Orbitofrontal Cortex and Social Behavior: Integrating Self-monitoring and Emotion–Cognition Interactions

Jennifer S. Beer[1], Oliver P. John[2], Donatella Scabini[2], and Robert T. Knight[2]

Abstract

■ The role of the orbitofrontal cortex in social behavior remains a puzzle. Various theories of the social functions of the orbitofrontal cortex focus on the role of this area in either emotional processing or its involvement in online monitoring of behavior (i.e., self-monitoring). The present research attempts to integrate these two theories by examining whether improving the self-monitoring of patients with orbitofrontal damage is associated with the generation of emotions needed to guide interpersonal behavior. Patients with orbitofrontal damage, patients with lateral prefrontal damage, and healthy controls took part in an interpersonal task. After completing the task, participants' self-monitoring was increased by showing them a videotape of their task performance. In comparison to healthy controls and patients with lateral prefrontal damage, orbitofrontal damage was associated with objectively inappropriate social behavior. Although patients with orbitofrontal damage were aware of social norms of intimacy, they were unaware that their task performance violated these norms. The embarrassment typically associated with inappropriate social behavior was elicited in these patients only after their self-monitoring increased from viewing their videotaped performance. These findings suggest that damage to the orbitofrontal cortex impairs self-insight that may preclude the generation of helpful emotional information. The results highlight the role of the orbitofrontal cortex in the interplay of self-monitoring and emotional processing and suggest avenues for neurorehabilitation of patients with social deficits subsequent to orbitofrontal damage. ■

INTRODUCTION

A host of clinical observations, case studies, and two empirical studies show that orbitofrontal damage is associated with impaired interpersonal behavior. Descriptions of orbitofrontal patients have associated damage to this area with the impaired ability to prioritize solutions to interpersonal problems (Saver & Damasio, 1991), a tendency to greet strangers in an overly familiar manner (Rolls, Hornak, Wade, & McGrath, 1994), and disruptive behavior in a hospital setting (Blair & Cipolotti, 2000). Aside from the descriptive evidence, two empirical studies show that orbitofrontal damage impairs interpersonal behavior (Beer, Heerey, Keltner, Scabini, & Knight, 2003; Kaczmarek, 1984). These studies suggest that patients with orbitofrontal damage behave with strangers in ways that are more appropriate for interactions with close others. Patients with orbitofrontal damage tease strangers in inappropriate ways and are more likely to include unnecessary personal information or tangential information when answering questions. Although it is clear that the orbitofrontal region is critically involved in adaptive interpersonal behavior, there has been less agreement on the psychological mechanism responsible for such adaptive behavior.

[1]University of California, Davis, [2]University of California, Berkeley

Social Function of the Orbitofrontal Cortex: Emotion–Cognition Synthesis and Self-monitoring

Current theories suggest that two types of variables contribute to the social deficits associated with orbitofrontal damage: deficient emotional systems or a lack of online behavioral monitoring. Several theories propose that emotional deficits, in one form or another, account for the impaired interpersonal behavior associated with orbitofrontal damage (e.g., Kringelbach & Rolls, 2004; Bechara, Damasio, & Damasio, 2000; Elliott, Dolan, & Frith, 2000). For example, the *somatic marker hypothesis* proposes that the orbitofrontal cortex is critical for interpreting somatic sensations (equated with emotion in this framework) that are needed to make decisions (e.g., Bechara et al., 2000; Bechara, Damasio, Tranel, & Damasio, 1997). From this perspective, people avoid making social blunders because particular physiological sensations guide them toward adaptive behavior and away from maladaptive behavior. Empirical support for the somatic marker hypothesis comes from a series of gambling studies that have found that patients with

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orbitofrontal damage do not show anticipatory anxiety before taking big risks (e.g., Bechara et al., 2000, 1997). Similarly, the orbitofrontal cortex has been implicated in guessing and theorized to be helpful for guiding behavior in ambiguous situations by incorporating intuition or "gut feelings" into decision making (Elliott, Dolan, & Frith, 2000). From this perspective, the orbitofrontal cortex acts like the lateral prefrontal cortex by supporting response selection. In contrast to the lateral prefrontal cortex, the orbitofrontal cortex is recruited as situations become more complex and uncertain, making decisions more intuitive or emotional (Elliott, Rees, & Dolan, 1999).

Reinforcement and reversal theory proposes that the orbitofrontal cortex is necessary for evaluating what behaviors will generate positive emotion (i.e., reward) and negative emotion (i.e., punishment) in a given context (Kringelbach & Rolls, 2004). Social mistakes may occur if people fail to make the correct computations about what is appropriate (rewarding) and inappropriate (punishing) in a given context. Empirical evidence for this position comes from research that shows the orbitofrontal cortex is important for inhibiting behavior that is not rewarded in go/no-go and reversal tasks (Fellows & Farah, 2003; Roberts & Wallis, 2000; Schultz, Tremblay, & Hollerman, 2000; Rolls et al., 1994). Similarly, patients with orbitofrontal damage may not be embarrassed by their inappropriate behavior and may actually report increased pride after behaving inappropriately (Beer et al., 2003).

A second perspective emphasizes the importance of the orbitofrontal cortex for self-monitoring (Prigatano, 1991; Stuss, 1991; Stuss & Benson, 1984) or the ability to evaluate one's behavior in the moment in reference to higher order goals or the reactions of other people (Duval & Wicklund, 1972). Self-monitoring has been used to describe the (not always conscious) cognitive process by which individuals evaluate their behavior in the moment to make sure that the behavior is consistent with how they want to behave and how other people expect them to behave. This type of self-monitoring is distinct from neglect syndromes in which individuals do not attend to an entire visual hemifield and may be anosognosic for this behavioral deficit. Rather, self-monitoring is a social anosognosia; social mistakes may occur because individuals lack self-insight into the inappropriateness of their behavior. Clinical characterizations and empirical research with lesion patients suggest that the frontal lobes are intricately involved in self-monitoring (Lhermitte, 1986; Luria & Homskaya, 1970). The orbitofrontal cortex may be important for self-insight into the appropriateness of behavior, whereas the lateral prefrontal cortex has been more commonly associated with motivation or execution of behavior (Stuss, 1991; Stuss & Benson, 1984). Patients with frontal lobe damage (including but not specific to the orbitofrontal cortex) are frequently characterized as knowing what is appropriate and what is inappropriate but not applying this knowledge to their behavior (Stuss, 1991). The stimulus-bound behavior typical of frontal lobe patients (including but not specific to the orbitofrontal cortex) exemplifies faulty monitoring processes (Lhermitte, 1986; Lhermitte, Pillon, & Serdaru, 1986; Luria & Homskaya, 1970). For example, objects placed in front of prefrontal patients may be picked up and used (utilization behavior) without the patient being asked to do so (Lhermitte, 1986). One case study of a patient with bilateral frontal damage (not specified as orbitofrontal or lateral prefrontal) found that the patient inappropriately approached members of the opposite sex and was bewildered to be told after the fact that the behavior was offensive (Prigatano, 1991). These studies suggest that prefrontal damage impairs the ability to monitor the appropriateness of behavior as a function of a given context. However, no previous empirical research has manipulated variables of self-monitoring in relation to specific subdivisions of the frontal lobes.

Although these theories have traditionally been studied separately, integration of the two perspectives is not only possible but may have greater explanatory power than either perspective on its own. Both the emotional deficits literature and self-monitoring literature characterize orbitofrontal function as important for applying knowledge to behavior but diverge on the psychological mechanism involved in this process (Kringelbach & Rolls, 2004; Bechara et al., 2000; Stuss, 1991). A critical relation between these two theories is suggested by functional accounts of emotion, which posit that self-monitoring is necessary for generating social emotions that help promote adaptive social behavior (Lewis, 1993). From an evolutionary perspective, social emotions such as embarrassment have evolved to promote survival and reproduction by motivating individuals to repair social relations (Miller & Leary, 1992; Goffman, 1956). For example, the experience of embarrassment signals that one has committed a social transgression and action is needed to repair social relations. It could be that orbitofrontal patients' disinhibited social behavior is accounted for by deficient online self-monitoring that may preclude the generation of emotions necessary to motivate appropriate behavior. In other words, patients with orbitofrontal damage may not automatically monitor their behavior and, therefore, do not have emotional reactions when they make social mistakes.

The present research brings together elements of all of the perspectives on the orbitofrontal cortex to examine this area's role in self-monitoring, appropriate interpersonal behavior, and social emotions (i.e., embarrassment). Patients with orbitofrontal damage, patients with lateral prefrontal damage (see Figure 2), and healthy controls completed an interpersonal task. The two patients groups were selected because although both had lesions to the frontal lobe and executive functioning deficits, only orbitofrontal damage has been characterized primarily by social deficits (Beer et al., 2003; Muller, Machado, & Knight, 2002; Stone, Baron-Cohen, & Knight, 1998). Lateral prefrontal cortex damage has been associated with impaired cognitive control, attention, response monitoring, working memory, and planning but has been less characterized by inappropriate, disinhibited social behavior (Beer, Knight, & Shimamura, 2004; Wagner, Bunge, & Badre, 2004; D'Esposito, Postle, & Rypma, 2000). However, as noted above, much of the research on the self-monitoring and frontal lobe damage was not derived from focal lesions within specific subregions of the frontal cortex. Therefore, the comparison of these two groups provides a strong test of whether the orbitofrontal cortex is selectively associated with impaired self-insight needed to generate the social emotions that motivate adaptive interpersonal behavior (or whether any kind of executive functioning deficits impact the appropriateness of interpersonal behavior).

The present research took place in two parts. In Part I, participants' self-perceptions of their appropriateness and emotions were assessed after they took part in a self-disclosure task with a stranger (Aron, Melinat, Aron, Vallone, & Bator, 1997). To measure accuracy of self-monitoring, self-reports of appropriateness were compared to expert judges' ratings of appropriateness. In Part II, participants watched a videotape of themselves completing the self-disclosure task. Watching a videotape has been shown to increase the self-monitoring of individuals who may not already be periodically monitoring their behavior by providing an objective, outside observer's perspective of their performance (Robins & John, 1997). After watching the videotape, participants reported on how they now felt about their task performance. To measure change in emotion as a function of self-consciousness, the discrepancy between reports of emotion from Part I and Part II was calculated.

METHODS

Participants

A total of 16 participants were tested (none of the participants were depressed as measured by the Center for Epidemiology Studies Depression Scale (CES-D) (Radloff, 1977; see Tables 1 and 2 for patient neuropsychological characteristics): 4 patients with orbitofrontal lesions (4 men), 4 patients with lateral prefrontal lesions (2 men), and a total of 8 healthy controls (6 men). Patients with orbitofrontal lesions had bilateral damage to the orbitofrontal cortex; 2 patients had damage extending into the anterior temporal lobe and 1 may possibly include the amygdala (see Figure 1). Patients with lateral prefrontal lesions had unilateral damage to either the left or right side of the lateral prefrontal cortex (see Figure 2). Lesion size was comparable across the patient groups.

All possible measures were taken to ensure the patients differed from the comparison participants on the basis of lesion alone. On average, the two patients groups differed in age (orbitofrontal mean age = 56 years, *SD* = 10.7; lateral prefrontal mean age = 76.0 years, *SD* = 7.2) and gender (orbitofrontal = 4/4 men; lateral prefrontal = 2/4 men). Therefore, two separate groups of healthy comparison participants were created. A particular comparison participant was selected to match a specific patient on the basis of age, gender, education, community of residence, and Mini Mental Status Exam performance. Therefore, there were four groups of four participants entered into the repeated measures analyses: orbitofrontal patients, lateral prefrontal patients, comparison participants for the orbitofrontal

Table 1. Background Information on Patients

Patient	*Age*	*Gender*	*Handedness*	*Cause of Lesion*	*Time Since Lesion Onset (Years)*	*Area of Damage*
M.R.	47	M	Right	Motorcycle accident	26	Bilateral OFC
D.H.	40	M	Right	Motor scooter accident	23	Bilateral OFC
R.B.	56	M	Right	Closed-head injury during military service	27	Bilateral OFC, ant. temporal lobe
R.V.	63	M	Right	Struck head on rock during military service	42	Bilateral OFC, ant. temporal lobe
W.E.	72	M	Right	Stroke	7	Lateral frontal (left)
M.F.	68	M	Right	Stroke	6	Lateral frontal (left)
E.B.	83	F	Right	Stroke	18	Lateral frontal (right)
S.R.	81	F	Right	Stroke	8	Lateral frontal (right)

Ant. = anterior; OFC = orbitofrontal cortex.

Table 2. Neuropsychological Data from the Patient Participants

Patient	Years Education	MMSE	Barona Percentile	WAIS-III Percentile		WMS-III Percentile (Logical Memory)	WCST (Categories/ Failures to Maintain Set)	Trails B (Percentile)
				Verbal IQ	Performance IQ			
Patients with orbitofrontal damage								
M.R.	10	29/30	70	71	20	50	5/0	92
D.H.	12	29/30	65	68	42	96	6/0	95
R.B.	12	30/30	92	45	17	62	6/0	79
R.V.[a]	GED	26/30						
Patients with lateral frontal damage								
W.E.[a]	15	27/30		AQ = 96.3[a] (not impaired)	CQ = 93.4[a] (not impaired)			
M.F.	12	26/30	45	28	24	75	3/4	14
E.B.	12	28/30	65	77	71	75	6/0	70
S.R.	13	27/30	75	63	13	95	3/5	1

Barona = Estimate of premorbid IQ (Barona, Reynolds, & Chastain, 1984); CVLT = California Verbal Learning Test (Delis, Kramer, Kaplan, & Ober, 1987); GED = High School Diploma Equivalent; MMSE = Mini-Mental State Exam (Folstein, Folstein, & McHugh, 1975); WAIS-III = Wechsler Adult Intelligence Scale III (Wechsler, 1997a); WMS-III = Wechsler Memory Scale III (Wechsler, 1997b); WCST = Wisconsin Card Sorting Test (Grant & Berg, 1948); Trails B task from the Halstead–Reitan Neuropsychological Test Battery.

[a]Not all patients were able to participate in additional neuropsychological testing because of illness. For these patients, the MMSE measured the day of the experimental session is reported and, for patient W.E., we report the Aphasia Quotient (AQ) and Cortical Quotient (CQ) measures from the Western Aphasia Battery (Shewan & Kertesz, 1980) collected in 1996.

patients, and comparison participants for the lateral prefrontal participants.

Knowledge of Social Norms

Perceptions of social norms governing intimate conversations with strangers were assessed to most closely approximate the norms governing the upcoming self-disclosure task. Participants were presented with 34 questions (9 of which were used in the self-disclosure task; see below, Aron et al., 1997) and asked to rate each one for how much intimate, personal information they would reveal if they were posed the question by a stranger ($\alpha = .82$). Participants used a scale ranging from 1 (*no intimate information*) to 5 (*an extreme amount of intimate information*).

Self-disclosure Task

Participants then engaged in a structured conversation with a stranger. The stranger was a graduate student experimenter who interviewed all participants and was unknown to the participants before the interview. All participants were instructed that they would take part in a conversation with the stranger. They were told that they would be asked questions by the stranger but that it was their decision how much information they volunteered in their answers. Furthermore, they were instructed that it was perfectly acceptable to completely pass on answering a question for any reason at any time. These instructions were designed to reduce any sort of experimental demand toward excessive self-disclosure. The stranger asked the participants a predetermined set of nine questions. Once participants stopped speaking after a question prompt, the experimenter asked them if they had anything else they wanted to say and if they did not, the next question was posed. The conversations lasted 24 min 53 sec, on average (*SD* = 7 min 55 sec). The nine questions were selected from a much larger set and some concerned intimate topics that strangers do not typically discuss so that participants had to monitor how much intimate information they revealed (Aron et al., 1997).

Monitoring of Self-disclosure Appropriateness

After taking part in the task, participants reported on how appropriate they felt their self-disclosure had been taking into consideration that they had been speaking with a stranger. This measure (three items measuring intimacy, four items measuring appropriateness; $\alpha = .73$; see Appendix B, derived from Cozby, 1973) assessed participants' self-monitoring of their appropriateness.

To measure the accuracy of participants' self-monitoring, self-perceptions were compared to an objective measure of their appropriateness derived from the consensus criterion approach (Robins & John, 1996). Objective

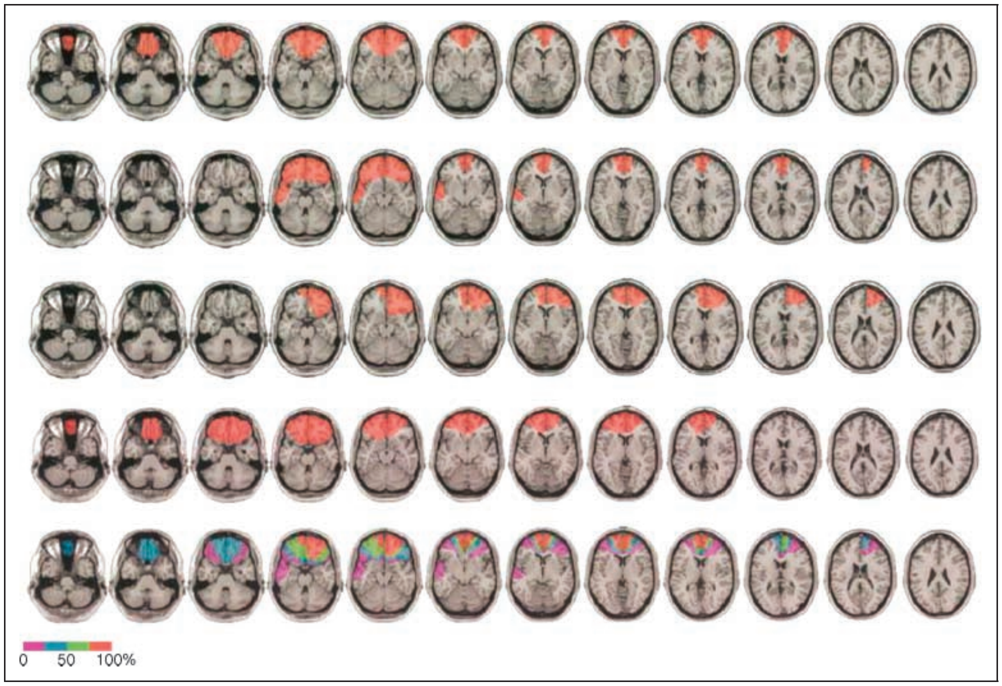

Figure 1. Lesion reconstructions of patients with orbitofrontal damage. In order to reconstruct lesions, 212 isovolumetric contiguous coronal slices, 5.0 mm thick, are initially obtained on a 1.5-T Picker (New York) superconductive scanner. Lesions are then transcribed from scans onto sequential axial templates in MRIcro. A high degree of interrater lesion reconstruction was found between two behavioral neurologists (Drs. Robert Rafal and Robert Knight). In previous cases using this method, autopsies reinforced the validity of this approach for reconstructing lesions. The first four rows portray an individual patient's lesion across contiguous slices, whereas the bottom row portrays overlap for each slice across the sample. The color bar represents the percentage lesion overlap in the group for specific areas within the orbitofrontal cortex.

measures were assessed using expert ratings of the participants' disclosures using the same scale that was used to assess self-report. Whereas participants completed the questionnaire with the stem, ''I . . .,'' the judges completed the same questions with the stem, ''This participant . . . .'' In order to rate aspects of self-disclosure independently of emotional expression, judges rated transcripts of the conversations. Each judge rated each

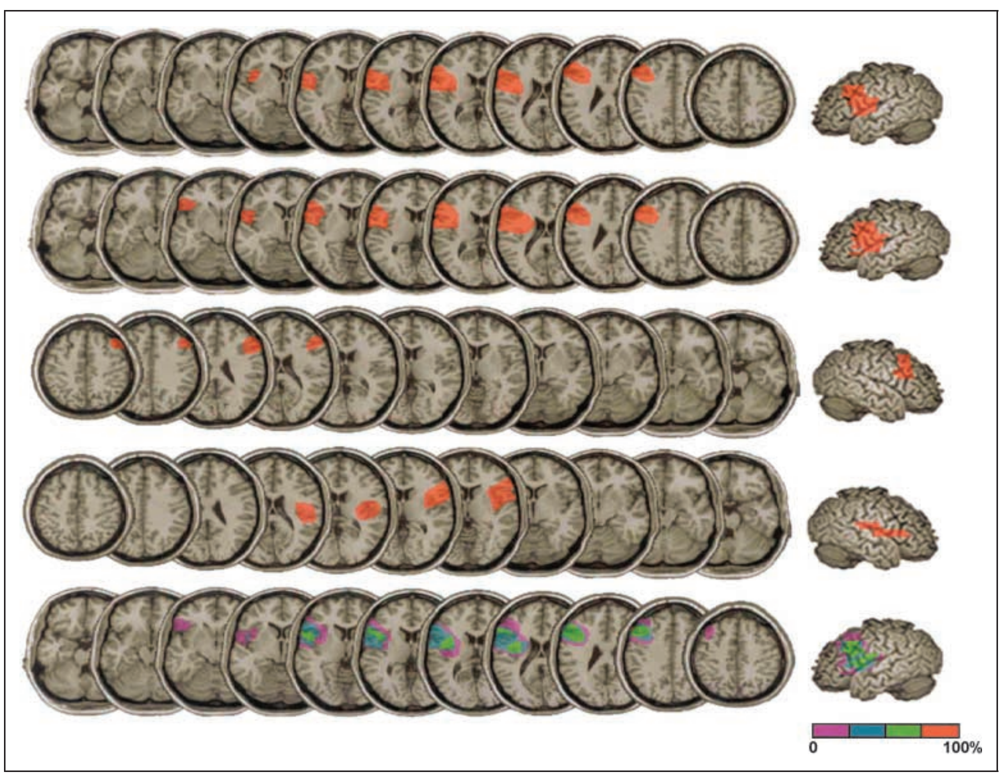

Figure 2. Lesion reconstructions of patients with lateral prefrontal damage (bottom). Lesion reconstruction procedures are the same as in Figure 1. The first four rows portray an individual patient's lesion across contiguous slices, whereas the bottom row portrays overlap for each slice across the sample. The color bar represents the percentage lesion overlap in the group for specific areas within the lateral prefrontal cortex.

of the nine questions for each participant separately on the seven items; these ratings were then averaged across questions for each participant. An average rating across questions for each participant from the judges was most analogous to the self-report. Finally, a reliability analysis was conducted across the three judges' ratings for all participants ($\alpha = .92$). These ratings were made by expert judges who were blind to the purpose of the study and that it included individuals with brain damage. The judges were trained in norms of self-disclosure through extensive literature review. A month-long intensive course on transcript coding was required of all judges. The course involved 10 practice transcripts from the procedure used in the present study. Judges coded each for the dimensions of self-disclosure appropriateness and then discussed individual codes as a group.

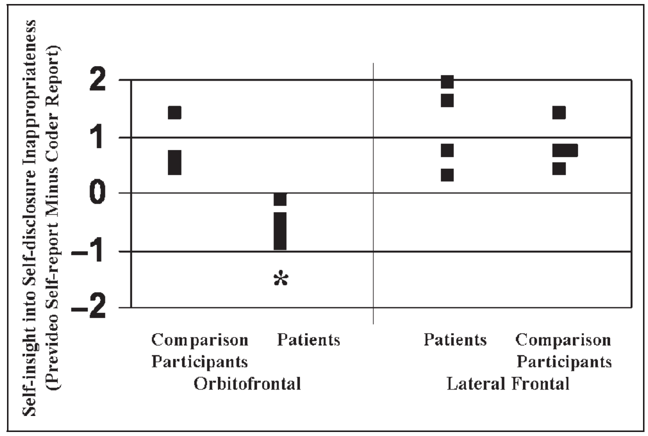

Figure 4. Discrepancy between self-perception and actual appropriateness. Negative scores reflect participants' overestimation of their appropriateness.

Change in Emotion

After completing the self-disclosure task and again after watching the videotapes, participants reported how much they felt amused, embarrassed, afraid, angry, and disgusted on a scale ranging from 1 (*not at all*) to 5 (*extremely*). After completing the self-disclosure task, the instructions read, "Below are a number of feelings that you may have felt during the interaction you just participated in. Please rate the extent to which you feel each emotion in relation to the interaction you just had." After watching the videotapes, the instructions read, "Please answer these questions about emotion now that you've watched the videotape of your study session. Please rate the extent to how you feel this way about your interaction." A change in emotion score was computed by calculating the discrepancy between prevideo and postvideo ratings.

RESULTS

The groups significantly differed in the appropriateness of their self-disclosure, $F(3,12) = 3.5$, $p < .05$ (see Figure 3). In comparison to orbitofrontal comparison participants, $t(1,6) = 3.3$, $p < .05$, and patients with lateral prefrontal lesions, $t(1,6) = 3.1$, $p < .05$, patients with orbitofrontal lesions were judged as objectively more inappropriate in their self-disclosure. It was not the case that patients with orbitofrontal lesions failed to understand that most people do not disclose personal information to strangers; there were no differences between the groups on social norms governing conversations between strangers $F(3,12) = 1.1$, *ns*. However, there were group differences in self-insight into appropriateness of behavior, $F(3,12) = 4.8$, $p < .05$ (see Figure 4). In comparison to orbitofrontal comparison participants, $t(1, 6) = 3.2$, $p < .05$, and lateral prefrontal patients, $t(1,6) = 7.13$, $p < .05$, patients with orbitofrontal damage underestimated their inappropriateness in comparison to the judged inappropriateness of their conversations. Upon watching their videotaped performance, the groups significantly differed in their change in embarrassment, $F(3,12) = 3.0$, $p < .05$ (see Figure 5). In comparison to orbitofrontal comparison participants, $t(1,6) = -5.0$, $p < .05$, and to lateral prefrontal patients, $t(1,6) = -2.6$, $p < .05$), orbitofrontal patients reported

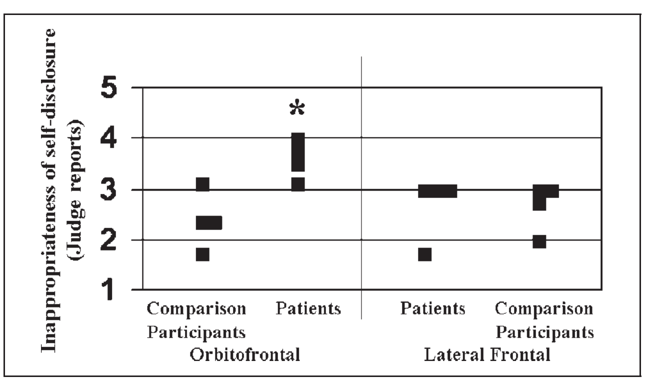

Figure 3. Appropriateness of self-disclosure. Higher scores indicate greater perceptions of inappropriateness by the judges.

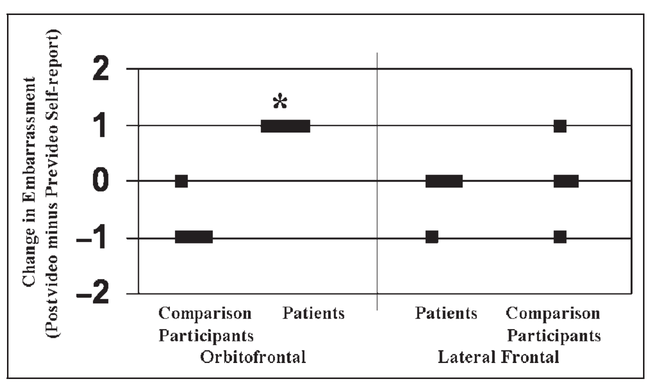

Figure 5. Change in emotion associated with increased self-consciousness. Higher scores indicate an increase in embarrassment after watching the videotape of the procedure.

a greater increase in embarrassment. It was not the case that the self-monitoring manipulation increased all emotions; no differences were found among the groups for changes in nonsocial emotions such as amusement, $F(3,12) = 2.0, ns$;[1] fear, $F(3,12) = .58, ns$; anger, $F(3,12) = .18, ns$; and disgust, $F(3,12) = 1.0, ns$.

DISCUSSION

The present research supports the hypothesis that orbitofrontal damage impairs self-monitoring precluding the generation of social emotions typically associated with the resolution of social mistakes (Tangney, Miller, Flicker, & Barlow, 1996). In comparison to patients with lateral prefrontal damage and healthy comparison participants, patients with orbitofrontal damage self-disclosed more inappropriately while talking with a stranger. Even though patients with orbitofrontal damage could successfully report the norms governing self-disclosure with a stranger, they were unaware of their inappropriateness after completing the self-disclosure task. Only after watching a videotape focusing their attention on their behavior did patients with orbitofrontal damage report embarrassment in relation to their inappropriate social behavior.[2]

Together these findings suggest that integrating the (a) emotion and (b) self-monitoring perspectives is a crucial approach for understanding the role of the orbitofrontal cortex in adaptive interpersonal behavior. For example, the present findings suggest a richer interpretation of the finding that patients with orbitofrontal damage are proud of their inappropriate teasing (Beer et al., 2003). In the present research, patients tended to overestimate their appropriateness. Therefore, the faulty monitoring processes associated with orbitofrontal damage may result in appraisals of inappropriate behavior as not only acceptable but praiseworthy.

More research is needed to understand the nature of the self-monitoring associated with orbitofrontal function. Orbitofrontal damage has been consistently associated with the ability to state the rules of a task with a seemingly paradoxical failure to apply these same rules to actual behavior (e.g., Bechara et al., 2000; Rolls et al., 1994; Stuss, 1991). These findings parallel the ability of the patients in the present study to state the social norms governing self-disclosure with strangers in combination with a failure to apply them. Knowledge of social norms or task rules is not enough to ensure appropriate social behavior; it is necessary to monitor or compare one's behavior in the moment to these abstract norms or rules in order to generate emotions. What kinds of monitoring comparisons does the orbitofrontal cortex support? Most of the current research on the orbitofrontal cortex has focused on deficits in applying recently learned rules (i.e., such as in a gambling task; Fellows & Farah, 2003; Bechara et al., 1997); very few studies have examined orbitofrontal damage in relation to well-learned social norms (Beer et al., 2003; Stone et al., 1998). New directions for research are suggested by models of self-regulation, which theorize that individuals need to compare online behavior to a multitude of references such as social norms (e.g., ''it's impolite to insult someone''), their own goals ranging in degree from abstract (e.g., ''be a good person'') to concrete (e.g., ''do not hurt this person's feelings by telling them their new haircut is not flattering''), as well as the expectations of other people (e.g., ''she won't want to hear the truth because there is nothing she can do about it'') (e.g., Vohs & Heatherton, 2000; Carver & Scheier, 1990; Deci & Ryan, 1987; Vallacher & Wegner, 1987). The monitoring of the expectations of other people is consistent with research associating orbitofrontal damage with impaired judgments of the intentions behind social faux pas (Stone et al., 1998).

Another direction suggested by an integrative perspective on the orbitofrontal cortex function is a greater focus on empirical studies of interpersonal tasks and social emotions. Much of the current research involves risk-taking paradigms that are not interpersonal (e.g., Fellows & Farah, 2003; Bechara et al., 2000; Rolls et al., 1994; but see Beer et al., 2003; Stone et al., 1998; Saver & Damasio, 1991; Price, Daffner, Stowe, & Marsel-Mesulam, 1990). However, in everyday life, social blunders are most often followed by social emotions such as embarrassment, shame, or guilt (Tangney et al., 1996).

One possible limitation to the interpretation of the present study is the difference in etiology between the two lesion groups. In contrast to damage arising from stroke, damage arising from traumatic brain injury can often be accompanied by diffuse axonal injury (DAI) (Smith, Meaney, & Shull, 2003). DAI consists of white matter lesions that mostly occur at the white matter–gray matter junctions in the brain. These lesions are caused by rotational forces upon the brain after high-speed collisions. Two of the orbitofrontal patients in our sample sustained their damage in high-speed collisions (M.R. and D.H.). If the orbitofrontal patients have DAI extending into the lateral regions of their frontal lobes, it would be misleading to characterize the findings from the present research as a functional dissociation between the orbitofrontal and lateral frontal regions. Although we cannot completely rule out the presence of axon shear in these orbitofrontal patients (Inglese et al., 2005), no evidence of axon shear is apparent in these patients either in initial CT scans and or later MRI scans, and the orbitofrontal patients perform better, on average, than the lateral frontal group on neuropsychological tests associated with lateral frontal functioning (see Table 2: Wisconsin Card Sorting Test [WCST] and Trails B).

In summary, the orbitofrontal cortex is best conceptualized as an area important for self-monitoring processes that underlie the generation of emotions useful for guiding behavior. This perspective suggests that future research should focus on understanding the exact nature of the monitoring processes (i.e., comparing behavior to abstract social norms, self-expectations, and/or the expectations of others) and employ more interpersonal tasks that evoke social emotions such as embarrassment, shame, guilt, and pride. Finally, the present study suggests that training using videotaped playback might be useful in treating the debilitating social deficits seen in patients with acquired damage to the orbitofrontal cortex.

APPENDIX A: QUESTIONS FROM SOCIAL INTERACTION TASK

1. What would constitute a perfect day for you and why?
2. Tell me about an embarrassing moment you've had.
3. Given the choice of anyone in the world, whom would you want to have as a dinner guest and why?
4. What is your most treasured memory and why?
5. When did you last cry in front of another person? By yourself? Why?
6. Is there something you've dreamed of doing for a long time? Why haven't you done it?
7. Would you like to be famous, if no, why not? If yes, in what way?
8. If you were going to pass this evening with no opportunity to communicate with anyone what would you most regret not having told someone? Why haven't you told them yet?
9. If a crystal ball could show you the truth about yourself, your life, your future or anything else, what would you want to know and why?

APPENDIX B: MEASURE OF INAPPROPRIATE SELF-DISCLOSURE

Intimacy (scored for inappropriate intimacy)

1. I hesitated to answer the questions very deeply because some of my answers contained personal information (R).
2. I tried to keep many of my thoughts and feelings to myself while answering the questions (R).
3. I held back my deeper feelings and thoughts while answering the questions (R).

Perceived appropriateness (scored for inappropriateness)

1. Most people would reveal as much as I did while talking with the interviewer (R).
2. While talking with the interviewer, I spoke candidly as I would with a close friend.
3. Considering that I don't know the interviewer very well, I disclosed an appropriate amount of information about myself (R).
4. I shared things with the interviewer that I wouldn't tell most strangers (R).

Acknowledgments

This research was supported by a Doctoral Dissertation Improvement Grant (NSF BCS 0121970) and National Research Service Award (NIMH MH66574) to J.S.B. and NINDS Grants NS21135, PO NS40813, NIMH MH 066737, and the McDonnell Foundation Cognitive and Neurobiological Research Consortium in Traumatic Brain Injury to R.T.K. The authors thank Christine Hooker for her help with the neuropsychological data.

Reprint requests should be sent to Jennifer Beer, Center for Mind and Brain, 267 Cousteau Place, Davis, California 95616, or via e-mail: jsbeer@ucdavis.edu.

Notes

1. The emotion ratings were not correlated with one another with the exception that amusement and fear were negatively correlated prevideo ($r = -.45$, $p < .05$), postvideo ($r = -.64$, $p < .05$), and for change in emotion ($r = -.59$, $p < .05$). Given their correlation, a composite score was calculated by averaging amusement ratings and reverse-scored fear ratings. However, analyzing the data in this manner still did not yield group differences, $F(3,12) = 1.46$, $p > .05$.
2. It should be noted that although participants were instructed after the videotape viewing to rate their emotions in reference to how they felt about their task performance, they may have ignored instructions. Additionally, insight into the inappropriate of behavior was not assessed. In this case, the increased embarrassment reported by patients with orbitofrontal damage may not be explained by a sudden explicit insight into their inappropriate behavior. Instead, the embarrassment may have arisen from a subconscious recognition of their inappropriateness or embarrassment from watching themselves on screen.

REFERENCES

Aron, A., Melinat, E., Aron, E. N., Vallone, R. D., & Bator, R. J. (1997). The experimental generation of interpersonal closeness: A procedure and some preliminary findings. *Personality and Social Psychology Bulletin, 4,* 363–377.

Barona A., Reynolds C. R., & Chastain R. (1984). A demographically based index of pre-morbid intelligence for the WAIS-R. *Journal of Consulting and Clinical Psychology, 52,* 885–887.

Bechara, A., Damasio, H., & Damasio, A. R. (2000). Emotion, decision making, and the orbitofrontal cortex. *Cerebral Cortex, 10,* 295–307.

Bechara, A., Damasio, H., Tranel, D., & Damasio, A. R. (1997). Deciding advantageously before knowing the advantageous strategy. *Science, 275,* 1293–1295.

Beer, J. S., Heerey, E. H., Keltner, D., Scabini, D., & Knight, R. T. (2003). The regulatory function of self-conscious emotion: Insights from patients with orbitofrontal damage. *Journal of Personality and Social Psychology, 85,* 594–604.

Beer, J. S., Shimamura, A. P., & Knight, R. T. (2004). Frontal contributions to executive control of cognitive and social behavior. In M. Gazzaniga (Ed.), *The cognitive neurosciences III* (pp. 1091–1104). Cambridge: MIT Press.

Blair, R. J. R., & Cipolotti, L. (2000). Impaired social response reversal: A case of "acquired sociopathy." *Brain, 123,* 1122–1141.

Carver, C. S., & Scheier, M. (1990). Principles of self-regulation: Action and emotion. In E. T. Higgins & R. M. Sorrentino (Eds.), *Handbook of motivation and cognition:*

Foundations of social behavior (pp. 3–52). New York: The Guildford Press.
Cozby, P. C. (1973). Self-disclosure: A literature review. *Psychological Bulletin, 79,* 73–91.
Deci, E. L., & Ryan, R. M. (1987). The support of autonomy and the control of behavior. *Journal of Personality and Social Psychology, 53,* 1024–1037.
Delis, D. C., Kramer, J. H., Kaplan, E., & Ober, B. A. (1987). *California Verbal Learning Test: Adult Version.* San Antonio, TX: Psychological Corp.
D'Esposito, M., Postle, B. R., & Rypma, B. (2000). Prefrontal cortical contributions to working memory: Evidence from event-related fMRI studies. *Experimental Brain Research, 133,* 3–11.
Duval, S., & Wicklund, R. A. (1972). *A theory of objective self-awareness.* New York: Academic Press.
Elliott, R., Dolan, R. J., & Frith, C. D. (2000). Dissociable functions in the medial and lateral orbitofrontal cortex: Evidence from human neuroimaging studies. *Cerebral Cortex, 10,* 308–317.
Elliott, R., Rees, G., & Dolan, R. J. (1999). Ventromedial prefrontal cortex mediates guessing. *Neuropsychologia, 37,* 403–411.
Fellows, L. K., & Farah, M. J. (2003). Ventromedial frontal cortex mediates affective shifting in humans: Evidence from a reversal learning paradigm. *Brain, 126,* 1830–1837.
Folstein M. F., Folstein, S. E., & McHugh P. R. (1975). Mini-Mental State: A practical method for grading the state of patients for the clinician, *Journal of Psychiatric Research, 12,* 189–198.
Goffman, E. (1956). Embarrassment and social organization. *American Journal of Sociology, 62,* 264–271.
Grant, D. A., & Berg, E. A. (1948). A behavioural analysis of degree of reinforcement and ease of shifting to new responses in a Weigl-type card sorting problem. *Journal of Experimental Psychology, 38,* 404–411.
Inglese M., Makani S., Johnson G., Cohen B. A., Silver J. A., Gonen O., & Grossman R. I. (2005). Diffuse axonal injury in mild traumatic brain injury: A diffusion tensor imaging study. *Journal of Neurosurgery, 103,* 298–303.
Kaczmarek, B. L. J. (1984). Neurolinguistic analysis of verbal utterances in patients with focal lesions of frontal lobes. *Brain and Language, 21,* 52–58.
Kringelbach, M. L., & Rolls, E. T. (2004). The functional neuroanatomy of the human orbitofrontal cortex: Evidence from neuroimaging and neuropsychology. *Progess in Neurobiology, 72,* 341–372.
Lewis, M. (1993). Self-conscious emotions: Embarrassment, pride, shame, and guilt. In M. Lewis & J. M. Haviland (Eds.), *Handbook of emotions* (pp. 353–364). New York: Guildford Press.
Lhermitte, F. (1986). Human autonomy and the frontal lobes. Part II: Patient behavior in complex and social situations: The ''environmental dependency syndrome.'' *Annuals of Neurology, 19,* 335–343.
Lhermitte, F., Pillon, B., & Serdaru, M. (1986). Human anatomy and the frontal lobes. Part I: Imitation and utilization behavior: A neuropsychological study of 75 patients. *Annuals of Neurology, 19,* 326–334.
Luria, A. R., & Homskaya, E. D. (1970). Frontal lobes and the regulation of arousal process. In D. I. Mostofsky (Ed.), *Attention: Contemporary theory and analysis* (pp. 303–330). New York: Appleton-Century-Crofts.
Miller, R. S., & Leary, M. (1992). Social sources and interactive functions of embarrassment. In M. Clark (Ed.), *Emotion and social behavior* (pp. 322–339). New York: Russell Sage Foundation.
Muller, N. G., Machado, L., & Knight, R. T. (2002). Contribution of subregions of the prefrontal cortex to working memory. *Journal of Cognitive Neuroscience, 14,* 673–686.
Price, B. H., Daffner, K. R., Stowe, R. M., & Marsel-Mesulam, M. (1990). The comportmental learning disabilities of early frontal lobe damage. *Brain, 113,* 1383–1393.
Prigatano, G. P. (1991). Disturbances of self-awareness of deficit after traumatic brain injury. In G. P. Prigatano & D. L. Schacter (Eds.), *Awareness of deficit after brain injury: Clinical and theoretical issues* (pp. 111–126). New York: Springer.
Radloff, L. S. (1977). The CES-D Scale: A self-report depression scale for research in the general population. *Journal of Applied Psychological Measures, 1,* 385–401.
Roberts, A. C., & Wallis, J. D. (2000). Inhibitory control and affective processing in the prefrontal cortex: Neuropsychological studies in the common marmoset. *Cerebral Cortex, 10,* 252–262.
Robins, R. W., & John, O. P. (1996). Self-perception, visual perspective, and narcissism: Is seeing believing? *Psychological Science, 7,* 279–287.
Robins, R. W., & John, O. P. (1997). In R. Hogan, J. Johnson, & S. Briggs (Eds.), *Handbook of personality psychology.* New York: Academic Press.
Rolls, E. T., Hornak, J., Wade, D., & McGrath, J. (1994). Emotion-related learning in patients with social and emotional changes associated with frontal lobe damage. *Journal of Neurology, Neurosurgery, and Psychiatry, 57,* 1518–1524.
Saver, J. L., & Damasio, A. R. (1991). Preserved access and processing of social knowledge in a patient with acquired sociopathy due to ventromedial frontal damage. *Neuropsychologia, 29,* 1241–1249.
Schultz, W., Tremblay, L., & Hollerman, J. R. (2000). Reward processing in primate orbitofrontal cortex and basal ganglia. *Cerebral Cortex, 10,* 22–283.
Shewan, C. M., & Kertesz, A. (1980). Reliability and validity characteristics of the Western Aphasia Battery (WAB). *Journal of Speech and Hearing Disorders, 45,* 308–324.
Smith, D. H., Meaney, D. F., & Shull, W. H. (2003). Diffuse axonal injury in head trauma. *Journal of Head Trauma and Rehabilitation, 18,* 307–316.
Stone, V. E., Baron-Cohen, S., & Knight, R. T. (1998). Frontal lobe contributions to theory of mind. *Journal of Cognitive Neuroscience, 10,* 640–656.
Stuss, D. T. (1991). Self, awareness, and the frontal lobes: A neuropsychological perspective. In J. Strauss & G. R. Goethals (Eds.), *The self: Interdisciplinary approaches.* New York: Springer.
Stuss, D. T., & Benson, D. F. (1984). Neuropsychological studies of the frontal lobes. *Psychological Bulletin, 95,* 3–28.
Tangney, J. P., Miller, R. S., Flicker, L., & Barlow, D. H. (1996). Are shame, guilt, and embarrassment distinct emotions? *Journal of Personality and Social Psychology, 70,* 1256–1269.
Vallacher, R. R., & Wegner, D. M. (1987). What do people think they're doing? Action identification and human behavior. *Psychological Review, 94,* 3–15.
Vohs, K. D., & Heatherton, T. F. (2000). Self-regulatory failure: A resource-depletion approach. *Psychological Science, 11,* 249–254.
Wagner, A. D., Bunge, S. A., & Badre, D. (2004). Cognitive control, semantic memory, and priming: Contributions from prefrontal cortex. In M. Gazzaniga (Ed.), *The cognitive neurosciences III* (pp.709–726). Cambridge: MIT Press.
Wechsler, D. (1997a). *Weschsler Adult Intelligence Scale-III.* San Antonio, TX: The Psychological Corporation.
Wechsler, D. (1997b). *Weschsler Memory Scale-III.* San Antonio, TX: The Psychological Corporation.