (Table 2). Emotions in category A are represented in most accounts of basic emotions.[21] Category B emotions have been much less studied and were adapted from Haidt's taxonomy of moral emotions.[3] After scanning, subjects rated the emotional impact of each sentence pair according to type and intensity, by reporting how they would feel in each situation.

Ratings were collected along four independent dimensions: one category A emotion, one category B emotion, and their respective intensities. Subjects were instructed to choose one item of each column and to assign them intensities on 4-point ordinal scales, where 1 represented "weak" and 4 represented "very strong" emotional experience. The "neutral" option conveyed an absence of emotional experience and was scored as 0 for the purposes of statistical analysis. Statements rated as "neutral" in both category A and B, and statements evocative of "disgust" and "indignation" were selected for the current study. This procedure was designed to disentangle moral from basic emotional experience, allowing possible associations between them to become explicit and quantifiable. For example, the statements "One night you were walking on a street. You saw a cat eating its own excrement" and "You went with a friend to a restaurant. When you passed by the kitchen, you saw rats in the pans" evoked the basic emotion of disgust in, respectively, 85% and 74% of the normal volunteers who participated in the standardization of the MEB. However, they differed notably in their moral emotion ratings: Whereas most subjects rated the first pair of

TABLE 2. Dimensions of Emotion-Related Stimuli Rated by Subjects After fMRI Scanning Procedures

Category A		Category B	
1	happiness	1	compassion
2	fear	2	guilt
3	disgust	3	admiration
4	anger	4	shame or embarrassment
5	surprise	5	gratitude
6	sadness	6	indignation
7	neutral	7	contempt
		8	neutral

Each statement was rated independently on categories A (basic) and B (moral) according to the type of emotional experience they elicited. Statements evocative of disgust, indignation, and neutrality compose the focus of the current investigation.

fMRI, functional magnetic resonance imaging.

statements as morally "neutral" (ie, "pure disgust" statements), the second pair evoked "indignation" in 94% of them. The current study reports the MEB findings referred to pure disgust, indignation, and neutrality based on the responses to the 15 statements of each category.

fMRI Procedure

Subjects were scanned while they viewed statements describing neutral and emotionally charged scenes with disgust or moral violations taken from the MEB (Table 3). There were three conditions of interest: (a) emotionally charged, unpleasant social scenarios describing moral violations (eg, intentional body harm, psychologic and/or physical damage caused by imprudence or negligence); (b) unpleasant statements evocative of pure disgust, without moral connotations (eg, disgusting animals, body excreta); and (c) neutral statements describing ordinary scenes of daily life. Importantly, all scenarios included the subject as an actor, to better control for possible effects of agency and social context.

Subjects were not informed about the rationale of the study. In particular, they were naive to the theoretical distinction between basic and moral emotions. Because our goal was to investigate spontaneous brain responses, no mental operations on the stimuli were required. Stimuli were presented through magnetically shielded liquid crystal display goggles (Resonance Technologies, Northridge, CA) controlled by a computer. Subjects were instructed to press a button when they finished reading each statement. An event-related design was employed, and statements were presented in a fixed randomized order. Each statement was displayed for 8 seconds, followed by a black screen that remained on from 1 to 8 seconds. Therefore, the interval between the presentation of each stimulus lasted from 9 to 16 seconds. After scanning, subjects reported their emotional experiences according to the MEB procedures already described.

Statistical Analysis of Behavioral Results

Nonparametric tests were used in the analysis of behavioral results, adopting a 0.05 threshold of significance (α), two tailed.[22]

fMRI Methods

Anatomic data consisted of volumetric T1-weighted gradient-echo images (repetition time [TR]/echo time [TE] = 14/4.6 milliseconds, matrix = 256×256, field of view [FOV] = 256 mm, thickness/gap = 1.25/0 mm, 128 slices). Functional data were acquired with blood oxygenation level–dependent echo planar imaging (TR/TE = 3100/60 milliseconds, matrix = 64×64, FOV = 240 mm, thickness/gap = 2/1.6 mm, 23–25 slices). All imaging data were obtained with a 1.5 T MR scanner (Siemens Vision, Erlangen, Germany) equipped with a gradient overdrive system. Warping of the echo planar data was minimized by the use of a fast gradient-switching system and by carefully performing a three-dimensional localized shimming procedure before image acquisition. To minimize signal dropouts and warping at the base of the brain, functional images were collected using a 30° oblique acquisition plane relative to the intercommissural plane. This allowed improved imaging of the anterior and inferior prefrontal cortex, medial temporal lobe, amygdala, hypothalamus, and basal forebrain.[23,24] Visual inspection of the raw echo planar datasets showed that severe signal dropouts (>50%) were observed in only a small extent of the midlateral basal temporal lobe adjacent to the petrous temporal bone and mastoid cells and in a small region of the posterior aspect of the medial OFC. Image transfer and initial preprocessing steps were performed with home-built software (DiAna and BrainAct, GNNC, Rio de Janeiro, Brazil). Functional datasets were three-dimensionally motion corrected, and slice time correction, linear trend removal, and spatial smoothing (isotropic Gaussian kernel, 8-mm full width at half-maximum) were performed. Temporal filtering was restricted to applying a high-pass filter (4 cycles/entire time course) to remove low-frequency, nonlinear drifts of the baseline. Datasets were co-registered and Talairach transformed.[25] The use of a variable time interval between individual stimuli introduces a "jitter" in the sampling of event-related hemodynamic responses, avoiding the adverse effects of synchronized stimuli and data collection on event-related paradigms.[26] Regressors representing the experimental conditions of interest were modeled with a hemodynamic response filter and entered into a multiple regression analysis, using a fixed effects model.[27] Contrasts between conditions of interest were assessed with t statistics. A 50- to 100-mm^3 cluster threshold was used to protect against type I errors.[28] Statistical parametric maps[29] were created with BrainVoyager version 4.6 (Brain Innovation, Maastricht, the Netherlands) and overlaid on a representative brain created by averaging anatomic data of individual subjects. Localizations

TABLE 3. Samples of Statements Used in Experimental Conditions

Pure Disgust	Indignation	Neutral
You saw a boy walking toward you. Suddenly, he started regurgitating pieces of food he had during breakfast.	As you arrived home, you saw that the nurse had put a spider on the baby's face.	You went to the museum and paid for being taught about antiques.
One night you were walking on a street. You saw a cat eating its own excrement.	Your brother told you that he read that a student was stuffed with stones while he still breathed.	You drove at high speed on Sunday to arrive at the countryside in time to lunch with your wife.
A friend told you about a newspaper headline. A man had died after he ate a living rat.	You took your mother out to dinner. At the restaurant, she saw a dead cockroach floating on the soap pan.	Your wife called you to say she was going to iron your clothes. You were supposed to travel the next morning.

were based on established anatomic landmarks.[30] Statistical results for contrasts between main conditions (Disgust and Indignation) and baseline condition (Neutral) were thresholded using an uncorrected $P < 0.00001$, together with a minimum cluster volume of 100 mm^3. The same parameters were employed for displaying the results of the conjunction analysis.[31] A smaller search volume was used by creating an activation mask for the comparisons between the main conditions (Disgust > Indignation and Indignation > Disgust). This mask was created by identifying the activated brain regions in the ([Disgust + Indignation] > Neutral) statistical parametric map and comprised 13 activation clusters. This reduced the number of voxels to be computed, allowing the adoption of a more lenient threshold ($P < 0.005$, together with a cluster threshold = 50 mm^3) for direct comparisons between Disgust and Indignation. An adjunctive analysis addressed possible gender effects. Brain activation associated with Disgust and Indignation was examined by directly comparing each of these conditions between male and female participants, using whole-brain fixed-effects analysis, $P < 0.0001$ (uncorrected), and cluster threshold = 50 mm^3.

RESULTS

Genders of participants were equally represented in the study sample. There were also no significant differences between men and women in age, years of education, or any of the background variables of interest. Thus, men's and women's scores were pooled together for further statistical analyses. Moreover, the scores of our fMRI subjects did not differ statistically from those of a larger group of control subjects on the background measures (Table 4).

Emotional Experience Ratings

The ratings of the subjects participating in the fMRI study were roughly equivalent to those of the MEB standardization sample. As planned, statements intended to convey pure disgust (Table 5) were rated as having a high frequency of disgust ($\chi^2 = 527$, $df = 5$, $P < 0.0001$) and were not significantly associated with any of the moral emotions. In contrast, statements conveying indignation (see Table 5) were associated both with anger and disgust ($\chi^2 = 138$, $df = 5$, $P < 0.0001$). Pure disgust statements were associated with a higher degree of disgust than indignation statements. Neutral statements were rated as neutral in both the basic and the moral domains ($\chi^2 = 395$, $df = 4$, $P < 0.0001$).

TABLE 4. Subject Demographic Variables and Background Measures*

		Statistical Comparisons
Participants	7 men; 6 women	$\chi^2 = 0.08$, $P > 0.78$
		Mann–Whitney *U* test
Age (y)	25.5 ± 4.5	$U = 278$, $P > 0.53$
Education (y)	14 ± 2	$U = 283$, $P > 0.69$
D-scale (0–32)†	14.5 ± 5.0	$U = 311$, $P > 0.57$
Interpersonal reactivity index		
Perspective taking (0–28)	18 ± 5	$U = 275$, $P > 0.80$
Fantasy (0–28)	13 ± 6	$U = 277$, $P > 0.83$
Empathic concern (0–28)	18 ± 5	$U = 241$, $P > 0.35$
Personal distress (0–28)	10 ± 4	$U = 263$, $P > 0.62$
Brief alexithymia scale (0–18)	6 ± 2	$U = 260$, $P > 0.49$
Beck depression inventory (0–3)	6 ± 3	$U = 172$, $P > 0.45$

*Results are expressed as means ± SD.
†Parentheses indicate possible range of scores.

TABLE 5. Correlational Analysis of MEB Categories (Disgust Versus Indignation) and Rozin et al's Taxonomy,[7] Utilizing Cramér's Correlation Coefficients (Φ)

	MEB Domains	
Rozin et al Taxonomy[7]	"Pure" Disgust (Disgust Devold of Moral Content)	Indignation (Moral Violations)
Core disgust	0.65*	0.45*
Animal reminder disgust	0.82*	0.87*
Interpersonal disgust	0.19	0.87*
Moral disgust	NA†	0.82*

MEB, moral emotions battery.
*$P < 0.0001$.
†Not applicable, because "moral disgust" is constantly absent from the MEB domain of "pure" disgust.

Conceptual Structure of Stimuli

To further analyze the stimuli employed in this investigation, three independent raters assigned each 1 of the 45 MEB statements to one or more of the four-item taxonomy of disgust developed by Rozin et al.[7] We assessed the strength of associations with Cramer correlation coefficient (Φ), which is the categorical equivalent of Pearson *r*.[22] Departing from the neutral statements as a baseline, we found that the MEB domain of "pure" disgust (ie, disgust devoid of moral violations) was significantly associated with the categories of core and animal-reminder disgust in the Rozin et al scheme (see Table 1). The MEB domain of indignation was additionally and strongly related to the interpersonal and moral disgust categories of the Rozin classification (see Table 5). These findings lend further support to the view that at least in some contexts, disgust is a major ingredient of the moral emotion of indignation as elicited by moral violations.

fMRI Results

To reveal the brain regions activated by the experience of pure disgust, we first contrasted the Disgust and Neutral conditions (Disgust > Neutral). Activations clustered in the medial and lateral posterior OFC, bilaterally, and in the subcallosal region (see Table 6 for summary and Fig. 1). In the left hemisphere, activations spread to the orbital division of the inferior frontal gyrus (IFG). The left frontal operculum and a bilateral region of the medial superior frontal gyrus (SFG) were also activated.

When indignation was compared with the Neutral condition (Indignation > Neutral), similar regions of the medial and lateral OFC were activated, along with the subcallosal region (Fig. 2). In the left hemisphere, the OFC activation extended to the anterior–inferior aspect of the insula. Two clusters were observed in the SFG: one similar to

TABLE 6. Location of Brain Areas with Significant Activations

		Center of Talairach Coordinates		
	Brodmann Area	X	Y	Z
Basic disgust > neutral				
Bilateral medial SFG	8,9	−02	+45	+43
L IFG	9,46	−48	+17	+27
L IFG	10,45,46	−49	+36	+09
R medial OFC	11,25,32	+07	+21	−09
R lateral OFC	11,47	+25	+25	−06
L medial OFC	11,25,32	−09	+21	−09
L medial OFC	10,11	−13	+38	−07
L lateral OFC	11,47	−23	+26	−08
L ITG	20,21	−46	−10	−21
Indignation > neutral				
R IFG	45,46	+53	+25	+10
L IFG	9,46	−46	+16	+22
L lateral SFG	10	−33	+56	+06
Bilateral dorsolateral SFG	9,10	−08	+60	+26
R medial OFC	11,25,32	+03	+21	−11
L medial OFC	11	−13	22	−10
L lateral OFC (extending to orbital IFG)	11,47	−22	24	−09
R lateral OFC	11,47	23	27	−07
L medial OFC	10,32	−12	+36	−09
R hypothalamus	—	+05	−07	−02
OFC uncus (piriform)	13,28,38,47	−27	+11	−18
L posterior insula	13	−32	−15	0
R anterior ITG	20,21	+62	−13	−11
L anterior ITG	20,21	−41	−10	−24
R posterior cerebellum	—	+14	−79	−39
L posterior cerebellum	—	−23	−78	−41
Indignation > disgust				
R orbitofrontal sulcus	10,11,32	+19	+43	−03
L lateral orbitofrontal gyrus	10,11	−29	+42	−01
R IFG	45,46	+53	+28	+14
R ITG	20,21	+55	−05	−25
L frontal, insula, and temporal piriform	13,38,47	−28	+13	−19
L anterior SFG	8,9	−04	+55	+38
Disgust > indignation				
R IFG	46	+43	+32	+16
R amygdala*	—	+18	−07	−11
R anterior cingulate	24,32	+05	+35	+09
Conjunction ([disgust + indignation] > neutral)				
Bilateral medial SFG	8,9	−02	+47	+42
L inferior frontal gyrus	45,46	−47	+34	+07
R medial OFC	11,25,32	+07	+23	−10
L medial OFC	11,25	−11	+22	−09
L medial OFC	10,32	−13	+37	−07
L lateral OFC (extending to orbital inferior frontal gyrus)	11,47	−24	+26	−07
L ITG	20,21	−43	−10	−22

*$P < 0.01$.
STG, superior frontal gyrus; IFG, inferior frontal gyrus; OFC, orbitofrontal cortex; ITG, inferior temporal gyrus.

that described above for Disgust > Neutral, and the other more anterior and lateral, close to the left frontopolar cortex. The IFG was activated bilaterally, with additional recruitment of the right lateral hypothalamus and the left caudolateral OFC/uncus region. To further explore the overlap in activation clusters for Disgust and Indignation, we used conjunction analysis to identify the brain regions activated by both Disgust and Indignation as compared with the Neutral condition

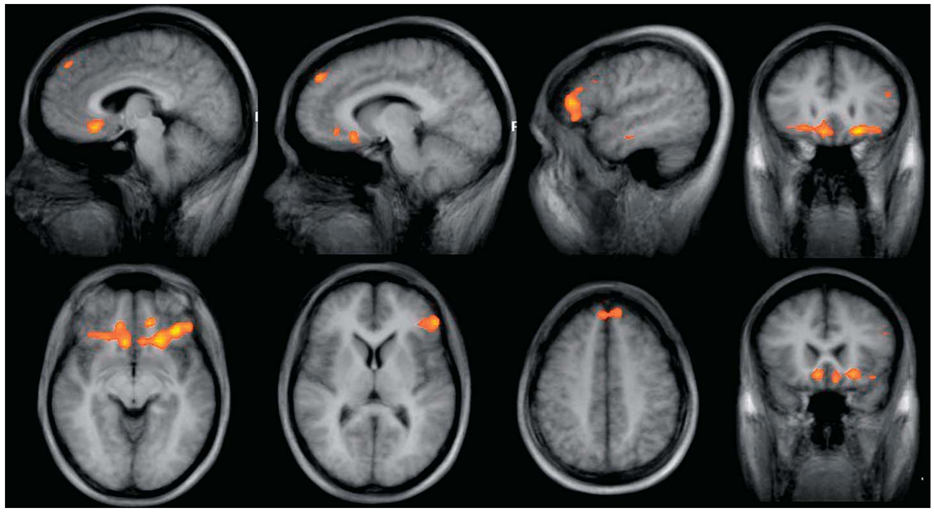

FIGURE 1. Areas of activation of disgust versus neutral statements.

([Disgust + Indignation] > Neutral). Results revealed co-occurring activation of the medial and lateral OFC, left IFG, and medial SFG (Fig. 3).

Mutually exclusive activations were revealed by direct comparisons between Disgust and Indignation. Disgust > Indignation evoked activation of the anterior cingulate gyrus at the plane of the genu of the corpus callosum and of the right IFG (Fig. 4). With a more flexible threshold ($P < 0.01$), there was also activation of the right amygdala. No activation of the OFC was observed. The opposite comparison, Indignation > Disgust, revealed activation of the left anterior SFG close to the frontal pole and bilaterally in the OFC (Fig. 5). The OFC clusters were centered in the anterior half of the OFC, more specifically in the right medial orbitofrontal sulcus and the left lateral OFG. Activated clusters were also observed in the right inferior temporal gyrus (ITG) and IFG, as well as in a region encompassing both the left posterolateral OFC and adjacent temporal piriform cortex. Notably, the more posterior medial and lateral OFC were not activated by comparisons between disgust and indignation ([Disgust > Indignation] or [Indignation > Disgust]). This result suggests that the functional activation of these regions, revealed via conjunction analysis described above, was not statistically different between these conditions. The results of the adjunctive analysis revealed certain gender effects on brain activation. Females had significantly higher activation to the Indignation condition in right frontopolar cortex (Brodmann area [BA] 9/10, center coordinates = 12, 56, 17), right ventral striatum (center coordinates = 11, 6, −3), and extrastriate occipital cortex (BA 18, center coordinates = −35, −74, 8). In contrast, males did not show any areas of increased activation as compared with females, even at $P < 0.0005$ (Fig. 6). When the Disgust condition was compared between genders, no differences in brain activations were observed at $P < 0.0001$, but decreasing the threshold to $P < 0.0005$ revealed higher activation in the gyrus rectus (BA 11, center coordinates = −7, 30, −15) and in the most posterior aspect of the OFC/basal forebrain in males (BA 14/25, center coordinates = −7, 7, −12) (Fig. 7).

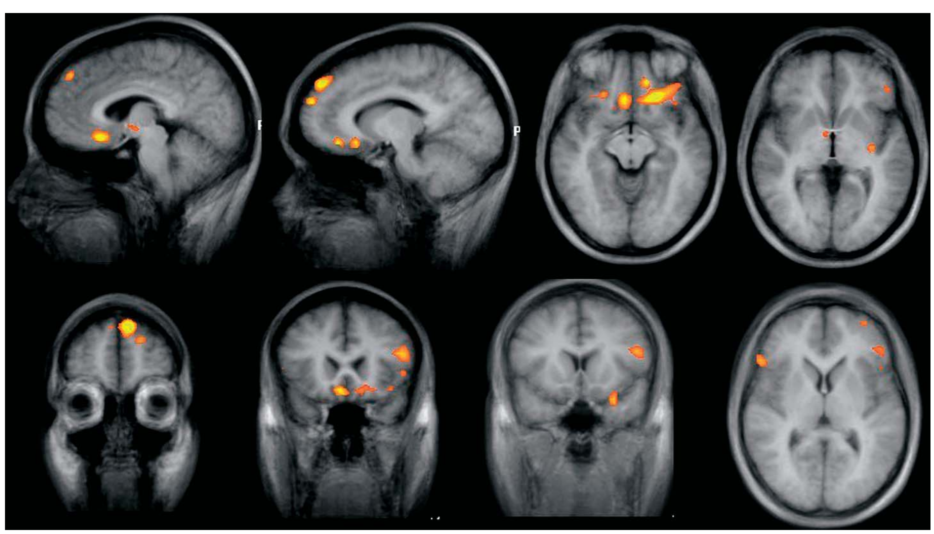

FIGURE 2. Areas of activation of indignation versus neutral statements.

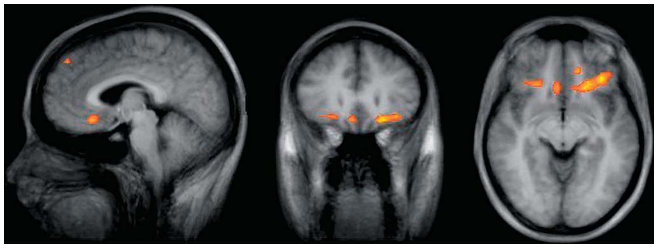

FIGURE 3. Areas of overlapping activation of disgust and indignation in comparison to neutral statements.

DISCUSSION

The main findings of this study were the demonstration that (a) different domains of disgust—"pure disgust" and indignation—could be elicited by written stimuli; (b) these stimuli were also effective in recruiting specific patterns of brain activation; (c) pure disgust and indignation recruited remarkably overlapping neural substrates, with a few but relevant differences in frontal and temporal lobes.

The empirical distinction between basic and moral emotions is an important step toward understanding the intricacies of human emotional experience and behavior. Most studies have focused on basic emotions as a repertoire of emotions that are shared among humans as a cultural species and with other mammals.[1] The taxonomy of basic emotions greatly varies from one author to another, but it regularly includes fear, happiness, disgust, surprise, sadness, and anger. Expansions of this repertoire have been achieved mainly by the fractionation of the basic types,[32] rather than by further qualitative differentiation. As a consequence, human emotional experience has been much less investigated in comparison with more generalized patterns of emotional experience[33] and has usually been biased by the animal literature.[34] In this study, our aim was to advance the experimental analysis of more socially relevant human emotional experiences. Hence, subjects were required to rate the emotional impact of declarative social scenarios, deriving separate scores for basic and moral emotions. Regarding disgust, at least two experiential domains were distinguished. One was related to what most people experience as "disgusting" and is roughly equivalent to what researchers have described as "core" and "animal-nature reminder" disgust.[7] In the other domain, disgust pervades conscious awareness disguised as indignation and is not as obviously experienced as "disgusting" in the physical sense (though immoral people and behaviors are frequently described as disgusting). Behaviorally, disgust underlies the inclination to break off contact and withdraw from the offending source. Thus, there are similarities in behaviors triggered by indignation and disgust, for both are typically sparked by moral offenses endowed with contamination, pollution, or violation of the human body as a sacred entity.

Pure disgust and indignation were associated with activation of the medial and lateral OFC. Anatomically, these regions have been linked to a ventral trend of progressive prefrontal architectonic elaboration that arises from the posterior orbitofrontal region and spreads rostrally and laterally.[35] These regions have also been described as orbital and medial prefrontal networks.[36] The orbital prefrontal areas are highly interconnected, permitting the integration of multiple sensory projections that subserve diverse reward and food-related processing. The medial prefrontal network encompasses the most medial regions and has been linked to visceromotor and emotional–motor processing, including visceral regulation in relationship to affective stimuli. Adult subjects experiencing visual, auditory, olfactory, and gustatory stimuli that have emotional valence (ie, pleasant and unpleasant) significantly activate these OFC regions.[37,38] The activations related to disgust and indignation also occurred in cortical regions associated with primary and secondary olfactory processing,[23,39,40] appetitive olfactory learning,[24] routine planning,[41] the evaluation of outcomes on the basis of contingent payoffs and losses,[42] and responses to abstract reward and punishment.[43]

When compared with disgust, indignation differentially activated the more anterior sectors of the OFC, left piriform cortex, anterior SFG and right anterior ITG. The OFC, though more medially, has also been differentially activated by visual stimuli depicting moral violations in comparison with aversive stimuli without moral content.[13] Given the role of this region in the regulation of interpersonal behavior, we hypothesized that the medial OFC is critical for the spontaneous generation of moral emotions in response to moral violations. In another fMRI study in which a moral judgment task on statements depicting social scenarios was employed, the left anterior medial OFC was responsive to moral violations, while nonmoral aversive scenarios activated the lateral OFC and the amygdala.[12] Both conditions involved social contexts, and a sizable proportion of the stimuli of the nonmoral aversive condition (such as "He licked the dirty toilet") was evocative of disgust. Overall, these results suggest that the OFC as a whole is more activated by stimuli with moral connotations and that a medial to lateral selectivity for processing emotional subtypes may exist as well.[44] Although the left insula was activated by stimuli associated with indignation, the lack of insula activation with pure disgust was somewhat surprising.

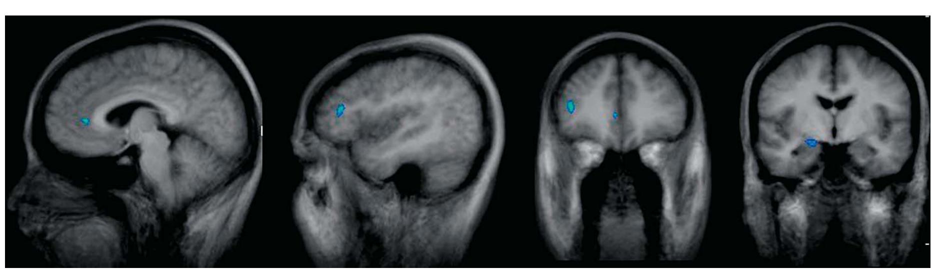

FIGURE 4. Areas of activation of disgust versus indignation.

FIGURE 5. Areas of significant activation during reading of indignation versus disgust emotional statements in normal adult participants.

The difference in results might be related to the use of either facial or vocal displays of disgust in most previous functional imaging studies, in contrast to the written stimuli used in the current study. It is possible that the sensory burden of "abstract" pure disgust is less salient and natural for the type of processing carried out by the insula than that evoked by visual and auditory stimuli. Indignation, on the other hand, is a more complex, social–emotional experience whose abstract ingredients are deeply ingrained in its structure and thus may be more effective in activating the insula. Another relevant aspect is the finding of consistent activation of the inferior aspect of the IFG with both pure disgust and indignation. This region was consistently activated in previous fMRI studies of disgust[9] and may represent a functional continuum of the anterior insula, as supported by extensive anatomic and physiologic evidence.[45] The most lateral aspect of OFC adjoining the IFG, activated by both Indignation and Disgust conditions, may also represent a transitional area to the anterior inferior insular cortex. In the macaque, for example, the frontal operculum contains the primary taste cortex, and the caudolateral OFC contains the secondary taste area.[45] Further studies will be necessary to address possible functional specializations of the insula–IFG–lateral OFC complex in pure disgust and interpersonal emotion processing.

The comparison Disgust > Indignation revealed clusters in right IFG/amygdala and anterior cingulate. The amygdala and right opercular activations have been related to aversive stimuli in multiple modalities.[38] Moreover, damage to neural circuits linking the amygdala, uncus, insula, and striatum has been implicated in perverted alimentary behavior and self-neglect,[46] suggesting that these circuits play a critical role in disgust processing. The activated region in the anterior cingulate has been related to provoked sadness in normal subjects and in depressive illness.[47] Its possible relationships to disgust, however, remain obscure. Similarly, the gender effects observed in this study cannot be interpreted on the basis of current knowledge and must await further developments in theoretical and experimental understanding of gender-related processing of social and emotional probes, as well as their relationships to personality and affective style measures.

The operational distinction between basic and moral emotions may be relevant for the interpretation of clinical and neuroimaging studies.[44] In view of the biologic propensity of human beings to socialize their perceptions, ideas, and emotions,[48] it should not be surprising that the activations in studies on human emotion might, in part, reflect social and moral factors that have not been explicitly considered in the activation protocols. In a previous study,[13] we have discussed the importance of passive fMRI task designs for the automatic elicitation of emotional experiences. In these protocols, subjects participate as spectators of the events, social or otherwise, to which they are exposed. Since they are not biased by orienting questions or asked to emit opinions or make judgments about what they are witnessing, they may be primarily affected by the sensory–emotional content of the exposures.[49] Thus, by bringing about patterns of cerebral activity that are dependent on minimal mental operations on stimuli, passive protocols seem to be well suited to disclose default modes of neurobehavioral organization in normal individuals as well as in behaviorally unresponsive or minimally cooperative

FIGURE 6. Areas activated more in females than in males in response to Indignation stimuli included the ventral striatum, frontopolar cortex, and occipital cortex.

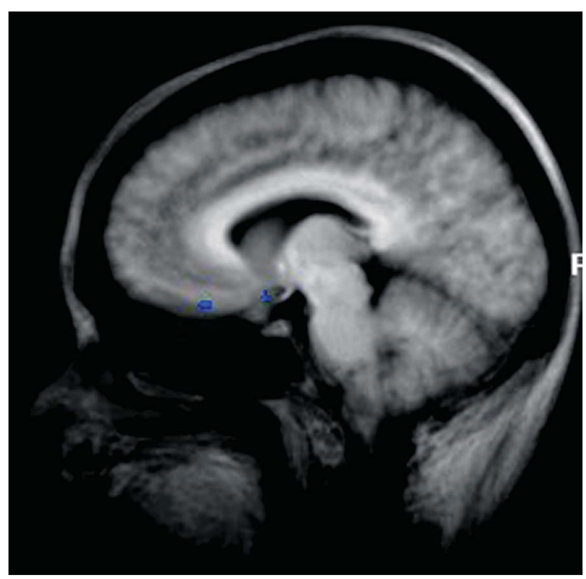

FIGURE 7. With use of more lenient thresholds, two locations of the medial posterior orbitofrontal cortex were more activated in males than in females in response to pure disgust.

patients.[50] In our previous studies, we have contrasted passive and effortful social emotion processing in normal adult participants while undergoing fMRI scanning. The specific cognitive judgments of moral violations disclosed an important role for the frontopolar cortex in such effortful processing.[51–53] In comparison, we have identified that the OFC is more directly implicated in the automatic attribution of morality to ordinary social events.[13]

Damage to several regions activated by disgust and indignation underlies the clinical expression of common neuropsychiatric syndromes. Moreover, pathologic changes in the experience of disgust may underlie a variety of neuropsychiatric symptoms. Recent reports have described impairments in the recognition of disgust in obsessive–compulsive disorder,[54] in Huntington disease,[55] and in healthy carriers of the Huntington disease gene.[56] In view of the powerful modulation that disgust exerts on sexual behavior,[57] it is noteworthy that the relationships between disgust (either pure or moral) and sexual deviation syndromes[58] such as pedophilia[59] have been so far neglected. Similarly, an impairment of disgust may be at the root of the most bizarre changes of the behavior of patients with the Klüver–Bucy syndrome, which results from damage to the temporopolar cortex or to its neural connections.[60,61] Examples include smearing feces around as a sign of protest[62] as well as reaching for, chewing, and eating all kinds of rubbish and inedible items such as toilet paper, feces, shoe polish, soil from plaint containers, tea bags, plastic wrapper from bread, ink, dog food, and pieces of wood and furniture.[63] Perverted oral–alimentary compulsions are potentially lethal and may be a direct cause of death.[59]

The loss of social appropriateness, which is a core symptom of antisocial behavior due to acquired frontal and temporal damage,[6,64] may be related in part to a lessening of the influence of the moral affiliations of disgust on social behavior. This hypothesis concurs with the suggestion that "low disgust might generate a highly antisocial person, since disgust is in many respects the emotion of civilization" (p. 849).[3] Our observations further suggest that, from the perspective of brain organization, the variability of antisocial behavior (which is the rule in neuropsychiatric and forensic practice) might be partially explained by the matrix of cognitive and emotional impairments prevailing in a given individual. For example, differences of antisocial style in individuals with a formal diagnosis of psychopathy might depend on the extent to which they differ in their impairments of disgust and its moral affiliations, social decoding abilities, impulsiveness, or strategy application. Disentangling these components with current neuroscientific methods is a fruitful area for research with far-reaching political and social implications.

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