Neural correlates of the judgmental capacity for the appropriateness of facial affect

Ji-Woong Kim

Department of Medical Science

The Graduate School, Yonsei University

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Directed by Professor Hong Shick Lee

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Ji-Woong Kim

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This certifies that the Doctoral Dissertation of Ji-Woong Kim is approved.

Thesis Supervisor: Hong Shick Lee

[Il Saeng Choi: Thesis Committee Member#1]

[Dong Goo Kim: Thesis Committee Member#2]

[Chan-Hyung Kim: Thesis Committee Member#3]

[Jae-Jin Kim: Thesis Committee Member#4]

The Graduate School

Yonsei University

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<TABLE OF CONTENTS>

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

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Ji-Woong Kim

Department of Medical Science
The Graduate School, Yonsei University

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Questions regarding the appropriateness of facial expression to particular situations arise ubiquitously in everyday social interactions. To detemine facial affect appropriateness, we should understand the mental state of others and ourselves. In this study, we identified the brain mechanism mediating special types of social evaluative judgments of facial affect in which the internal reference is related to theory of mind (ToM) processing. Many previous ToM studies have used non-emotional stimuli, but because valuable social information is conveyed through non-verbal emotional channels, this investigation used emotionally salient visual materials to tap ToM.

Fourteen healthy, right-handed subjects volunteered for our study. Each subject performed judgmental task for the appropriateness of facial affects (experimental task) and gender matching tasks (control task) during scanning. Functional images of the whole brain were

acquired using a 3.0 Tesla MRI system (4 mm contiguous slices; TE, 35 ms; TR, 3000 ms; matrix size, 64 x 64; FOV, 22 x 22 cm). The functional images were realigned to the first images by SPM99 and normalized to the standard space of Talairach and Tournoux and smoothed with 10 mm Gaussian kernel. Statistical analyses used in the present study were performed according to the random effects model and contrast images for a given category of stimulus were subjected to a 'one-sample t-test' to test for significant activation during the task. The threshold was set at $p < 0.005$(uncorrected) and cluster size > 25. We identified activation of a brain network which includes both medial frontal cortex, left temporal pole, left inferior frontal gyrus, left thalamus, left superior temporal sulcus and inferior parietal lobule during the judgmental task for evaluating the appropriateness of facial affect as opposed to gender matching task. These regions have been known to involve in theory of mind task and are responsible for the detection of social cue, creating representation of mental or emotional state of both self and others, and comparing between them, etc. The results of the present study suggest that the brain system involved in ToM plays a key role in judging the appropriateness of facial affect in an emotionally laden situation. In addition, our result supports that common neural substrates are involved in performing diverse kinds of ToM task irrespective of perceptual modalities and the emotional salience of test materials.

Key words: theory of mind, facial affect, empathizability, appropriateness, fMRI

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I. INTRODUCTION

Theory of mind (ToM) is the ability to attribute mental states, such as intentions, beliefs, and desires, to oneself and others and thereby to understand and predict behavior.[1,2] Therefore, ToM ability forms the basis of diverse interpersonal activities. Lots of neuroimaging studies have been conducted using various kinds of paradigms and test materials to explore the neural substrate of ToM and elicit the activation of discrete parts of the brain, including the medial prefrontal cortex,[2-8] the temporal pole,[2-5,7-11] the superior temporal sulcus(STS),[12-17] the inferior frontal cortex,[4,6,18-20] and the parieto-occipital cortex.[2,7,8] In most of these previous ToM studies, verbal materials were used to tap ToM.[3,5,7,8,19] In some studies, non-emotional visual materials were used as a test material to tap ToM.[2,4] However, in real life situations, more valuable social information is conveyed through nonverbal emotional channels, not through overt verbal or non-emotional channels. Despite the importance of nonverbal emotional communication in our daily life, little is known about the neural basis of ToM processing for this type of test material.

A judgment generally can be defined as the assessment of an external or internal stimulus using an internal scale or reference. We make judgments about the multi-aspect of other people's facial expressions continuously in daily life. Evaluative judgment about the aesthetic aspects of facial expression (she looks beautiful even when she express anger: yes/no) is an example of such judgments. The internal reference for this type of judgment is related to an individual's value system.[21] This value system is internally fixed and does not change easily. However, in real social interaction, internal references should be reactive to our continuously changing external environment. Because humans continuously judge the social behavior of others,[22] the representation of the mental state of oneself or others can be a valuable internal references to evaluate and predict an appropriate facial affective response to diverse external social situations. Especially in an emotionally laden situation, we should use representations of emotional states induced by the social situation as a reference to make social evaluative judgment. For example, psychotherapists evaluate the state of patients through introspecting their own counter-transference emotional reaction.

The face is a source of complex signals and provides individuals with important cues regarding how to interpret the behavior of others and how to regulate their own behavior appropriately. Individuals who are better at decoding non-verbal cues are more involved in positive social interaction, while individuals who are less skilled in decoding facial expression demonstrate less social competence.[23,24] Therefore, successful evaluation of facial affective expression is fundamental to appropriate reciprocal social interaction. Lots of neuroimaging studies using various paradigms have been conducted to understand the brain system involved in the evaluation of facial affect.[25-29] Evidence from these studies indicates that both cortical and subcortical areas such as amygdala, hippocampus, inferior frontal cortex, cingulate, and temporoparietal cortex, are involved in the processing of these cognitive tasks.

However, real human interaction requires complex social cognitive abilities that go beyond simple labeling or discrimination or matching of emotions. The question, "Do you empathize with the affective response of that person in this situation?" arises constantly in normal social interaction, and, to behave and react in a socially appropriate manner, we must answer the question using an internal reference based on a representation of our own or other's emotional state that is induced by the social situation. Especially in situation where verbal information is not available, we rely on facial affective expressions and other visual and emotional information. In this sense, the above question is synonymous with the question, "Is the facial affect of that person appropriate to this emotional situation?" This kind of question provides the basis for higher degrees of social cognitive processes such as moral judgments. It is suggested that failure to make this kind of social evaluative judgment is implicated in the inappropriate social functioning of patients with diverse neuropsychiatric disorders such as autism[30-33] and schizophrenia.[34] Despite the many studies investigating the neural mechanism of ToM processing and the evaluation of facial affects, this kind of paradigm (ToM-referential social evaluative judgment for facial affects) has never been used before, as far as the authors know. We think that this paradigm realistically reflects the complex human interactions in which ToM capacity should be mobilized.

Therefore, we chose to conduct this study to identify the brain mechanism mediating special types of social evaluative judgment for facial affect in which the internal reference is related to the representation of emotional state (that is, ToM). Because more valuable social information is conveyed through non-verbal emotional channels, as mentioned above, we used visual and emotional task materials in our investigation. This study will provide new insights on the neural mechanism of facial affect processing in social situations, and will go beyond traditional knowledge about brain processing related to simple labeling or discrimination or matching of emotion. This study will be helpful for understanding the mechanism of social pathologies, observed in patients with diverse psychiatric disorders who exhibit inappropriate behavior, difficulty in interpersonal relationships, failure of empathetic judgment, and so forth.

II. MATERIALS AND MEHTHODS

1. Subjects

Fourteen healthy, right-handed subjects, 7 males and 7 females, participated in the experiment. Handedness was assessed by a revised version of Annett's hand preference questionnaire.[35,36] Exclusion criteria included current or past history of psychiatric disorders, traumatic brain injury, neurological illness, alcohol or drug abuse, or relevant visual defects. All subjects had more than 12 years of formal education and fulfilled the inclusion criteria of age (18 to 35 years); the mean age of experimental subjects was 23.3 ± 2.0 years (range: 19 to 27 years old). All subjects gave informed written consent after the nature of the experiment was explained.

2. Stimulus, tasks, and study design

This experiment used a blocked paradigm consisting of a judgmental task of evaluating the appropriateness of facial affect (an experimental condition) and a gender matching task (a control condition), and a baseline crosshair.

To examine the judgmental capacity for the appropriateness of facial affect, we use two pictures as stimuli (Fig 1). One picture depicts a facial affect, and the other displays an affectively loaded situation. The pictures depicting various facial affects were selected from color photographic sets of faces that were standardized by Gur et al.[37] The pictures displaying an emotionally laden situation were selected from International Affective Picture System.[38,39]

These preliminary stimuli were presented to groups of raters (n = 32) who were asked to judge whether or not the facial affect presented in one picture was appropriate for the affectively loaded situation presented in the other picture. To ensure validity, a subset of stimuli was selected based on a high degree (> 90%) of concordance by the raters. This final subset, administered during the fMRI study, was composed of 22 appropriate and 14 inappropriate facial affective pictures. The mean concordance rate of this final subset was 97.68 ± 2.39%. Examples of the pairings are presented in Figure 1.

Figure 1. Stimuli used in both the judgmental task for the appropriateness of a facial affect and the gender matching control task. The picture set on the left is an example of appropriate facial affect, while the set on the right is an example of an inappropriate one. For the gender matching task, the right picture is an example of the same gender and the left one is an example of different gender.

During the scanning, the subjects were asked to perform the task described above, and to respond by pressing either the left button (appropriate facial affect) or right button (inappropriate facial affect). All subjects used their right hand to respond.

In the gender matching task, the subjects were asked to judge whether the gender of the people displayed in the two pictures was the same (left button) or not (right button). The same stimuli were used in both the activation task and the control task. Therefore, the number of facial affects in each category (happy, sad, fearful, disgusted, surprised) was equal in the two tasks. The ratio in the experimental condition (11:7) of appropriate facial affect versus inappropriate affect was equal to the ratio of matched versus unmatched gender in the control condition, thus maintaining the same proportion of motor responses. Facial affective pictures of the same individual were not repeated within one block. Data on accuracy and reaction times were collected during the scanning session. A practice session with different stimuli was conducted prior to initiating the scan to ensure optimal performance.

Participants were placed in the scanner in a supine position, wearing earplugs to muffle the noise. Head fixation was assured through a foam-rubber device mounted on the headcoil. Participants viewed the target stimuli through a mirror.

In both the experimental tasks and the control tasks, each stimulus was presented for four seconds followed by a one-second inter-stimulus interval. Each task block contained 18 trials of either judgmental tasks for the appropriateness of facial affect or gender matching tasks, resulting in blocks of 90 seconds each (Fig 2). 30 seconds blocks of baseline crosshair followed each condition and each scanning session comprised four blocks (A-R-C-R or C-R-A-R, where A indicates activation condition, C indicates control condition, and R indicates baseline crosshair). During the baseline crosshair block, subjects gazed at a cross (+) on the screen. Each subject underwent two scanning sessions. The presentation order was counterbalanced across subjects (A-R-C-R-A-R-C-R or C-R-A-R-C-R-A-R) (Fig 2).

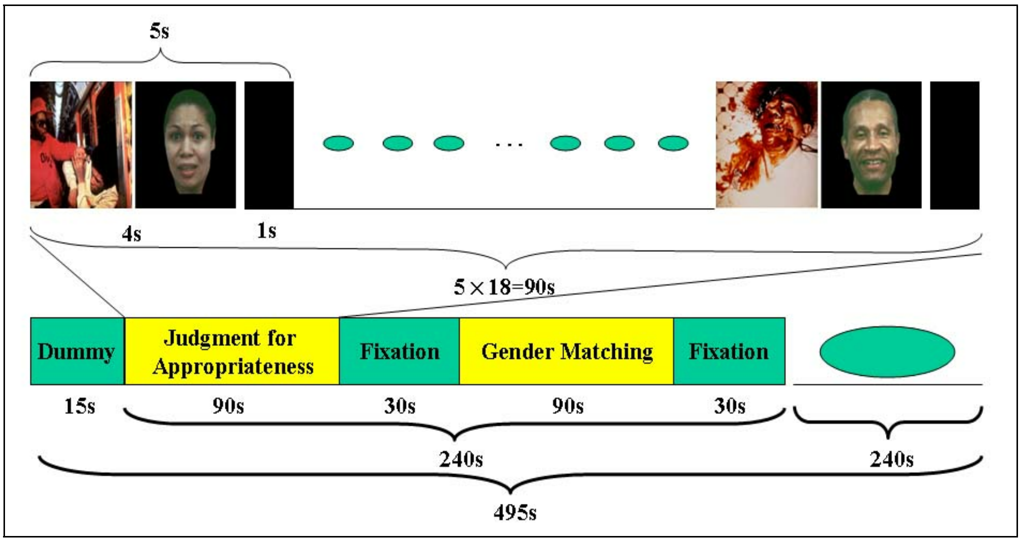

Figure 2. Experimental paradigm. In both the experimental tasks and the control tasks, each stimulus was presented for four seconds followed by a one-second inter-stimulus interval. Each task block contained 18 trials of either judgmental tasks for the appropriateness of facial affect or gender matching tasks, resulting in blocks of 90 seconds each. 30 seconds blocks of baseline crosshair followed each condition and each scanning session comprised four blocks. Each subject underwent two scanning sessions.

3. fMRI data acquisition

MRI imaging was performed with a 3.0T imager (ISOL technology, South Korea).

Before imaging, a global shimming procedure, using first- and second-order shims, was performed to optimize the magnetic field over the imaging volume of interest.

Whole-brain axial T1-weighted anatomical images were acquired using an inversion recovery sequence (4 mm contiguous slices; TE, 16 ms; TR, 3200 ms; matrix size, 256 x 192; FOV, 22 x 22 cm). During the study, echo planar functional images were acquired using a gradient echo pulse sequence (4 mm contiguous slices; TE, 35 ms; TR, 3000 ms; matrix size, 64 x 64; FOV, 22 x 22 cm).

4. Image analysis

All image data were analyzed with Statistical Parametric Map software (SPM 99; Wellcome Department of Cognitive Neurology, London) implemented in Matlab (The Mathworks, Inc., Sherborn). All analysis of imaging data was performed in fMRI laboratory, Brain Science Research Center, Korea Advanced Institute of Science and Technology. Movement correction was done by using the first image (dummy scans were excluded) in the time series as the reference image. The images were co-registered and resliced, and the sampling errors were adjusted (sinc interpolation). This correction reduces motion artifacts by a rigid-body transformation (translation in the direction of the x, y, and z axes and rotation around these three main axes), minimizing the total square difference between the images and the reference image. In order to perform intersubject averaging, all images were transformed into a standard space[40] by matching each scan to a template image that already conformed to the standard space. This spatial normalization involved a 12 parameter affine (linear) and quadratic (nonlinear) three-dimensional transformation, followed by a two-dimensional piece-wise nonlinear matching using a set of smooth basis functions that allow for normalization at a finer anatomical scale. As a final preprocessing step, all images were smoothed using a Gaussian kernel (full-width half-maximum of 10 mm) to increase the signal to noise ratio. Analysis was carried out using the general linear model and a boxcar waveform convolved with a hemodynamic response function accounting for the delayed cerebral hemodynamic response after stimulus presentation. Subject-specific, low-frequency drifts in signal changes were removed by a high pass filter, and global signal changes were treated as a covariate of no interest. The mean activity of each voxel throughout the whole was used as a dependent variable. Specific effects for each voxel were tested by applying appropriate contrast to the parameter estimates for each condition, resulting in t statistic for every particular voxel. The resulting set of voxel values for each contrast constituted a statistical parametric map of the t statistics $SPM_{\{t\}}$.

$SPM_{\{t\}}$ maps were thresholded at $P < 0.005$ (uncorrected for multiple comparisons), with an extent threshold of 25 contagious voxels. A threshold *t* score of 3.01($P < 0.005$, uncorrected for multiple comparison) has been demonstrated by Reiman et al[41] to be associated with a low rate of false positive activation and to constitute the most optimal trade-off between type I and type II statistical errors. We also used a minimum cluster size of 25 voxels in an effort to control type I errors. This combined application of a statistical threshold and cluster filter has previously been shown to reduce substantially the false-positive identification of activated voxel at any given threshold.[42]

III. RESULTS

1. Behavioral data

Performance was measured by the subject's reaction time and the percentage of correct answers. Table 1 shows the subjects' responses during the activation condition and control condition. As expected, participants did not have difficulty performing the tasks. For the judgmental task for the appropriateness of facial affects, they averaged 96.4 ± 2.8% correct (range 91.7-100) with reaction time averaging 1.92 ± 0.53 seconds (range 0.84 to 2.87 seconds). For the gender matching task, they averaged 95.2 ± 4.0% correct (range 88.9-100) with reaction time averaging 1.69 ± 0.35 seconds (range 1.12 to 2.30 seconds). Paired t-test showed that neither accuracy (t = 1.15, P > 0.05) nor reaction time (t = 1.82, P > 0.05) was significantly different between the two tasks.

Table 1. The performance of judgmental task for the appropriateness of facial affect and gender matching task

Task	Judgmental task for the appropriateness of facial affect	Gender matching task	t	P
Accuracy	96.4 ± 2.8%	95.2 ± 4.0%	1.15	P > 0.05
Reaction time	1.92 ± 0.53 seconds	1.69 ± 0.35 seconds	1.82	P > 0.05

2. Imaging data

Table 2 shows the results of subtracting the gender matching condition from the judgmental condition for the appropriateness of facial affects. This table indicates the brain regions with higher activity during experimental condition compared with the control condition, using names based on inspection of the co-registered MR images, as well as x, y, z coordinates from the Talairach atlas.

The data are presented by using the Talairach atlas convention, with x referring to the left/right position with respect to the midsaggital plane, y referring to the rostral/caudate (anterior/posterior) position with respect to the verticofrontal plane as defined by the anterior commissure, and z referring to the superior/inferior position with zero at the anterior-posterior commissure plane.

Compared to the gender matching task, the judgmental task for the appropriateness of facial affect appeared to activate several brain regions that are predominantly in the left hemisphere. The medial prefrontal lobe including the right anterior cingulated gyrus (BA 32) and the dorsal medial frontal cortex (BA 8) of both hemispheres, the left temporal pole (BA 38/21), the left inferior frontal cortex (BA 45/47), the left superior temporal sulcus (BA 22), the left inferior parietal lobule (BA 40) and the left thalamus were activated during the experimental condition as compared to control condition (Fig 3).

Table 2. Anatomical specification, Talairach coordinates (x, y, z), and maximal t scores of significantly activated voxels during the judgmental task for the appropriateness of facial affect in contrast to during the gender matching task (control condition)

Task and brain region	Brodmann's Area	t Max	Talairach Coordinates x	y	z	number of voxels
Both dorsal medial frontal cortex	8	6.30	-4	37	39	574
	8	5.72	10	37	46	
Right anterior cingulate gyrus	32	3.84	2	41	7	43
Left inferior frontal gyrus	47	4.47	-51	21	-4	61
	47	3.54	-38	25	-11	28
	45	3.37	-52	26	8	27
Left temporal pole	38/21	5.92	-44	16	-23	159
Left superior temporal sulcus	22	3.56	-56	-44	6	46
Left inferior parietal lobule	40	4.35	-59	-45	30	26
Left thalamus		5.17	-4	-6	6	71

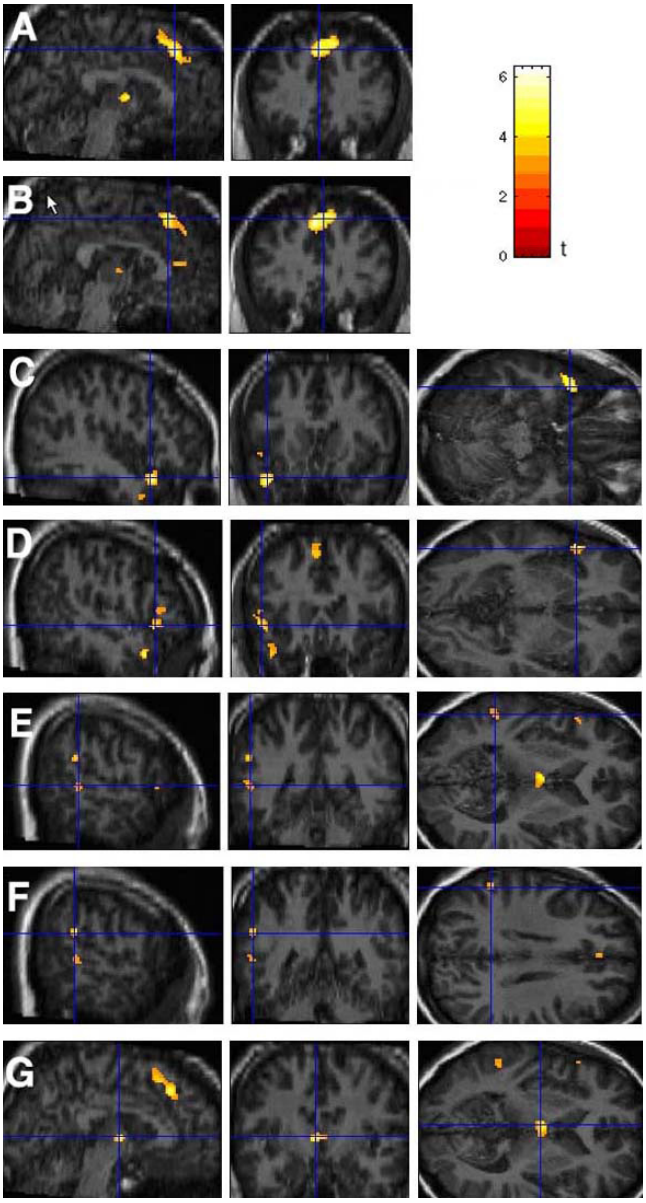

Figure 3. Brain regions activated by judgmental task for the appropriateness of facial affect as compared to gender matching task. (A) Left medial frontal cortex, (B) right medial frontal cortex, (C) left temporal pole, (D) left inferior frontal cortex, (E) left superior temporal sulcus, (F) left inferior parietal lobule, (G) left thalamus.

IV. Discussion

Our experimental task is a special type of social evaluative judgment in which internal reference is related to the representation of an emotional state (that is, ToM) of self or others. Therefore, it may be named the ToM-referential social evaluative judgment for facial affects. As predicted, the results show that, compared to gender matching tasks, judgmental tasks for the appropriateness of facial affect elicited activation of network of brain areas that have been associated with ToM, including medial frontal cortex, inferior frontal cortex, temporal pole, and superior temporal sulcus. This result suggests that the brain system involved in ToM plays a key role in judging the appropriateness of facial affect in an emotionally laden situation.[2-5,8,9,11,18,43] In addition, in contrast to many previous studies in which non-emotional stimuli were used to tap ToM, in this study we used emotionally salient visual materials. In spite of these differences, most of the activated regions overlapped with those observed in previous studies. Therefore, our result supports that common neural substrates are involved in performing diverse kinds of ToM tasks, regardless of the perceptual modalities of test materials.

In addition, our experimental task is a kind of judgmental task for the violation of social norms. The term “inappropriate facial affect” implies that the facial affective response violates the social norm. Several studies investigating the neural mechanism of judgment for the violation of social norm elicited the activation of the medial frontal cortex,[10,44-47] the temporal pole,[45-47] and the inferior frontal cortex.[10,47] Theories on the activation of these areas during judgment of the violation of social norms have been based on the consideration that most, though not all, this kind of judgment make use of processing specifically dedicated to ToM processing.[10,48] Our results also suggest that the neural network associated with ToM processing exert an essential role during the judgment about whether given facial affect violate of social norm. Our results also suggest that the neural network associated with ToM processing plays an essential role in determining whether a given facial affect violates the social norm. In all of these previous studies, subjects judged violations of social norms based on verbal sentences that were used as task materials. However, our results are in line with these studies in spite of the difference in perceptual modalities of test materials.

Medial Prefrontal Cortex

Until now, most ToM studies have been conducted by using verbal materials. In one of the first positron emission tomography (PET) studies on ToM, Fletcher et al[3] found left BA 8 to be associated with inference about a character's intention during a story comprehension task. Gallagher et al[2] also observed the activation of the left medial frontal cortex (BA 6/8) using the same story comprehension task. Calarge et al[8] conducted a PET study of ToM using a verbal task that required subjects to actively place themselves in a another person's emotional shoes and to attribute a mental state to that person, and found this activity activated both the medial frontal cortex (BA 32/10) and right anterior cingulate (BA 24/32). Some ToM studies were conducted with visual materials. Gallagher et al,[2] using a story comprehension task and a comparable non-verbal comprehension task involving a single-frame cartoon, found a convergence between activation that included BA 6 and 8/9 in response to verbal and visual stimuli that prompted mental state attribution. Brunet et al[4] also found the activation of BA 6 and 8/9 in participants who viewed comic strips that required the participant to attribute intention to the story character. Castelli et al[11] and Calder et al[6] also elicited the activation of BA 8/9 by using visual materials. Summarizing the results of the above studies, BA 8 in the medial part was one of the most consistently activated areas during ToM processing, regardless of the perceptual modalities of test materials, but it was particularly active when the studies were conducted with visual material. In this study, the most prominent activation was also observed in BA 8 in the medial part of both hemispheres. Therefore, our results agree that BA 8 is critical in ToM processing, regardless of the emotional salience of test materials. It has been thought that the activity in the medial prefrontal cortex is connected with representations of the state of self and others. In our study paradigm, only through referencing the representation of the emotional state of self and others can we determine the appropriateness of facial affect. Therefore, the role of the medial frontal cortex, especially BA 8, is essential in making these decisions.

Temporal pole

In comparison to a simple evaluation of facial affect, to judge the appropriateness of a facial affect we must first understand the contextual situation. To do this, we might draw on our knowledge of past experiences and their related emotional information. It has been suggested that the temporal pole area is concerned with generating, on the basis of past experiences, a wider semantic context for the material currently being processed.[49-53] Therefore, regardless of perceptual modalities of test materials, previous ToM studies elicited the activity in the temporal poles bilaterally, with somewhat greater effects on the left.[2-5,7-11] In addition, the temporal pole constitutes a component of the paralimbic cortex which has putative functions that include imparting affective tone to experience.[54] This area was reported to activate during the incidental retrieval of emotional contextual information in single word recognition,[55] and during the retrieval of previously studied emotional pictorial materials in comparison with the retrieval of neutral materials.[56] These results suggest the importance of the temporal pole in the retrieval of emotional and semantic script. In the point of view we use emotional materials to mobilize ToM, the role of the temporal pole may be more particular.

Inferior frontal cortex

The activation of the inferior frontal cortex including BA 47 and part of BA 45 was observed during the activation condition of our experiment.

Previous functional neuroimaging studies have demonstrated increased blood flow and activation during periods of guilt [57] or sadness.[58] These regions were also reported to activate during the internal generation of emotion guided by autobiographic script,[41] and while recalling personal memories[59] and emotional autobiographic memories,[60] as well as in response to facial expressions displaying different negative emotions,[61] particularly when specific tasks were performed in response to the expressions.[62] Such emotional and cognitive processing is essential for judging the appropriateness of facial affect.

Various kinds of ToM task as used in previous studies elicited the activity in inferior frontal cortex.[4,8,63] Farrow et al[19] compared brain activity and observed a greater activation of BA 47 when judging another's emotional states than was associated with performing simple social reasoning tasks. Our ability to judge the appropriateness of facial affect draws substantially on our ability to empathize with other people. Therefore, this finding is in line with our observation. The report[64] of impaired empathy following left frontal cortex injury are also congruent with our result.

The inferior frontal area has been activated in studies of mental imagery,[65] a cognitive process likely to be invoked by the simulation of a situation and of another's emotion response to that situation. Moreover, in the inferolateral frontal cortex, there is a group of neurons called mirror neurons[66] that have the unique property of discharging during both the execution of actions and during the observation of the same actions made by others. It has been hypothesized that the inferolateral frontal cortex and its mirror neuron circuit allow for mental state matching between self and others, and thereby this matching system is involved in the mental attribution process and simulation mechanism.[67-69] Taken together, these reports indicate that one of the most important roles of the inferior frontal cortex during judgmental tasks for the appropriateness of facial affect is attributing a mental or emotional state to self and others and matching between them.

Posterior STS and Inferior parietal lobule

The posterior STS and inferior parietal lobule are known to activate in response to biological motions such as mouth, lip, or eye movement, gaze direction, and implied biological motion.[12-16] Narumoto et al[70] found that selective attention to facial emotion enhanced the activities of these regions. Consideration of these findings has led researchers to speculate on the role of this region as a social cognitive function. Until now, it has been suggested that STS is involved in analysis of social cues, detection of the behavior of agents, analysis of the goals and outcome of this behavior, and determination of intention from visual cues.[17,29] The present study also indicates that judgment of appropriateness of facial affect activates the inferior parietal lobule. Selective attention to gaze direction or passive viewing of faces with an averted gaze elicited the activation of the inferior parietal lobule in previous studies.[15-16] Therefore, the role of STS and the inferior parietal lobule may be important in understanding a given contextual situation and in recognizing the mental or emotional state of protagonists in this situation. Whereas the knowledge and emotional memory supplied from past experience may be associated with the activity of the temporal pole, information from observation and detection of current behavior may be associated with the activity of STS and the inferior parietal lobule.

Thalamus

Though the limitations of spatial resolution and anatomical localization prevent us from precisely identifying the thalamic nucleus, peak activation was observed adjacent to the medial dorsal nucleus or anterior nucleus of thalamus. These nuclei receive input from certain regions such as the amygdala or mamillary body which are known to be critically involved in the processing of emotional information, and project to the prefrontal cortex.[71] Reiman et al[41] observed activation of the thalamus during emotional experience generated by both internal recall and external visual stimuli. Critchley et al[72] also observed activation of the thalamus during processing of facial expression. Thus, processing of emotional stimuli may induce activation of the thalamus. In addition, because our activation task is a cognitive task that uses emotional material, the thalamus may have a significant mediatory function between the prefrontal cortex and limbic region.

V. CONCLUSION

In this study, we identified the brain network that is activated during judgmental tasks for the appropriateness of facial affect in emotionally laden situations as compared to gender matching task. This network is made up of several interactive units that are known to be involved in ToM. The superior temporal sulcus and inferior parietal lobule use information based on observation to detect and analyze social cues and goals of behavior. This information from observation is relayed to the temporal pole to be integrated with knowledge of past experiences and their related emotional information to understand context. These regions are also interconnected with the medial frontal cortex and inferior frontal cortex in which representations of mental or emotional states of both self and others are created and compared. Therefore, the results of the present study suggest that the brain system involved in theory of mind (ToM) plays a key role in judging the appropriateness of facial affect in an emotionally laden situation.

In contrast to many previous ToM studies that used non-emotional stimuli, we used emotionally salient visual materials to tap ToM. Our result supports that common neural substrates are involved in performing diverse kinds of ToM tasks regardless of the perceptual modalities of test materials.

The limitation of our study is that we did not use another type of gender matching task in which test materials were not emotionally salient. If we had included this type of control task, we would have obtained more valuable information about ToM processing of emotional stimuli.

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ABSTRACT (IN KOREAN)

표정 정서의 적절성 판단 능력의 신경상관체

<지도교수 이홍식>

연세대학교 대학원 의과학과

김 지웅

일상적인 사회생활에서 "이 표정이 상황에 적절합니까?"라는 질문에 우리는 끊임없이 답해야 한다. 이를 위해서는 자신 또는 타인의 정신 상태를 이해할 수 있어야 한다. 저자는 이와 같이 마음의 이론 작업의 결과를 준거로 하는 특수한 종류의 사회적 판단의 신경 기전을 알아보기 위해 본 연구를 시행하였다. 특히, 보다 중요한 사회적 정보는 비언어적, 감정적 통로를 통해 전달되기 때문에, 마음의 이론의 신경기전에 대한 이전의 연구와는 달리 시각적이고 감정을 유발하는 자료를 이용하여 연구를 시행하였다.

총 14명 (남자 7, 여자 7)의 오른손잡이 정상인을 대상으로 하여, 표정적절성판단과제 (활성 과제) 및 성별일치여부판단과제 (대조 과제)를 수행하게 하면서 스캔닝을 실시하였다. 모든 기능적 뇌영상은 3.0 Tesla 자기공명영상 시스템을 이용하여 얻었다. 모든 기능적 뇌영상은 statistical parametric mapping (SPM 99) software를 이용하여, 재정렬 (realignment), 정규화 (normalization, 10mm Gaussian kernel size) 등의 과정을 거친 후, random effect model에 따라 one-sample ttest로 집단 분석하였고, $p<0.005$(비수정)인 voxel들이 25개 이상 뭉쳐 있는 경우에만 의미 있는 것으로 보았다.

대조 과제에 비해 표정적절성판단과제의 시행시, 양측의 내측 전두엽, 좌측 측두극, 좌측 하전두이랑, 좌측 시상, 좌측 상측두고랑 및 하두정소엽 등으로 이루어진 신경 네트워크의 활성화가 관찰되었다. 이 부위들은 마음의 이론과제 처리의 신경 기전과 관련된 것으로 알려진 부위로, 사회적 단서의 포착, 자신 또는 타인의 정신상태에 대한 표상의 창출 및 비교 등에 중요한 역할을 한다. 본 연구의 결과는 정서적 상황에서 표정의 적절성 여부를 판단하는 데에는 마음의 이론과 관련된 뇌부위가 중요한 역할을 함을 시사한다. 또한, 다양한 종류의 마음의 이론 과제 수행시, 정보가 제공되는 지각적 양식이나, 감정적 현저함의 유무와는 상관없이 공통된 신경회로가 관여함을 시사한다.

핵심되는 말: 마음의 이론, 표정, 공감, 적절성, 기능적뇌자기공명영상