시각 단어 재인동안 정서적 속성과 언어적 속성에 의해 활성화되는 대뇌 영역 : fMRI 연구

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The Cerebral Activation of the Emotional and Linguistic Attributes during Visual Word Recognition: fMRI Study

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ABTRACT

We examined the cerebral activation of the emotional and linguistic attributes during the visual word recognition. This research investigated the affective priming effect preserving the behavioral paradigm. We used the primed-evaluation task in which the participants classify the target as positive or negative, and manipulated the emtoinal attributes by emtional relations of the prime-target word pairs(PP, PN, NP, NN). ROIs analyses for the semantic processsing and emotional processing were performed. The results showed that the semantic processing areas including the IPL, SMG, and aSTS were activated differently according to the experimental condition. The activations of the IPL were increased only on the NN condition, whereas the activation of the SMG was decreased only on the PP condition. Furthmore, the activation of the emotional processing areas including the mPFC and ACC, was different according to the emotional realtions of word pairs. Similar to the SMG, the BOLD signal of the mPFC was decreaed only on the PP condition, whereas the activation of ACC was increased only on the NN condition. These results were seemed to show the interactive cerebral activations for processing the emtoional and linguistic attributes in a word, during visual word recognition.

I. Introduction

Neuroimaging studies to investigate the visual word recognition have demonstrated that many specified cerebral area are activated by different properties of words. Theses studies have focused on the linguistic attributes of the words, such as orthography, pholony, syntax, and semantics. For example, Pugh et al.(1996b) used the semantic relatedness matching task with visually presented word pairs. In the phonological task, participants judged whether two visual pseudo words are rhymed. Pugh et al.(1996b) observed no differential activation in the inferior frontal gyrus, whereas the greater activation by the semantic task was observed in a medial temporal region.

Recently, it has been emphasized that the emotional attributes of words have important roles on the visual word recognition. These results came from the affective priming studies. For example, Fazio, Sanbonmatsu, Powel, Kardes (1986) presented their participants positively and negatively valenced adjecjtvies (e.g., repulsive, appealing). Participants were instructed to classify these target words as positive or negative as quickly as possible. And, they showed that the decision latency for the target words was faster when the prime-target pairs were emotionally congruent rather than incogruent.

Similar affective priming effects have also been founded in a number of other tasks, such as the lexical decision task, the naming task , and the ratings of liking.

But, all researches about the affective priming effects have not been obtained the consistent results. For example, Klauer, Roβ nagel, and Musch (1995) observed no affective priming effects using adjective-adjective pairs. Kaluer and Munch(2001) also failed to obtain the affective priming effect. They examined the affective priming effect with manipulating the stimulus set size or the SOA (Stimulus Onset Asynchrony). No affective priming effect emerged regardless of the manipulation of the stimulus set size or SOA.

In summary, the previous studies have been showed the mixed results to the affective priming effects. So, it is very controversial where the affective priming effects is occurred, or where the emotional attributes in the visual word is processed.

Within the theoretical framework based on the behavioral research, the inconsistent results of affective priming studies can be explained only at the descriptive level. At this point, neuroimaing studies can help the behavioral research shed some light on the way words are actually represented in the brain, providing more biological level for the affective priming and related issues.

The purpose of current research is to examine whether the emotional attributes are processed during visual word recognition. For this purpose, we examined the cerebral activation of the emotional and linguistic attributes during the primed-evaluation task, using fMRI technique. We manipulated the emotional attributes by the emotional relations of prime-target word pairs.

II. EXPERIMENT

2.1 METHODS

Participants: Thirteen right-handed participants (5 male, 8 female; mean age 23.3) were recruited by bulletin board on the web in Chung-Buk National University. They had the normal vision and no participants had a known history of neurological damage or psychiatric disorder. The participants were informed about the experimental procedures and potential risk. They signed a written consent form before the start of the experiment.

Stimulus: The emotional valence of words was evaluated for constructing prime-target word pairs as follows. First, 201 animal nouns, and 206 person nouns were chosen from the dictionary, 'The Present Ages Korean Learning Dictionary Categorized by Semantics (2000)'. Second, 93 students not participated in the experiment have evaluated the emotional valence of the words with the 5-point scale(1:very negative- 5:very positive), and 60 words with strong emotional valence (positive or negative) in two semantic categories were chosen. Finally, the selected words for the experiment were all 120 words. The other features of word were controlled. All words were nouns, 1 to 4 letters long, with high frequency. 10 words from each four category used for the prime and the others used for the target. Each four category was composed of these arranged 20 prime-word pairs. Four categories were consisted by the relations of prime-target words: (1) Positive Prime - Positive Target (PP), (2) Positive Prime - Negative Target (PN), (3) Negative Prime - Positive Target (NP), and (4) Negative Prime - Negative Target (NN).

Table 1. Prime-Target Pairs By the realtions of prime

		Prime words	
		Positive	**Negative**
Target words	**Positive**	Tiger-Puppy 호랑이-강아지	Snake-Bride 뱀-신부
	Negative	Deer-Earthworm 사슴-지렁이	Serpent-Ugly man 독사-추남

Procedures: Stimuli was presented using the stimulation software, StreamDX, and projected via LCD projector (with maximum refresh rate 60Hz, display 640×480,maximum view angle 30° FOV) onto a screen in magnet room. Participants viewed the screen via a reflection mirror attached on the head RF coil.

The fixation point (+) was presented for 500ms in the middle ofthe monitor. In sequence, a primee word for 200ms, the blank screen for 100ms, a target word for 1000ms was presented. The inter trials interval was 4200ms.

Participants were asked to determine the valence of the target word as possible as quickly. They were asked to determine to click left mouse button for positive and right mouse button for negative. The response time for the primeed-evaluation task was recorded at the computer outside the magnet room.

Experimental session was composed of

activationl block with four categories .and control bolck with Positive-Neutral conditon. Each block had 10 trials and lasted 60 seconds. Block sequence in a session was randomized across participants.

Image Data Acquisition: Imaging data was acquired by using a 3.0T MRI scanner (ISOL fORTE in KAIST fMRI Lab., KOREA). T1 images for the anatomical reference were acquired using an MPRAGE (Magnetization-Prepared RApid Gradient Echo) sequence (TR=8.1ms, TE=3.7ms, FOV=240mm, FA=8°, Matrix=256× 256, thickness=5 mm and no gaps). Functional image of 20 slices were acquired by using an EPI-BOLD (Echo Planar Imaging - Blood Oxygenation Level Dependent) technique (TR=3000ms, TE=35ms, FOV=240mm, FA=80°, Matrix=64×64, thickness=5mm and no gaps).

Image Analysis: Imaging data were analyzed using SPM2 (Wellcome Department of Cognitive Neurology, London). For motion correction, the acquired image data realigned using the first scan of the session. T1 anatomical images of each participant were coregistered with the mean EPI of each participant and then normalized to the T1 template provided in SPM2. Finally, the images were smoothed by the Gaussian filter with 7.5mm FWHM (full-width at half maximum).

Statistical Analysis: Statistical analyses were done with these preprocessed image data. The SOA from the experimental setting was defined as events and convolved with the HRF (Hemodynamic Response Function). The GLM (General Linear Model) was used and significant difference for each condition were assessed using t-statistics. Contrasting pairs were as the followings: (1) PP-control, (2) PN-control, (3) NP -control, and (4) NN-control. The threshold for T=3.6, $p<0.0001$ (uncorrectd) at the single voxel level was chosen for contrasting the experimental bock versus control block. Brain activations were based on the extent of 20 voxels.

Next, a random effect model was used about contrast images of single participants for the group analysis. The group analysis was conducted by one sample t-test about 4 simple contrasts, respectively. Activation areas in group anlaysis have a statistical threshold of $p<0.001$($T>4.02$) and minimal 20 voxels were adjusted for search volume.

Five anamtomically constrained 20mm spherical regions of interest (ROI) were examined along the four experimental conditions. ROIs that have been implicated in previous studies of semantic processing of words, and emotional processing of words. The ROIs were as follows: the left medial prefrontal cortex (mPFC, BA9;-2 48 24), the right anterior cingulated cortex (ACC; 6 40 8), left inferior parietal lobe (IPL,BA40; -52 -46 42), left anterior superior temporal lobe (aSTS, BA38;-46 12 -28), and the right supramarginal gyrus (SMG; 54 -50 32).

The variation of signal of each ROI and each subject was calculated. The calculated variation within each ROI were analyzed using repeated-measure ANOVA (ANalysis Of VAriance) to compare activations between experimental conditions. Experimental conditions were treated as fixed, within-subejct effects and subjects were treated as a random effect.

The brain regions in this paper were transformed from the MNI coordinates to the Talairach-Tournoux coordinates (Talairach & Tournoux, 1988).

2.2 RESULTS

Behavioral Data: Behavioral measures of primeed-evaluavtion task are given in Table 2. The decision accuracy didn't vary across conditions. But, the decision latency were different significantly in the two contrast pairs. PN vs. PP($p<0.05$), and PN vs. NP($p<0.05$) were significantly different, and the other conditions were not. The decision latency of PN condition was more slower than PP condition or NP condition.

Table 2. The decision accuracy and latency during primeed-evaluation task.

	PP	PN	NP	NN
accuracy (%)	92.5%	80%	89%	90%
latency (msec)	909	1087	890	964

And, the simple comparison the emotionally positive word pairs with the emotionally negative word pairs were not significant.

Imaging Data: During the primed-evaluation

Table 3. The cerebral activation regions along the 4 experimental conditions

Regions	BA	x,y,z	Cluster	T-score	Regions	BA	x,y,z	Cluster	T-score
PP condition > control									
R. IFG	BA 47	36,16,-4	22	4.52	L. IFG	BA 47	-46,22,-14	45	5.72
R. MFG		32,10,54	110	6.56	L. MFG	BA 40	-36,16,54	157	7.97
R. Postcentral Gyrus	BA 2	52,-24,30	646	8.89	L. IPL	BA 39	-50,-44,46	244	6.96
R. SMG	BA 40	54,-52,32	31	5.79	L. STG		-50,-58,28	73	5.76
R. STG		40,4,-16	30	4.78					
PN condition > control									
R. MFG		6,38,34	881	9.6	L. MFG		-42,40,24	264	6.2
R. MFG	BA 6	30,8,58	27	5.22	L. SFG	BA 8	-38,16,50	42	5.52
R. IPL	BA 40	52,-36,44	207	7.15	L. IPL		-50,-46,44	78	6.81
R. Postcentral Gyrus		56,-22,30	93	6.32	L. MTG		-46,8,-24	71	6.01
NP condition > control									
R. MFG	BA 8	32,24,42	29	5.5	L. Cingulate Gyrus	BA 32	-2,22,36	82	4.93
R. ACC		6,44,6	46	9.11	L. MFG		-42,40,24	350	7.98
R. IPL		62,-32,40	166	6.64	L. IPL		-50,-46,42	123	8.46
R. Postcentral Gyrus	BA 5	32,-44,58	62	6.46	L. ITG	BA 37	-60,-52,-10	23	5.38
					L. MTG		-44,10,-34	80	4.93
NN condition > control									
R. MFG	BA 9	4,40,32	71	4.91	L. MFG		-46,26,28	101	5.96
R. ACC		6,38,8	20	5.18	L. SFG	BA 8	-38,16,52	27	5.82
R. IPL		38,-48,54	103	5.34	L. IPL		-52,-46,42	47	6.97

Notes. Sterotaxic coordinates (mm) are drived from the human brain atlas of Talairach and Torunoux (1998). BA, Broadmann Area; PP condition, Positive-Positive word pairs condition; PN condition, Positive-Negative word pairs condition; NP condition, Negative-Positive word pairs condition; NN condition, Negative-Negative word pairs condition; R., Right hemispher; L., Left hemisphere; SFG, Superior Frontal Gyrus; IFG, Inferior Frontal Gyrus; MFG, Medial Frontal Gyrus; SPL, Superior Parietal Lobe; IPL, Inferior Parietal Lobe; SMG, Supramaginal Gyrus; STG, Superior Temporal Gyrus; MTG, Middle Temporal Gyrus; ITG, Inferior Temporal Gyrus; ACC, Anterior Cingulate Cortex.

task across every condition, the left mPFC, the left IPL, the right medial frontal gyrus, the right inferior parietal lobe were activated (see the Table 3). And, the activation in the ACC was right-handed in NP condition and NN condition.

The results of ROIs analysis are given in Figure 1. ROIs-based ANOVAs revealed that the semantic processing areas including the left IPL, the SMG, and the aSTS,were activated differently according to the experimental condition.

The activation of the left IPL was increased when the NN condition($p<0.01$), compared to the other experimental conditions, whereas the activation of the right SMG was decreased when the PP condition($p<0.01$), compared to the others.

And, the aSTS was not significanlty different across the experimental condition.

The activation of the emotional processing areas including the left mPFC and the right ACC were different across the experimental condition. The variation of BOLD signal of the right ACC on the NN condition($p<0.01$) exhibited significantly greater than the others. The left mPFC's activation were not different significantly along the experimental condition.

III. DISCUSSION

Using fMRI technique, we examined the cerebral areas related to process the emotional and linguistic attributes in a word during the visual word recognition. We hypothosized that the emotional attributes of words have different influences on the visual word recognition.

The major findings of this research showed that the emotional attributes is processed during visual word recognition and, the different types of emotional relations of prime-target word pairs have different influences on the visual word processing.

The previous studies showed that the anterior part of the superior temporal lobe (BA38) was activated for semantic representation (Bottini et al., 1994; Perani, 1996; Price et al., 1997; Pugh et al.,1996b;). Pugh et al. (1996) have noted that the phonological and semantic processing requirements of rhyming and category decision tasks activated different cortical regions.

Specially, greater activation was seen in inferior and lateral orbital frontal regions in phonological tasks compared with semantic processing tasks, whereas semantic processing demonstrated greater activation in superior and middle temporal regions.

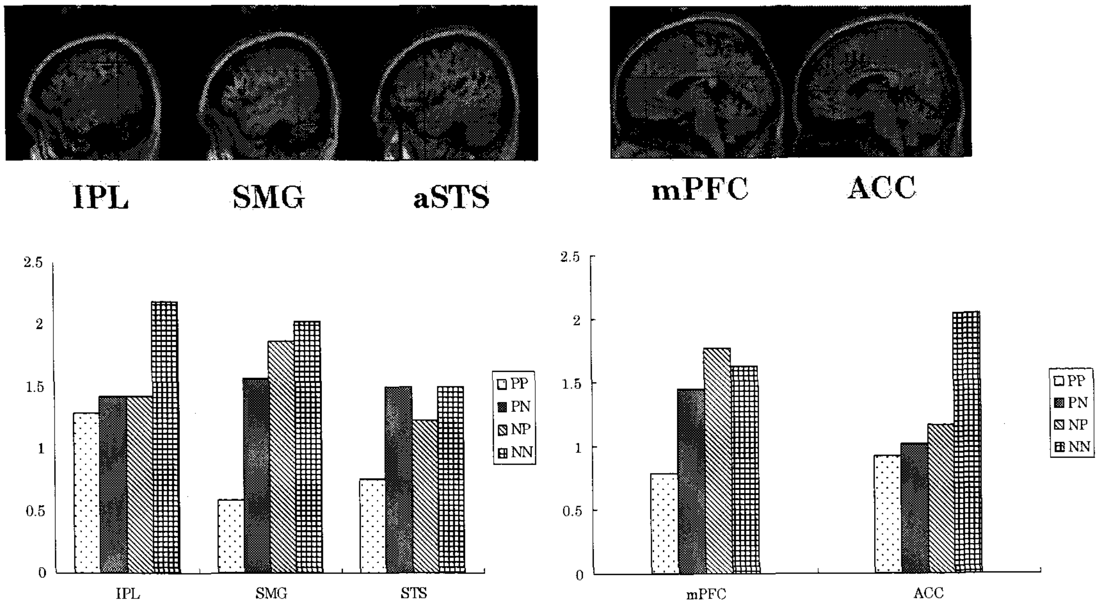

Figure 1. The ROIs and the variation of BOLD signal across the experimental condition.
Upper left, the ROIs related to the semantic processing; Upper right, the ROIs related to the emotional processing; Lower, the variation of BOLD signal in the ROIs along the experimental conditions; IPL, inferior parietal lobe; SMG, supramarginal gyrus; aSTS, anterior superior temporal sulcus; mPFC, medial prefrontal cortex; ACC, anterior cingulate cortex; PP, positive-positve word pairs condition; PN, positive-negative word pairs condition; NP, negative-positive word pairs condition; NN, negative-negative word pairs condition.

The anterior superior temporal lobe appears to be crucially involved in "speech object" access and or access to intelligible lexical entities (Scott et al., 2000). The present study found the activation of aSTS in the primed-evaluation task. The results of ROIs analysis indicate the semantic processing of words were not different across the relations of prime-target pairs. This result can be interpreted that the access to lexical entities is not affected by the relationship between prime and target in terms of the emotional attributes.

Many researches have reported that the IPL and the SMG were activated on the task related to the integrative enconding between the activated semantic representation and the phonological representation (Binder et al., 1997; Bookheimer, 1995; Bottini et al., 1994; Demonet et al., 1992; Price et al.,1997; Pugh et al., 1996). Especially, the IPL is involved in the control of selective attention (Pugh et al., 1996), and the SMG is involved in the retrieval of the phonological code in a word (Demonet et al., 1994; Paulesu et al., 1993).

Our study showed the specified activations of these areas. Greater activation was seen in the left IPL in the NN condition, compared to the other conditions, whereas the decreased activation was seen in the right SMG in the only PP condition, compared to the others. The left IPL seemed to require the greater memory load of semantic processing when the word has negative emotional information.

Althoguh the present study can not distinguish the activation of prime duration from the activation of target duration, the other word pairs except for the PP condition included the negative word in terms of emotional attributes.

Because of this experimental manipulation, the decreased activation in the right SMG in the PP condition can be interpreted that the retrieval of the phonological code on a word is affected by the negative attributes.

Likewise, the results of ROI analysis about emotional processing have showed the greater activation in the ACC only in the NN condition. Bush et al.(2000) reported that the anterior cingualte cortexis involved in cognitive functions and emotional functions. Especially, the rostral-ventral part of the anterior cingulate cortex is involved in emotional processing such as evaluating the significance of emotional and motivational information, regulating emotional response. We found the the

ACC increased activation in NN condition. This results implicated that the significance of emotional information is increased when the prime-target word pairs all have the negative emotional attributes.

Also, the mPFC appears to be crucially involved in the emotional processing. Many PET and fMRI studies have reported the involvement of the mPFC in the emotional processing. Similar to the SMG, the BOLD signal of the mPFC was decreaed only on the PP condition.

Based on these results, the inconsistent results of previous studies can be interpreted that these studies did not controlled the prime-taget pairs in terms of the emotional relations between primee and target word. Behavioral results on the current study, also, support that the effect of emotional attributes on the decision latency during the primeed-evaluation task is varied according to the relations between primee and target.

In conclusion, this research investigated the affective priming effect preserving the behavioral paradigm. The results of present study showed that that the emotional relations of word pairs has different infulences on the visual word processing.

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