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Faux pas deficits in people with medial frontal lesions as related to impaired understanding of a speaker's mental state

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ABSTRACT

This study examined the nature of deficits in mentalizing, the ability to read the mental state of other people, as measured by a faux pas task in people with medial frontal lesions. A total of 56 Mandarin-speaking Chinese individuals participated (9 participants with medial frontal lesions, 12 participants with lateral frontal lesions, 5 participants with non-frontal lesions, and 30 healthy controls). The faux pas test ascertained the participants' ability to identify and understand a social faux pas, and to understand the mental states of the characters (the speaker and the recipient in a conversation with a social faux pas). Although the participants with medial frontal lesions performed less well than the other clinical participants and the control participants on all aspects of the faux pas test, the most significant deficit was observed in understanding mental states and hence inferring the speaker's intentions. The performance on the various aspects of decoding a social faux pas by people with medial frontal lesions suggests that the cognitive processes, and hence the respective neural correlates subserving these various processes, may be different. Our results add to existing literature and illustrate the very nature of deficits of mentalizing, measured by a faux pas test, experienced by people with medial frontal lesions. The data have also prompted that future behavioral and neuroimaging studies may be applied to further decode both the neural mechanisms and the cognitive variables affecting "mentalizing".

1. Introduction

Humans are social animals that under normal circumstances seek rewarding social interactions for adaptive learning and psychological satisfaction (Amodio & Frith, 2006; Cohen, 2004). To accomplish this important goal, we must be equipped with cognitive processes and the accompanying neural mechanisms that underpin both competent and successful interaction and communication with other people. These processes are classified under the construct termed *social cognition*, which, as defined by Brothers (1990), is the mental operation underlying social interactions, including the human ability to perceive the intentions and dispositions of others.

Among the various social cognitive skills essential to adaptive social learning and interactions, the ability to "mentalize," that is, to read the mental states of other agents (Frith & Frith, 2006), enables the attribution of cognitive and affective states of self and others. It is this awareness that allows one to detect the intentions and inner mental states of the self and others during social interactions (Baron-Cohen, Leslie, & Frith, 1985; David et al., 2008). In other words, mentalizing is the ability to represent another person's psychological perspective so that one may predict the behaviors of others (Amodio & Frith, 2006).

One strategy for assessing the ability to mentalize is the use of faux pas tests (Stone, Baron-Cohen, & Knight, 1998). *Faux pas* is a French term meaning a "false step," in other words, a speaker

Abbreviations: ANOVA, analysis of variance; FC, frontal cortex; FL, frontal lesion group; fMRI, functional magnetic resonance imaging; LFC, lateral frontal cortex; MFC, medial frontal cortex; NFC, non-frontal lesion control; DMFC, dorsomedial medial frontal cortex; VMFC, ventromedial frontal cortex.

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says something he or she should not have said, not knowing or not realizing the words' inappropriateness, which could hurt the recipient's feelings. An example of a social faux pas is as follows:

> "*Jessica was at Maria's apartment. While appreciating a crystal vase that she gave Maria as a birthday gift, she accidentally dropped the vase to the ground, which was then shattered into pieces. Jessica felt really sorry about breaking the vase. Maria said, "Don't worry about it. I never like this vase anyway.*"

When an individual recognizes the occurrence of a faux pas, he or she mentalizes that the speaker who said what was said did not intend to hurt the listener's feelings, and predicts that the individual who heard the words will be upset (Stone et al., 1998). Being able to mentalize another person's inner psychological state allows us to evaluate the intentions behind the behavior of others and hence decide how to react. According to previous research, children aged 9–11 years are able to recognize a faux pas involving the capacity to understand a situation in which one character should have kept information from another but did not (Baron-Cohen, O'Riordan, Stone, Jones, & Plaisted, 1999).

Applying the principle of faux pas, Stone et al. (1998) developed a faux pas test to assess the ability to mentalize. Ten stories, each containing a faux pas, are presented to participants one at a time. The participants are required to answer the following questions:

1. Detecting a faux pas: did someone say something he (or she) should not have said?
2. Understanding the faux pas: who said something he (or she) should not have said?
3. Understanding the recipient's mental state: why should he (or she) not have said it?
4. Understanding the speaker's mental state: why did he (or she) say it?

The participants are then asked a final control question to tap the important details of the story without inferring another's mental state in order to test their story comprehension.

Impaired faux pas performance has been widely reported in various clinical groups. Children with Asperger syndrome or high-functioning autism were found to perform significantly poorer than a control group in detecting faux pas stories, while performing well on first- and second-order false belief tasks (Baron-Cohen et al., 1999; Stone et al., 1998).

It has been suggested that the ability to mentalize other people's mental states and the capability of processing information about oneself may be subserved by a similar group of neural substrates (Mitchell, Macrae, & Banaji, 2004) in the frontal cortex (FC). The FC is functionally and anatomically heterogeneous (Happaney, Zelazo, & Stuss, 2004) and can be broadly subdivided into the lateral, dorsomedial, and orbital FC. Functionally, the dorsomedial and orbital FCs are often considered together as the medial FC (MFC). As such, the orbital FC, together with the dorsomedial FC, may function collaboratively (Öngür & Price, 2000) in processing inputs from sensory modalities for regulating consummatory behaviors (Kringelbach, 2005).

About possible neural correlates of mentalizing, the MFC, the superior temporal sulcus, the temporal–parietal junction, and the temporal poles (adjacent to the amygdala) are candidates serving social cognitive functions (Amodio & Frith, 2006; Frith & Frith, 2003). Researchers have suggested that the MFC, plays an important role in mentalizing (Mazza et al., 2007; Stuss, Gallup, & Alexander, 2001). Earlier studies have reported impaired performance on a faux pas test in patients with lesions in the orbitofrontal cortex and amygdala (Stone et al., 1998; Stone, Baron-Cohen, Young, Calder, & Green, 1999). Amodio and Frith (2006) proposed that the MFC is important for monitoring action, person perception, inferences about others' thoughts, and outcomes related to punishments and rewards. Krueger, Barbey, and Grafman (2009) proposed the structural and temporal representation binding theory, which delineates the special role of the MFC in mediating social event knowledge via structural and temporal binding processes with that in the posterior cerebral cortex and the limbic structures. Critchley et al. (2003) theorized that the MFC is important for integrating interoceptive, cognitive, and motivational states, thereby representing or producing changes in visceral sensations that are present in affective states.

In contrast to the MFC, the lateral FC (LFC) is responsible for non-emotion-related cognitive processes. The literature suggests that the LFC is a key neural substrate of cognitive control for inhibiting a prepotent behavior (Huettel & McCarthy, 2004), selecting a novel behavior (Ranganath & Rainer, 2003), and selecting a response option when competition exists between more than one (Frith, 2000; Robinson, Blair, & Cipolotti, 1998). In clinical studies, damage to the LFC is associated with impaired selection of plans for behavior. Such patients are unable to choose between possible alternatives, preferring well-practiced behaviors regardless of context (Lhermitte, 1986; Mesulam, 2002).

Shamay-Tsoory, Tibi-Elhanany, and Aharon-Perertz (2006) examined patients with MFC damage and observed impairment in tasks requiring affective mentalizing, particularly in reasoning about affective irony and lie conditions involving more contextually embedded mindreading, but not other cognitive theory-of-mind tasks. Following this line of thinking, people with MFC damage should be more impaired in the affective (i.e. understanding mental states) than the cognitive (i.e. identifying a social faux pas) aspects of a faux pas test. Hence, we employed a lesion study methodology, the essence of which is the establishment of testable relationships between brain regions and behaviors (Damasio & Damasio, 1989), to examine the nature of faux pas deficits experienced by people with frontal lesions. We first classified patients with frontal lesions into two groups: one group with lesions in the LFC and the other group with lesions in the MFC. We hypothesized that people with MFC lesions would perform significantly worse than those with LFC lesions, in accordance with the literature on the neural correlates of performing a faux pas test. We then examined scores on each of the faux pas questions to identify the neural correlates of mentalizing, as well as the nature of the faux pas deficits presented by people in the MFC group. We hypothesized that impaired performance on the faux pas test would be related to the understanding of mental states but not to the identification of a faux pas.

2. Methods

2.1. Participants

The participants included a total of 56 right-handed Chinese individuals from Hefei in the Anhui Province of China. Among them were 26 patients of Anhui Medical University who had acquired localized, well-defined brain lesions caused by surgical removal of brain tumors. Their premorbid general intellectual functioning was within average limits as estimated by their premorbid vocational achievement (all participants were engaging in stable full-time competitive employment). Learning disabilities were screened by a neuropsychologist. Potential participants diagnosed of such disabilities were excluded from participation in this study. Developmental history and premorbid social conduct were normal as reported by their respective caregivers. In addition, they had no premorbid history of medical and/or psychiatric illnesses affecting cognitive functioning. The 30 neurologically healthy controls, who had no history of medical conditions affecting cognitive functioning, were recruited from the Hefei community. We matched the clinical and control groups in terms of years of education, general cognitive functioning as measured by the Mini-Mental State Examination (MMSE; Folstein, Folstein, & McHugh, 1975), and mood state as measured by the Hamilton Depression Scale (HAMD; Hamilton, 1960). The study was approved by the Research Ethics Committee of Anhui Medical University. All participants gave their informed consent to take part in the study according to the Declaration of Helsinki. In addition, for the patients, consent was also obtained from their caregivers.

All lesions were localized and circumscribed onto standard templates, and the grouping was based on their respective lesion sites (Damasio & Damasio, 1989). The clinical participants were first classified into the frontal lesion group (FL, $n = 21$) and the non-frontal lesion control group (NFC, $n = 5$). Among the participants in the FL group, 18 suffered from unilateral lesions (right hemisphere = 11, left hemisphere = 7). The FL group included 15 males and six females, aged 24–66 (mean = 37.9, SD = 11.08), and with 4–15 years of education (mean = 7.67, SD = 2.94). The NFC group consisted of five patients, three of whom presented with right unilateral lesions and the remaining two with left unilateral lesions. The NFC consisted of three males and two females, aged 21–39 (mean = 31.80, SD = 9.42), and with 3–14 years of education (mean = 8.60, SD = 4.827). No significant differences were reported between the clinical and the control participants with respect to age [$t(54) = .767$, $p = .447$], years of education [$t(54) = 1.151$, $p = .255$], gender composition [$\chi^2(1) = .216$, $p = .642$], MMSE scores [$t(37.28) = 1.670$, $p = .447$], or HAMD scores [$t(52) = 1.108$, $p = .273$].

We further classified the participants in the FL group into the lateral frontal (LFC) group ($n = 9$) and the medial frontal (MFC) group ($n = 12$) according to the Damasio and Damasio lesion analysis method (1989) (see Fig. 1). The percentage of total brain area lesion was obtained by dividing the lesion area by the total area for all axial slices and the areas were quantified by counting the number of pixels (Alexander, Stuss, Shallice, Picton, & Gillingham, 2005). The ANOVA revealed no significant differences among the lesion groups (i.e. LFC, MFC, and NFC) with regard to age [$F(2, 23) = .812$, $p = .456$], years of education [$F(2, 23) = .186$, $p = .831$], days post-onset of illness [$F(2, 23) = 3.203$, $p = .059$], percentage of total brain area lesion [$F(2, 23) = .73$, $p = .493$], MMSE scores [$F(2, 23) = .136$, $p = .873$] or HAMD scores [$F(2, 23) = .194$, $p = 0.825$].

Table 1 presents the patients' basic demographic information, etiology, days post-onset, lesion size percentage, and handedness.

2.2. Faux pas test

We used a total of 10 faux pas stories. Each contained a social faux pas that involved two or three characters, whose actions were described in at least two separate statements. Each story was read to the participant. After each story had been presented, the participant was asked the five questions for

1. detecting a faux pas;
2. understanding the faux pas;
3. understanding the mental state of the faux pas' recipient;
4. understanding the mental state of the one delivering the faux pas; and
5. understanding the details but without inferring to the mental states of any characters in the story.

To control for the confound introduced by memory load, we gave the participants printed copies of each story while it was being read, and when they were requested to answer the questions. Those participants who gave a "no" response to the first question would skip questions 2–4 and be immediately presented with question 5. In such case, questions 2–4 were assigned zero points. We recorded the responses of all participants verbatim. For scoring, we assigned one point for any correct response, producing scores for individual questions (sum of the respective scores obtained for the 10 stories) as well as a faux pas total score (sum of the scores for questions 1–4 of all 10 stories). The 3-month test–retest reliability of the Chinese version of the faux pas was 0.83, and the interrater reliability was 0.76 (Zhu et al., 2007).

2.3. Data analysis

We have described the classification of the groups above. We performed an analysis of variance (ANOVA) procedure to test the differences in performance on the faux pas test between the FC group, the NFL control group, and the neurological healthy control group. All statistical computations were performed with the significance level set at $p < 0.05$ (two-tailed) unless otherwise specified.

3. Results

3.1. Behavioral data – faux pas test

The scores for the four faux pas related questions were summed to form a faux pas total score, which indicated the participants' general ability to understand and represent others' mental states. The brain lesion group performed significantly worse than the healthy control group in the overall faux pas performance (whose scores were at the ceiling) [$t(54) = 5.689$, $p < .001$]. Specifically, people with frontal lesions performed significantly worse than the healthy controls as revealed in the total faux pas score [$t(31.69) = 5.678$, $p < .001$]. For the control question, we found no significant differences between the brain lesion group and the healthy control group

Table 1
Demographic information and performance on the Mini-Mental State Examination and the Hamilton Depression Scale of the clinical and control participants.

	NHC group ($n = 30$)	LFC group ($n = 9$)	MFC group ($n = 12$)	NFC group ($n = 5$)	NHC vs. clinical group differences	Lesion subgroup differences (LFC, MFC, and NFC groups)
Gender	19 males; 11 females	8 males; 1 females	7 males; 5 females	3 males; 2 females	$\chi^2(1) = .216$, $p = .642$	$\chi^2(2) = 2.50$, $p = .286$
Age, mean (SD)	34.67 (9.28)	36.22 (6.92)	39.17 (13.57)	31.80 (9.42)	$t(54) = .767$, $p = .447$	$F(2, 23) = .812$, $p = .456$
Years of education, mean (SD)	8.80 (2.92)	7.89 (3.52)	7.50 (2.58)	7.67 (3.35)	$t(54) = -1.151$, $p = .255$	$F(2, 23) = .186$, $p = .831$
MMSE, mean (SD)	28.83 (.83)	28.22 (1.39)	28.17 (1.75)	28.60 (1.517)	$t(37.28) = -1.670$, $p = .447$	$F(2, 23) = .136$, $p = .873$
HAMD, mean (SD)	1.20 (1.00)	1.33 (.71)	1.60 (1.17)	1.60 (1.14)	$t(52) = 1.108$, $p = .273$	$F(2, 23) = .194$, $p = .825$
Time since injury in days, mean (SD)	*	89.89 (114.78)	280.75 (722.83)	1626.60 (2468.67)	*	$F(2, 23) = 3.203$, $p = .059$
Lesion size percentage, mean (SD)	*	1.94 (1.72)	2.38 (1.53)	1.43 (.86)	*	$F(2, 23) = .73$, $p = .493$
Laterality	*	5 right; 4 left	6 right; 0 left; 3 both	3 right; 2 left;	*	$\chi^2(4) = 4.19$, $p = .381$
Etiology	*	9 glioma	9 glioma; 1 glioma post-operation; 1 AVM; 1 tumor	1 glioma; 1 tumor; 1 cerebral cysticercosis; 1 cerebral infarction; 1 temporal angioma	*	*

NHC = neurologically healthy control; LFC = lateral frontal cortex; MFC = medial frontal cortex; NFC = non-frontal lesion control; MMSE = Mini-Mental State Examination; HAMD = Hamilton Depression Scale. * = Not applicable.

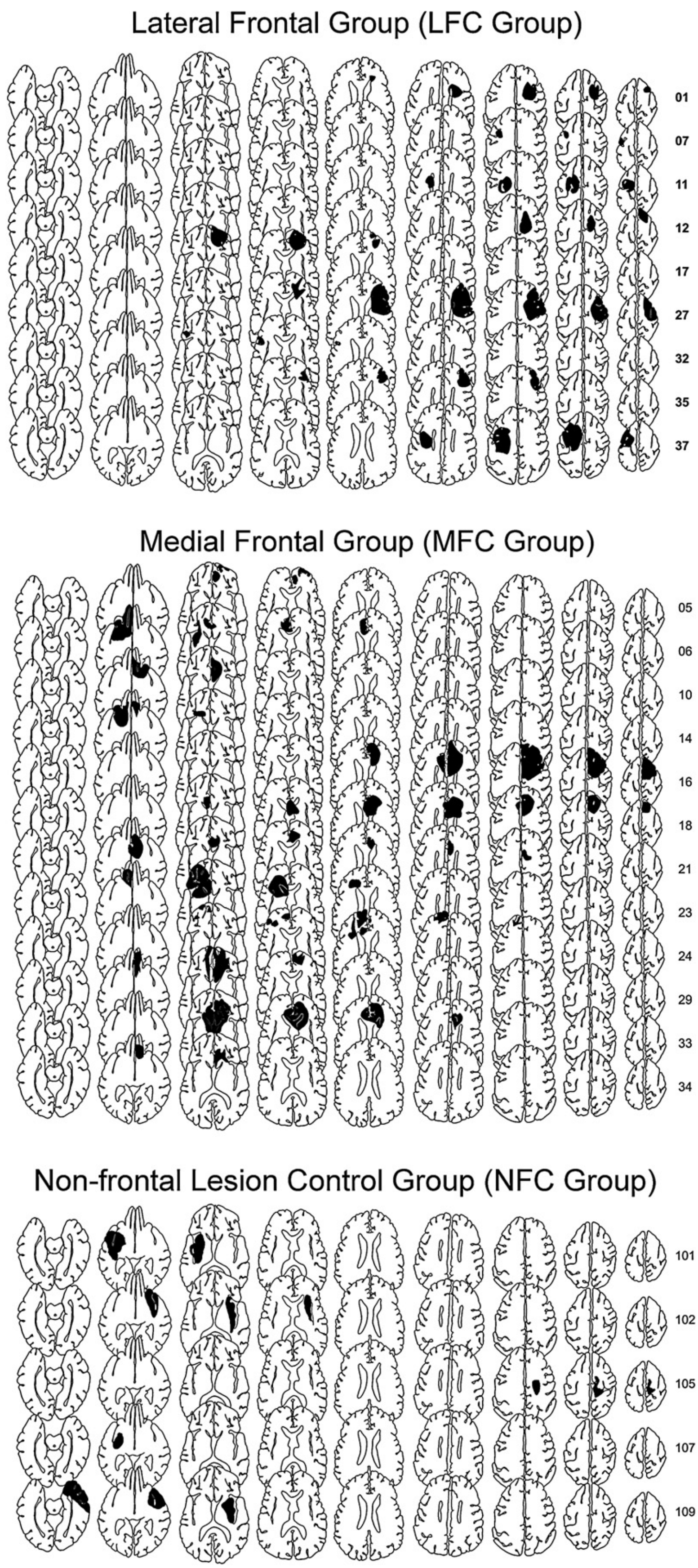

Fig. 1. Lesion location of each participant within the three clinical groups: lateral frontal group ($n = 9$), medial frontal group ($n = 12$) and non-frontal lesion control group ($n = 5$).

[$t(54) = 1.608$, $p = .114$]. This pattern of findings is consistent with a previous lesion study revealing the frontal lobes' important role in the theory of mind (Stuss et al., 2001).

One-way ANOVA procedure was conducted to examine the group differences between the LFC, MFC, NFC groups and the neurologically healthy control group. Significant group difference was observed in the faux pas total score and all faux pas individual question [total: $F(3, 52) = 16.227$, $p < .001$; question 1: $F(3, 52) = 6.379$, $p = .001$; question 2: $F(3, 52) = 8.328$, $p < .001$; question 3: $F(3, 52) = 16.227$, $p < .001$; question 4: $F(3, 52) = 21.871$, $p < .001$]. Also, a significant group by question interaction was observed. ($F(9, 156) = 3.53$, $p = .001$). The *post hoc* analysis revealed that the neurologically healthy control group performed significantly better than all three lesion groups. Furthermore, comparable performance on questions 1–3 by the LFC, NFC, and the neurologically healthy control groups was observed. However, the MFC group, relative to the other lesion groups and the neurologically healthy control group, performed significantly worse on question 4 (p values ranged between 0.41 and <.001).

No such patterns were observed when the data on the other three faux pas questions were analyzed. The MFC group also obtained the lowest total faux pas scores. No significant group differences on the control question were observed [$F(3, 52) = 1.758$, $p = .167$].

For the issue of statistical variance and to further verify the pattern of performance on the faux pas test by people with frontal lesions, we conducted a one-way ANOVA to compare the mean differences among the three brain lesion subgroups (LFC, MFC, and NFC groups) in the faux pas total score. The data from the neurologically healthy control group were excluded from this analysis. We observed significant group differences [$F(2, 23) = 3.93$, $p = .034$]. *Post hoc* analysis (LSD) revealed that the MFC group performed significantly worse than the other two brain lesion subgroups. Regarding the control questions, the performance of all three lesions subgroups approached the ceiling. We observed no significant differences among these subgroups [$F(2, 23) = .587$, $p = .564$]. This finding suggests that worse performance on the faux pas test should not be related to difficulties with comprehension (Table 2).

Separate analysis of each faux pas question revealed other interesting findings. We observed no significant group differences in the first three faux pas questions. These questions assess the participants' ability to detect a faux pas (question 1) [$F(2, 23) = 2.65$, $p = .092$], and their understanding of the faux pas situation (question 2) [$F(2, 23) = 1.54$, $p = .237$] and the recipients' mental state (question 3) [$F(2, 23) = 1.98$, $p = .161$], respectively. But we did observe significant group differences in question 4, which examines the respondents' understanding of the speaker's mental state [$F(2, 23) = 5.80$, $p = .009$]. Subsequent *post hoc* analysis (LSD) indicated that patients in the MFC group performed significantly worse than the LFC and the NFC patients. In other words, patients with lesions in the MFC would find it quite challenging to understand a speaker's benign intention in a faux pas situation (Fig. 2).

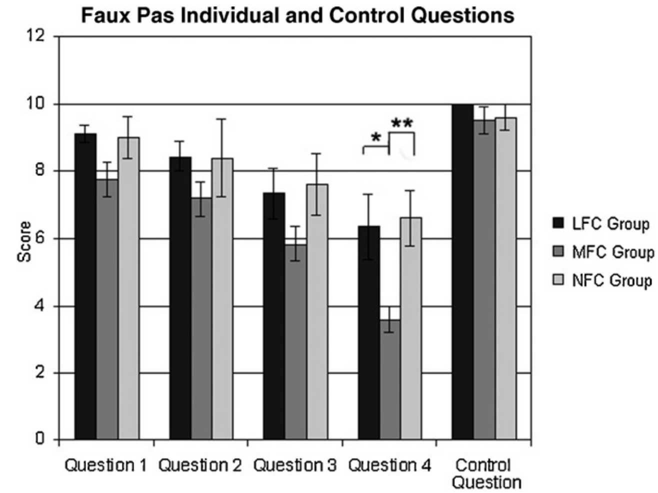

Fig. 2. Performance on the faux pas and control questions by the clinical participants in the lateral frontal (LFC) group, medial frontal (MFC) group and the non-frontal lesion control (NFC) group. The MFC group performed significantly worse than the LFC group and the NFC group on question 4 (LSD *post hoc* analysis: $^{*}p < 0.05$ $^{**}p < 0.01$). *Notes*: question 1 detects recognition of a faux pas; question 2 detects understanding of the faux pas; question 3 detects understanding of the mental state of the recipient in a faux pas conversation; question 4 detects understanding of the mental state of the speaker in a faux pas conversation; and control question detects understanding of the details but without inferring to the mental states of any characters in the story.

4. Discussion

This study examined the nature of mentalizing deficits presented by people with frontal lesions, especially medial frontal lesions. We administered the faux pas test to 56 participants: clinical participants (LFC or MFC lesions), clinical controls (non-frontal lesions), and neurologically healthy controls. Consistent with previous published literature, our findings support our first *a priori* hypothesis that participants with MFC lesions performed worse on the faux pas test than those with lateral PFC or non-frontal lesions as well as the neurologically healthy controls. Further to this observation, the findings also partially confirm our second *a priori* hypothesis that impaired performance on the faux pas test observed in the MFC group was mostly related to the significantly worse performance on the question asking about the mental states of the speakers. Our results are consistent with that of previous reports on the important roles played by the MFC in performing social faux pas task (e.g. Shamay-Tsoory, Tomer, Berger, Goldsher, & Aharon-Peretz, 2005; Stone et al., 1998). The findings also highlight the differential roles of the lateral and medial frontal cortex in enabling this important social cognitive function for building rewarding social relationships. In other words, the ability to recognize a social faux pas by inferring the mental states of others requires diverse cognitive processes that could be differentially affected in brain lesions. For our sample, the most significant social

Table 2
Mean performance (standard deviations) on the faux pas test.

	Group, mean (SD)			
Scores	LFC group ($n = 9$)	MFC group ($n = 12$)	NFC group ($n = 5$)	Group differences
Question 1	9.11 (0.78)	7.75 (1.82)	9 (1.41)	$F(2, 23) = 2.65$, $p = .092$
Question 2	8.44 (1.33)	7.17 (1.80)	8.4 (2.61)	$F(2, 23) = 1.54$, $p = .237$
Question 3	7.33 (2.35)	5.83 (1.80)	7.6 (2.07)	$F(2, 23) = 1.98$, $p = .161$
Question 4	6.33 (2.96)	3.58 (1.38)*	6.6 (1.82)	$F(2, 23) = 5.80$, $p = .009$
Total	31.22 (6.08)	24.33 (6.10)*	31.6 (7.57)	$F(2, 23) = 3.93$, $p = .034$
Control question	10 (0)	9.50 (1.45)	9.6 (.89)	$F(2, 23) = .59$, $p = .564$

LFC = lateral frontal cortex; MFC = medial frontal cortex; NFC = non-frontal lesion control; total = summation of scores on questions 1–4.
* Significance at $p < .05$.

deficit for people with MFC lesions is their impaired ability to differentiate the individual's intention to hurt the feelings of others in social interactions. Subsequent social behaviors affected by misinterpreting the intention to hurt will likely affect the quality of social interactions and relationships for people with MFC lesions.

Examining the pattern of performance across the four faux pas questions reveals that people with MFC lesions performed worse on all four questions, but the worst on question 4. Hence, performing a social faux pas task may involve load of cognitive processes at least at two levels of difficulty: identification and understanding of a social faux pas as well as the understanding to the mental state of the recipient being at a lower level of difficulty, relative to understanding the mental state and intentionality of the speaker. Guessing the mental representation of the speakers could be a more demanding task for it involves the complex meta-representation of the value of actions of others that enables inference of the intention of the speakers. Following this line of thoughts, the poor performance on question 4 by people with MFC lesion may relate to increase complexity and difficulty as demanded by question 4, relative to the other questions. Future studies controlling for this difficulty confound would help verify if deficit of inferring the intention of the speaker observed in people with MFC lesion is function specific or cognitive loading specific. Furthermore, generalization of the findings of this study should take into the consideration of the varying levels of difficulty of the questions of the faux pas test.

Krueger et al. (2009) have proposed a functional segregation within the MFC for mediating social event knowledge. Specifically, the more dorsal MFC is more involved with actions relative to the ventral MFC, which is more involved with feelings and outcomes (Amodio & Frith, 2006). Further along this line of thought, Van Overwalle (2009) suggests that inferences about self-schemata preferentially activate the ventral MFC and the medial orbitofrontal cortex, but that inferences about schemata relating to the judgment of other people preferentially activate the dorsal MFC. Amodio and Frith (2006) proposed functional divisions within the MFC. We compared performance on the faux pas test between subgroups within the MFC region based on their respective lesion sites (Damasio & Damasio, 1989). No significant differences in performance on all faux pas questions between the MFC subgroups were observed. However, the sample size of each group was small and unbalanced, which may cause significant limitation to the generalizability of this observation. Future lesion and neuroimaging studies using a larger MFC sample to delineate the specific roles within the sub-regions of the MFC as well as the functional effect of the size of MPF lesions would provide data essential for understanding the neural mechanisms behind mentalizing and other theory-of-mind abilities.

Some studies have suggested that the superior temporal sulcus, temporal–parietal junction, and temporal poles may also play an important role in specific tasks of mentalizing (e.g. Amodio & Frith, 2006; David et al., 2008; Saxe & Kanwisher, 2003; Saxe & Wexler, 2005). In a meta-analytic review, Van Overwalle (2009) proposed that the MFC and the temporal–parietal junction have different functional roles; specifically, the temporal–parietal junction is engaged in inferring temporary goals and intentions at a relatively more perceptual level of representation, and the MFC integrates social information across time and allows for reflection and representation of traits, norms, and intentionality at a more cognitive level. Mitchell, Mason, Macrae, and Banaji (2006) discuss how the mirror system in the frontal temporal–parietal regions (Van Overwalle, 2009) is important for tracking the continually changing states of the emotions and intentions of others. Others have also commented on the relationships between the mirror system and mentalizing (e.g. Grezes, Frith, & Passingham, 2004; Hynes, Baird, & Grafto, 2006; Walter et al., 2004). However, Shamay-Tsoory et al. (2006) argue that previous studies of patients with temporo-parietal junction lesions may have recruited patients suffering from large lesions, including the superior temporal and the angular gyri, that might have caused them to have language deficits. Hence, a general reasoning deficit owing to attentional deficits and language impairment might explain the impaired performance in theory-of-mind tasks.

People with lateral FC lesions performed less well on the faux pas test compared with the neurologically healthy controls. But their performances at recognizing the occurrence of a faux pas in social situations, making inferences about others' emotional mental states, and understanding people's intentions were comparable with those observed in people with non-frontal lesions. The comparable performance between the LFC and the non-frontal lesion groups is consistent with previous observations (Saver & Damasio, 1991; Stone et al., 1998). Damasio (2005) suggested that patients with LFC lesions may also have impaired social functioning that may be understood as part of a larger picture of cognitive defects. This speculation awaits verification in future research. In this connection, the interrelationships between other cognitive skills that contribute to intact mentalizing, such as logical reasoning, memory and learning, and reward and punishment processing, would be worth studying in future research.

The different pathologies presented by the frontal lesion patients may raise concerns about possible confounding effect on the findings. Klein et al. (2002) observed that patients suffering from low-grade glioma performed worse on cognitive domains than those with vascular diseases. Since all patients in the dorsolateral group suffered from glioma and should have performed worse than the medial group, the observation that the latter performed worse than the former group on the faux pas test provides reassuring evidence that the findings were not related to the impact of glioma on cognitive functioning. After all, the near ceiling performance on the control questions of the entire lesion group indicates an unimpaired performance in comprehending the stories. Hence, the results obtained in this study should be considered a fair representation of the social cognitive deficits experienced by people with frontal lesions.

The constraint on time for assessment set by the hospital where the data were acquired greatly limits the number of neuropsychological tests that could be administered for obtaining a more comprehensive cognitive profile for each participant. This time constraint together with the small sample size of the study may affect the generalizability of the findings. Future research may consider increasing the sample size by adopting a multi-center design. A meta-analytic review of lesion studies in social cognition should yield important insights into the neural mechanisms underlying mentalizing. Due to the process of cortical reorganization, the varying duration of post-onset of illness among the three lesion subgroups might have confounded the results of this study. According to literature, maximum recovery usually occurs in the very early stages post-injury. Hence other studies have used 1.3 months post-injury as the cut-off (see Stuss, Binns, Murphy, & Alexander, 2002). It is accepted that there might be some continuing albeit smaller post-injury recovery during the time period post-injury covered by our participants. In order to control for the confounding variance, exploratory analysis of covariate analysis procedure was performed on the faux pas test results with the days post-onset as a covariate. The results suggested that duration in days post-lesions was not a significant covariate in this study, suggesting that chronicity of lesion is not related to the faux pas test performance in this sample. However, the generalizability of this observation should be reaffirmed in future studies using a larger sample of varying post-lesion duration.

Our findings shed light on the unique nature of social deficits that challenge the quality of life for people with MFC lesions. Further neuroimaging and behavioral studies should be performed to decode the neural correlates and mechanisms as well as the cognitive variables affecting mentalizing. The data acquired will be essential for eventually constructing a neurocognitive model of mentalizing for verification in future experimentation. From the perspective of clinical practice, our findings support clinical observations regarding the heterogeneous profiles of impairment in social functioning in people suffering from frontal lesions at different locations. This information enables a better understanding of the challenges encountered by these individuals in their daily social interactions.

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