한국심리학회지 : 인지 및 생물
The Korean Journal of Cognitive and Biological Psychology
2015, Vol. 27, No. 2, 231-251

Sad but beautiful; Brain responses to aesthetic judgment and emotion appraisal of visual art*

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Appreciation of art involves both cognitive and affective processes. However, the two processes and the neural underpinnings of them have not been differentiated clearly in the previous studies of neuroaesthetics. Moreover, aesthetic experience has often been confounded by positive emotional contents in artworks or positive emotion appraisal. Aesthetic appreciation and accompanying neural activity regarding artworks evoking negative emotion have not been studied extensively. In the current work using fMRI, we investigated whether brain areas involved in aesthetic judgment can be distinguished from those involved in emotion appraisal. We also explored neural correlates of artworks judged as beautiful yet inducing sad emotion. Our results identified brain regions differentially involved in aesthetic judgment and emotion appraisal, despite the widely shared network. Specifically, the medial prefrontal lobe showed greater activation for aesthetic judgment, while areas including the middle frontal gyrus, putamen, middle temporal gyrus, caudate nucleus, and precuneus showed greater activation for emotion appraisal. We also found increased neural activity in areas including the insula, anterior cingulate cortex (ACC), pre-, and post-central gyri in association with perceiving and judging "sad but beautiful" artworks. These results suggest that the two core processes in experiencing art are closely related to each other, but not identical, and that beauty and positive emotion do not always go hand in hand.

Key words : visual art, appreciation, aesthetic judgment, emotion appraisal, fMRI, neuroaesthetics

* This work was supported by the National Research Foundation of Korea Grant funded by the Korean Government (NRF-2011-327-B00981). The authors thank Ran Lee for her assistance in data analysis during revision.

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Experiencing art is multifaceted phenomenon; It involves preceptual processing of given sensory information of the artwork, hearing music or viewing a painting, for example. It also brings back our old memories or what we learned from a highschool art class. Personal preference of the given artwork -- e.g., like it or not -- is often followed though not asked. Those various components of art experience are often classified into two categories: one is the analytical approach to contents, and the other is the psychological experience such as aesthetic enjoyment (Bosanquet, 2005). The former involves cognitive processes, whereas the latter is based on an individual's internal states including subjective emotion. This was proposed in the theoretical frameworks of aesthetic experience by several groups of researchers (Chatterjee, 2003; Leder, Belke, Oeberst, & Augustin, 2004; Nadal, Munar, Capo, Rossello, & Cela-Conde, 2008). According to those frameworks, experience of art comprises cognitive and affective processes. The former includes such processes as perceptual analysis, implicit memory integration, explicit classification, and cognitive mastering (Leder et al., 2004) whereas the latter is subdivided into the representation of the reward value and the awareness of the emotional states.

However, in the literature of so-called "neuroaesthetics" investigating the neural correlates of aesthetic experience, the distinction between the two component processes has not been clear and they are rather intermingled in many studies. For example, three early neuroimaging studies on art had the participants "express their preference (Vartanian & Goel, 2004a) or rate the beauty of artwork (Cela-Conde, 2004; Kawabata & Zeki, 2004)" while their neural activity was monitored (Cela-Conde, Agnati, Huston, Mora, & Nadal, 2011). Expression of subjective preference concerns the affective aspect of art experience (Vartanian & Goel, 2004b), while judging the beauty of artwork is related more to cognitive process, though not entirely independent of affective process. Therefore, the neural correlates of the two processes could not be differentiated, which might be a reason behind the inconsistent activation foci reported in those studies as neural correlates of aesthetic experience.

Moreover, in those studies, the focus was on the neural response to positively appraised artwork contrasted with the neural response to negatively appraised artwork, not on the aesthetic experience per se. Kawabata and Zeki (2004) compared neural response to the stimuli judged as beautiful and those judged as neutral or ugly. Cela-Conde et al. (2004) also contrasted brain responses to beautiful and not beautiful stimuli. Also, Vartinian and Goel (2004a) performed a parametric analysis on the stimuli rated as 0-4 in the degree of preference to

identify brain areas that correlate positively with increasing preference. Experience of art however, can include not only positive but also negative appraisal, and 'beauty' is not the only value artists seek for (Conway & Rehding, 2013). Thus, the neural correlates subserving aesthetic judgment and affective response regarding artwork per se, irrespective of the judged degree of beauty or the evoked emotional valence, need to be identified.

Furthermore, in brain imaging studies on art, aesthetic experience has been confounded with positive emotional contents in artworks. In a brain imaging study of music, for example, musical melodies defined as "pleasant" based on consonance were contrasted with musical melodies defined as "unpleasant" based on different degrees of dissonance (Koelsch, Fritz, Müller, & Friederici, 2006). Brain areas showing greater responses to the former, compared to the latter were identified as neural correlates of emotional response to music. Aesthetic experience is often confused as experience of artworks which evoke positive emotion (Di Dio & Vittorio, 2009). In other words, most studies of "neuroaesthetics" tend to focus on positive valance while overlooking negative valence (Brown, Gao, Tisdelle, Eickhoff, & Liotti, 2011; Son, Lee, Jung, Jee, & Jung, 2013). Contrary to such tendency in the field of neuroaesthetics, people often find artworks inducing negative emotion as beautiful. For instance, the deep sorrow evoked by listening to Vitali's Chaconne in G minor or the tragic feelings expressed in Piccasso's "Poor People on the Seashore" is associated with experiencing beauty. Therefore, it is necessary to differentiate the emotional appraisal from the aesthetic judgment and investigate whether viewing artworks that are judged to be beautiful while inducing negative emotion recruits brain areas dissimilar to viewing artworks judged to be beautiful while inducing positive emotion.

In this study using functional Magnetic Resonance Imaging (fMRI), we aimed at addressing two simple and straightforward questions as follow. First, we examined whether brain areas involved in (cognitive) aesthetic judgment can be distinguished from those involved in affective appraisal. Second, we explored neural correlates of artworks judged as beautiful yet inducing negative emotion. For these purposes, we presented the same artwork twice, once with aesthetic judgment task, again with emotion appraisal task. This allowed us to control different brain responses due to difference in stimulus characters, and to exclude common processes such as visual analyses and decision-making. This also allowed us to classify the stimulus events based on the combination of the responses in aesthetic judgment (beautiful or not beautiful) and emotion appraisal (positive or

negative), with which we could monitor brain responses to artworks experienced as beautiful yet evoking sad feelings. Results from this fMRI study are described below.

Methods

Participants Fifteen healthy volunteers (11 females, age: 20-29, all right-handed) participated in the fMRI study. Participants were screened based on their interest in art. A questionnaire composed of four questions was given to the potential participants and they rated the degree of their interest in art using a 5-point scale (Belke, Leder, & Augustin, 2006). Only those who marked 2 or higher on average were selected as participants. None of the participants were specialized in art. They gave written, informed consent prior to participation (1040548-KU-IRB-11-23-A-2).

Stimuli 64 images of the 19th century impressionist paintings were selected for the fMRI study following careful stimulus selection procedures. These procedures are very important in studies using existing artworks as stimuli, which are difficult to be controlled and manipulated. Also, we wanted to have comparable number of trial events for each of the four categories concerning aesthetic judgment (beautiful vs. not beautiful) and emotion appraisal (positive vs. negative). Though the response collected inside the scanner cannot be planned out completely, we attempted to select stimuli presumably generating responses distributed over the four categories.

Seven volunteers (3 males, 4 females, ages 25-31) participated in the stimulus selection test. None of them participated in the subsequent fMRI experiment. Participants were screened based on their interest in art but none of them were specialized in art. 100 images of the 19th century impressionist paintings created by Paul Gauguin, Vincent van Gogh, Edouard Manet, and Claude Monet were used to minimize the variability of the painting styles. The images were presented on a computer monitor (Samsung, Sense Q35) with the screen resolution of 640 X 480. Participants were presented with 6 questions for each image including one question concerning aesthetic judgment, four questions concerning emotion appraisal, and one question concerning familiarity. The 5-point Likert scale was used for the aesthetic judgment (1: “not beautiful at all” to 5: “extremely beautiful”) and for the familiarity (1: “never seen this painting before” to 5: “familiar with and well aware of this painting”). In the case of emotion appraisal, four specific questions which are related to emotional valence were used (1: sad - 5: happy, 1: bad mood - 5: good mood, 1: gloomy - 5: glad and 1: dark feeling - 5:

bright feeling) indicating "negative" and "positive" respectively. These word choices were to select an optimal task question for the main fMRI experiment.

Based on the rating response, the 100 images were first classified into two groups with the criterion of the mean rating value of the aesthetic judgment and further categorized into four groups based on the rating value of the emotion appraisal. The number of images in each category (beautiful-positive: 30, not beautiful-positive: 19, beautiful-negative: 16, not beautiful-negative: 35) was adjusted to the number of images in the category with the minimum number of images (beautiful-negative). Images with extreme values were selected to maximize the difference between categories. In addition, images with relatively high scores in the familiarity were excluded to minimize potential influence from memory and learning. As a result of factorial analysis, the four questions concerning the emotion appraisal were categorized as one factor. The factor structure accounted for 81.6% of the variance. The factor score of the question of "sad-happy" was the highest (81.595%) and therefore selected as the task question in the fMRI experiment. Finally, a total of 64 images of paintings (16 images for each category) were selected for the fMRI study. To examine the validity of the stimulus classification, paired t-test was performed. The difference of aesthetic value between the two conditions (beautiful vs. not beautiful) was statistically significant ($t(6) = 11.211$, $p<.001$). The difference of emotional valence between the two conditions was also significant (positive vs. negative, $t(6) = 22.202$, $p<.001$). The four categories of images, however, did not present statistically significant differences in terms of familiarity ($F(6)=.803$, $p>.05$). Brightness ($F(3)=1.163$, $p>.05$) and saturation ($F(3) = 1.554$, $p>.05$) also showed no significant difference across the four categories.

The width of each stimulus was adjusted to 480 pixels, while the height was varied to maintain the width-height ratio of the original paintings. All 64 images were matched in resolution (150 pixels per inch).

fMRI Procedures The scanning session comprised 4 event-related runs, each of which lasted 272 seconds. The stimulus set of 64 painting images was divided into 2 groups and presented twice in separate runs; once for the aesthetic judgment and again for emotion appraisal. The order of 4 runs was randomized between participants. The order of stimuli in each block was counterbalanced. The images were displayed on a LCD monitor mounted on top of the RF head coil. The LCD subtended 12 x 16 degree of visual angle and was set at the screen resolution of 640 x 480. The

Integrated Functional Imaging System-Stand Alone (IFIS-SA, Invivo Corporation, Orlando, Florida) and E-prime 1.1 (Psychology Software Tools, Inc., Pittsburgh, PA) was used for the stimulus presentation and response recording. Each image was presented for 2 seconds and the rating question was presented for 3 seconds. Two types of questions which were related to aesthetic judgment and emotion appraisal were presented in separate runs. Participants pressed one of four buttons to rate each image. A fixation cross in varied duration between 2 and 5 secs was followed (See Figure 1).

fMRI data acquisition and analysis

Scanning was performed using a Siemens Magnetom Espree 1.5 Tesla MRI System with Head Marix A Tim Coil (TR: 2000ms, TE: 35ms, FOV: 240mm, slide thickness: 5mm, flip angle: 90°, echo spacing: 0.67 ms, FOV: 240mm, matrix size: 64 X 64) at Eunpyeong Hospital. Head and arm movement of participants was restricted by using foam cushions. Participants were provided with earplugs to attenuate scanner noise. Statistical analysis was performed with SPM5 (Wellcome Department of Imaging Neuroscience, London, UK) with standard procedures.

For preprocessing, the EPI images were realigned spatially. This was followed by temporal realignment, which corrected for slice-time differences using the first slice as reference slice. Images were normalized in respect to the Montreal Neurological Institute (MNI) template provided in SPM5 and smoothed spatially with an 8mm FWHM isotropic

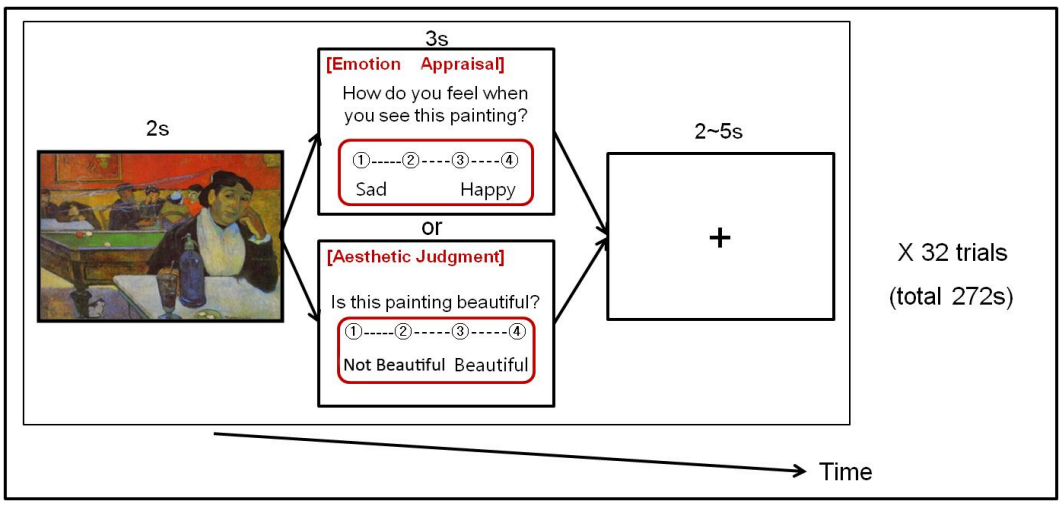

Figure 1. Run Structure. Aesthetic judgment and emotion appraisal tasks were given in separate runs.

Gaussian kernel. For the analysis, three event conditions, i.e., 1) observation prior to the response, 2) aesthetic judgment, and 3) emotion appraisal, were identified. In the aesthetic judgment condition, images rated as 1 or 2 were classified as "not beautiful" whereas images with rating scores of 3 or 4 were classified as "beautiful", which generated $\text{aesthetic}_{\text{not beautiful}}$ and $\text{aesthetic}_{\text{beautiful.}}$ Likewise, in the emotion appraisal condition, images rated as 1 or 2 were classified as "sad" whereas images with rating scores of 3 or 4 were classified as "happy", which generated $\text{emotion}_{\text{sad}}$ and $\text{emotion}_{\text{happy.}}$ It should be noted that events in the observation condition were labeled based on the post-observation responses in "aesthetic judgment" and "emotion appraisal" tasks, resulting in four types of the events - "beautiful-happy", "beautiful-sad", "not beautiful-happy", and "not beautiful-sad". Statistical inference was based on a random effects model. The resulting statistical parametric maps were thresholded at a voxelwise uncorrected $p < .001$ and a spatial extent of five contiguous voxels (Zarhan, Aguirre, & D'Esposito, 1997). Whole-brain family-wise (FWE) corrected $p < .05$ was also applied where possible for multiple comparisons. Conjunction analyses (Price & Friston, 1997) were used to characterize brain activations common to aesthetic judgment and emotion appraisal. There were three major analyses. We first performed conjunction and contrast analyses of aesthetic judgment and emotion appraisal to identify the brain regions commonly and differentially involved in these two processes of art appreciation. Second, we performed a conjunction analysis between $\text{aesthetic}_{\text{beautiful}}$ and $\text{emotion}_{\text{sad}}$ response and between $\text{aesthetic}_{\text{beautiful}}$ and $\text{emotion}_{\text{sad>happy}}$ to find a network of brain regions commonly involved in judging an artwork as "sad but beautiful". The final analysis concerned whether the BOLD signal during observation of an artwork is modulated by difference in future judgments. Specifically, a paired t test was carried out to determine whether there were significant differences in BOLD signals during observing art stimuli soon to be judged as "beautiful-sad" and as "beautiful-happy".

Results

Behavioral Results Table 1 shows the frequency of the behavioral data collected during the scanning experiment and classified for the four response categories: paintings judged to be not beautiful-sad, not beautiful-happy. beautiful-sad, and beautiful-happy. 4.27% of the total of 960 stimulus events (64 stimuli x 15 participants, presented once for aesthetic judgment and again for emotion appraisal) was excluded for further analyses due to failure in response

Table 1. Frequency of behavioral responses classified by combination of aesthetic judgment and emotion appraisal.

		Emotion Appraisal		Total
		sad	happy	
Aesthetic Judgment	not beautiful	296	99	395
	beautiful	259	265	524
Total		555	364	919

recording. The number of stimulus event in the four categories were significantly different (X^2 = 61.2695, p<.01). However, the critical pair of comparison for our purposes, - i.e., paintings judged to be beautiful-sad (N=259) and paintings judged to be beautiful-happy (N=265) - were comparable in frequency.

Brain areas differentially or commonly involved in aesthetic judgment and emotion appraisal of artworks First, we found extensively shared neural mechanisms between aesthetic judgment and emotion appraisal; a conjunction analysis revealed that areas including bilateral postcentral gyri and cerebellum, left middle temporal gyrus, left cuneus, right lingual gyrus, right thalamus, right precuneus, right middle frontal gyrus, and right superior temporal gyrus are involved in both aesthetic judgment and emotion appraisal (p<.001, *uncorrected,* shown in orange in Figure 2). Among those areas, bilateral postcentral gyri and the left cuneus survived for the more conservative statistical cut-off (p<.05, FWE *corrected*) indicating their particularly strong involvement. Activation in those areas might reflect common processes associated with aesthetic judgment and emotion appraisal, which include visual perception and decision making. We also examined a network of brain regions showing differential responses to the two processes in experiencing art. The areas showing greater responses to emotion appraisal compared to aesthetic judgment included left middle frontal gyrus, left putamen, left precuneus, and right caudate nucleus. In contrast, only right medial prefrontal lobe showed greater activation for aesthetic judgment compared to emotion appraisal (p<.001, *uncorrected)*. These areas commonly and differentially involved in aesthetic judgment and emotion appraisal are listed in Table 2.

Brain areas involved in judging an artwork 'beautiful' and appraising induced feeling as 'sad' Next we moved

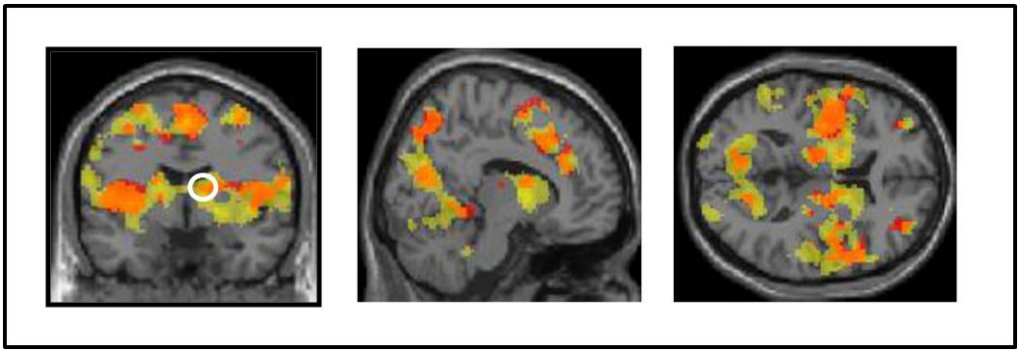

Figure 2. Brain Areas involved in aesthetic judgment and emotion appraisal of paintings. Areas showing grater activation for aesthetic judgment are depicted in red and areas showing greater activation for emotion appraisal are depicted in yellow. The commonly activated regions are shown in orange. Thalamus (x=12, y=-2, z=10, Z=1.02), one of those common activation sites, is marked in white circle.

Table 2. Brain areas differentially or commonly involved in aesthetic judgment and emotion appraisal of artworks.

Condition	Brain areas	Cluster size	Hemi -sphere	MNI coordinates x	y	z	Z	BA
Aesthetic judgment > Emotion appraisal	medial frontal gyrus	6	R	4	10	68	3.51	6
Aesthetic judgment < Emotion appraisal	middle frontal gyrus	112	L	-56	24	28	3.97	9
	putamen	44	L	-28	12	0	3.88	
	middle temporal gyrus	36	L	-46	-62	16	3.59	39
	inferior frontal gyrus	7	R	60	28	12	3.43	45
	caudate nucleus	35	R	10	16	6	3.42	
	precuneus	5	L	-8	-50	46	3.24	31
Aesthetic judgment U Emotion appraisal	postcentral gyrus	8144	L	-64	-18	26	1.02	1
		45	R	50	-22	48	1.02	1
	middle temporal gyrus	43	L	-54	-46	6	1.02	22
	cerebellum	95	L	-46	-70	-24	1.02	
		83	R	8	-50	-6	1.02	
	cuneus	660	L	-18	-78	8	1.02	17
	lingual gyrus	83	R	12	-56	0	1.02	19
	thalamus	1511	R	12	-2	10	1.02	
	precuneus	1207	R	10	-80	44	1.02	7
	globus pallidus	94	R	26	-12	-4	1.02	
	middle frontal gyrus	205	R	26	42	28	1.02	9
	superior temporal gyrus	166	R	52	-30	2	1.02	22

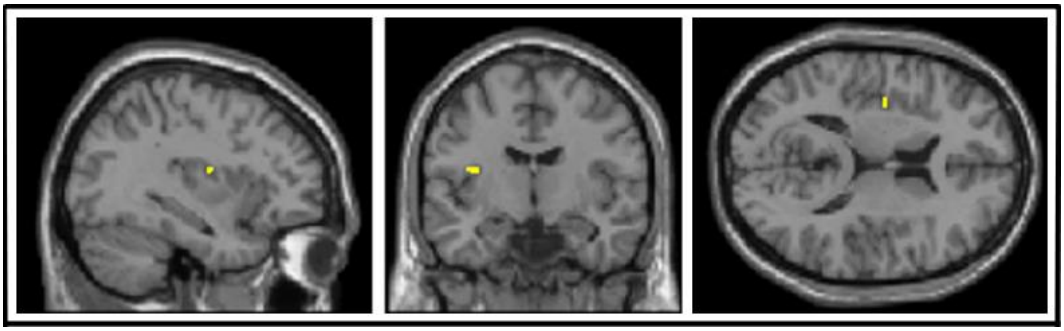

Figure 3. (a) Insula (x=-40, y=-8, z=16, Z=1.02, p<.001, *uncorrected*) identified by the conjunction analysis of $\text{aesthetic}_{\text{beautiful}}$ and $\text{emotion}_{\text{sad}>\text{happy}}$. *left*: sagittal, *middle*: coronal, *right*: axial view.

on to our second question regarding neural correlates of artworks judged as beautiful yet inducing negative emotion. We first examined neural activity during aesthetic judgment and emotion appraisal by performing a conjunction analysis between BOLD response to $\text{aesthetic}_{\text{beautiful}}$ and $\text{emotion}_{\text{sad}}$. This analysis was expected to show brain regions commonly

Table 3. Brain areas commonly involved in judging an artwork 'beautiful' and appraising induced feeling as 'sad' (p<.001, *uncorrected*).

Brain areas	Cluster size	Sphere	MNI coordinates			Z	BA
			x	y	z		
precentral gyrus	478	L	-58	6	32	1.02	6
postcentral gyrus	1272	L	-56	-20	48	1.02	1
middle occipital gyrus	6611	L	-48	-84	12	1.02	19
insula	288	L	-38	-8	14	1.02	13
inferior parietal lobule (IPL)	318	L	-34	-58	46	1.02	40
cuneus	45	L	-12	-72	8	1.02	30
cingulate gyrus	30	L	-12	18	34	1.02	32
medial frontal gyrus	725	L	-10	-12	56	1.02	6
cerebellum	25	R	6	-60	-16	1.02	
precuneus	156	R	10	-74	20	1.02	18
putamen	158	R	18	6	8	1.02	
middle frontal gyrus	162	R	48	16	34	1.02	9

involved in judging an artwork beautiful and appraising it inducing sad emotion. Results showed areas in the left hemisphere including pre- and post-central gyrus, middle occipital gyrus, insula, inferior parietal lobule, cuneus, cingulate gyrus, and medial frontal gyrus. In the right hemisphere, cerebellum, precuneus, putamen, and the middle frontal gyrus were identified by the conjunction analysis (Table 3).

To be more selective about those areas commonly involved in the two processes of aesthetic appreciation, we then conducted an additional conjunction analysis between $\text{aesthetic}_{\text{beautiful}}$ and $\text{emotion}_{\text{sad>happy}}$. Among a number of areas identified in the previous conjunction analysis, only the insula remained (Figure 3). These results suggest that the identified part of the insula is involved in both aesthetic judgment and emotion appraisal and it is more sensitive to negative than to positive responses in both kinds of processes of aesthetic appreciation.

Brain areas showing greater response to artworks judged to be "beautiful-sad" than those judged to be "beautiful-happy" In our last analyses, we contrasted BOLD responses during the 2-secs of stimulus presentation based on the subsequent rating response. Observation of paintings which would be judged to be beautiful-sad elicited greater BOLD response in the areas including

Table 4. Brain areas showing greater response to observation of paintings judged to be beautiful-sad compared to observation of paintings to be beautiful-happy (p<.001, *uncorrected*).

Brain areas	Cluster size	Sphere	MNI coordinates			Z	BA
			x	y	z		
middle temporal gyrus	91	L	-40	-70	6	4.41	39
anterior cingulate	30	L	-8	40	-10	4.01	32
posterior cingulate cortex	33	R	26	-68	6	3.96	30
parahippocampal gyrus	8	R	16	-38	-12	3.91	30
precentral gyrus	32	L	-54	-4	22	3.71	6
postcentral gyrus	32	L	-60	-6	14	3.38	43
	37	R	62	-12	26	3.50	4
superior temporal gyrus	32	R	56	2	0	3.71	22
inferior frontal gyrus	7	L	-56	8	26	3.44	9
cerebellum	18	L	-18	-54	-30	3.43	
	11	R	24	-54	-18	3.37	

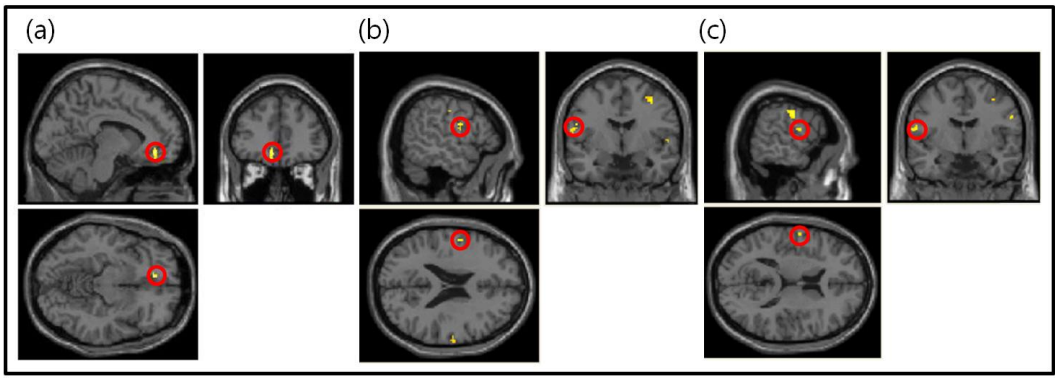

Figure 4. Brain areas showing greater activity when participants observed paintings later to be judged as "beautiful-sad" than those to be "beautiful-happy". Areas include (a) anterior cingulate cortex (x=-8, y=40, z=-10, *Z*=4.01, *p*<.001, *uncorrected*) (b) precentral gyrus(x=-54, y=-4, z=22, *Z*=3.71, *p*<.001, *uncorrected*) (c) postcentral gyrus (x=-60, y=-6, z=14, *Z*=3.38, *p*<.001, *uncorrected*).

left anterior portions of the cingulate cortex and right parahippocampal gyrus than did observation of paintings judged to be beautiful-happy. Similar pattern of activation was also found in the left precentral gyrus, bilateral postcentral gyri, left middle temporal gyrus, right posterior cingulate cortex, right superior temporal gyrus, left inferior frontal gyrus, and bilateral cerebellum (Table 4 and Figure 4). In contrast to those distributed activation sites, the opposite contrast - i.e., beautiful-sad < beautiful-happy - did not leave any statistically significant activation.

Discussion

Results from our investigation into the brain areas involved in aesthetic judgment and emotion appraisal revealed both shared and distinct neural mechanisms subserving the two core processes of art experience. As a *shared* mechanism, brain areas distributed over the entire cortical surface and beneath were identified. Some of these areas - e.g., cuneus - are related to visual perceptual process, while others - e.g., prefrontal lobe - are responsible for decision making those of which are commonly relevant to both aesthetic judgment and emotion appraisal. Most of those identified areas have been implicated in the studies of neural responses to art; pre- and post-central gyri in the left hemisphere were found to show greater response to stimuli judged as ugly and as beautiful (Di Dio et al., 2007; Kawabata & Zeki, 2004). The involvement of these motor-sensory cortices in aesthetic appreciation is suggestive to "embodiment" of

aesthetic experience (Freedberg & Gallese, 2007). In addition, areas including cerebellum, superior temporal gyrus, and precuneus have been implicated in a wide range of studies on neural responses to music with emotional valence (Blood et al., 1999; Mitterschiffthaler et al., 2007).

We also identified brain regions *differentially* involved in aesthetic judgment and emotion appraisal, despite the widely shared network. Specifically, the medial frontal gyrus showed greater activation in response to aesthetic judgment. It is interesting that the medial frontal gyrus was the only region that showed greater response to aesthetic judgment than to emotion appraisal, given that a number of regions shared by the two processes. Previous studies have shown this area's involvement in general preference judgment, implying its role in "the representation of complex appetitive states" (Paulus & Frank, 2003). More directly relevant to our work, however, are the findings of Jacobsen and colleagues (2006) and Ishizu & Zeki (2013), both of which found the medial prefrontal lobe associated with aesthetic judgment. Importantly, these two studies and the current study have a critical feature in the experimental design in common. All three studies included an additional judgment task for the stimuli, neural responses to which were contrasted with those to aesthetic judgment. In Jacobsen et al., for example, complex visual patterns were presented to the observer and brain activity during observers' aesthetic judgment and symmetry judgment were compared. Ishizu & Zeki presented paintings to the participants in the fMRI scanner and compared neural response to aesthetic judgment and neural response to brightness judgment. The inclusion of the second judgment task in these previous studies is methodologically comparable to the inclusion of emotion appraisal in the current study, although emotion appraisal was not just a control task, but the task of equal interest in the current study. The contrast between neural responses to the aesthetic judgment and neural responses to the second judgment excluded most processes associated with judgments in general, leaving only those specific to the "aesthetic" contents. In all three studies, the medial prefrontal lobe showed increased activation specific to aesthetic judgment, verifying its special role in aesthetic experience.

While the medial prefrontal lobe was the only area specifically involved in aesthetic judgment, a wide range of areas including the left middle frontal gyrus, putamen, middle temporal gyrus, precuneus, and the right caudate nucleus showed greater activation for emotion appraisal than for aesthetic judgment. Most of these areas have been repeatedly associated with general affective processes; The middle frontal gyrus, putamen, and the middle temporal gyrus were shown to

be involved in perceiving emotional pictures and regulating one's own emotion (Kim & Hamann, 2007). Caudate nucleus has been associated with the processing of primary rewarding stimuli by animals (Rolls, 2000; Schultz, Tremblay, & Hollerman, 2000) as well as abstract rewards in humans (Delgado, Nystrom, Fissell, Noll, & Fiez, 2000; Knutson, Westdorp, Kaiser, & Hommer, 2000). In the literature on neuroaesthetics, Vartanian and Goel (2004) showed that neural responses to paintings in putamen and right caudate nucleus decreased as preference decreases. These results suggest that the specific involvement of the caudate nucleus in emotion appraisal might reflect the subcortical processing of the representation of reward value (Nadal et al., 2008).

Taken together, our results regarding the common and the distinct neural mechanisms for aesthetic judgment and emotion appraisal of artworks imply that aesthetic appreciation involves a complex of sub-processes subserved by distributed network of brain areas. These results also imply that aesthetic judgment and emotion appraisal are associated with brain areas specifically related to each of the two processes, despite the extensive overlap. In this vein, the inconsistencies found in previous studies on the neural responses to experiencing art might be reconcilable. Each of these studies might have examined a specific aspect of complex art experience by employing particular stimuli, tasks, and experimental designs. It remains for future studies to delineate each aspect of art experience by exploiting optimized experimental paradigms. The current work is one of initial attempts for that.

Turning now to the brain mechanisms underlying *judgment* of the beauty of an artwork evoking negative emotion, our conjunction analysis of $\text{aesthetic}_{\text{beautiful}}$ and $\text{emotion}_{\text{sad}}$ identified areas such as the insula, the cingulate gyrus, and the medial prefrontal lobe. The insula and the cingulate gyrus are known to be associated with perception and regulation of emotion in valence-specific ways (Kim & Hamann, 2007; Mak, Hu, Zhang, Xiao, & Lee, 2009). Insula, in particular, has been implicated in both positive (Teasdale et al., 1999), and negative feelings (Bornhövd et al., 2002; Harrison et al., 2008; Sawamoto et al., 2000; Stein, Simmons, Feinstein, & Paulus, 2007; Wicker et al., 2003; Wright, He, Shapira, Goodman, & Liu, 2004; Yaxley, Rolls, & Sienkiewicz, 1990). In studies of which topics are more specifically relevant to ours, activity in bilateral insula was associated with subjective experience of the mood of paintings (Cupchik, Vartanian, Crawley, & Mikulis, 2009), and aesthetic judgment (Di Dio, Macaluso, & Rizzolatti, 2007; Lee, Jung, Son, & Jo, 2011). This region remained active in our study using

more selective conjunction analysis between $aesthetic_{beautiful}$ and $emotion_{sad>happy}$. Therefore, it seems that the insula plays a key role in judgment of an artwork as "sad but beautiful".

In our last analysis, we also explored the brain mechanisms underlying *observation* of an artwork later judged to be beautiful and yet evoking negative emotion. The left ACC and right parahippocampal gyrus showed greater activation for paintings judged to be beautiful-sad than for paintings judged to be beautiful-happy. Both ACC and parahippocampal gyrus were found to be related to negative emotional contents defined by the degree of dissonance in music (Blood et al., 1999). The involvement of the medial temporal lobe, however, might raise a question whether memory played a role in the area's differential response to paintings judged to be beautiful-sad and paintings judged to be beautiful-happy. The region situated anterior to the parahippocampal gyrus, in particular, has been implicated in familiarity-based memory (Diana, Yonelinas, & Ranganath, 2007). Therefore, one might question whether the differential activity in the left parahippocampal gyrus stems from the different degree of familiarity participants had with the paintings judged to be beautiful-sad and paintings judged to be beautiful-happy. This, however, is not so plausible because 1) the stimuli used in the current study were selected based on low familiarity rating score in general, and 2) the selection procedure nullified the familiarity difference between stimulus categories. Still, the potential modulatory influence of familiarity on aesthetic appreciation itself is an important topic in future studies.

Observation of beautiful-sad paintings elicited increased activation in the PCC, which is one of the major nodes in the so-called default mode network (DMN) subserving "self-referential mentation" (Schulman et al., 1997; Mazoyer et al., 2001; Raichle et al., 2001). This area has been highlighted in a couple of recent neuroaesthetics studies, since aesthetic appreciation requires self-reflection and monitoring (Jacobs, Renken, & Cornelissen, 2012; Vessel, Starr, and Rubin, 2013). Along with the PCC, the medial prefrontal cortex is also considered as an important part of the DMN. In our study, the medial prefrontal cortex is found to be specifically related to aesthetic judgment (Table 2) and also related to judgment of an artwork as beautiful yet sad (Table 3) Therefore, both viewing a beautiful but sad painting and judging it as it is seem to direct viewers' attention to their own inner states.

One might question the disproportionate assignment of male (N=4) and female (N=11) participants in the current study, in consideration of a gender-specific difference in neural correlates of aesthetic judgment and emotion appraisal of

art. This concern is not far-fetched, since it has been shown that males and females differ in aesthetic behaviors including interest, sensitivity, and choice of art (Bernard, 1972). Of particular relevance to the concern, a study using magnetoencephalography (MEG) showed gender-specific difference in brain activity during aesthetic judgment (Cela-Conde et al., 2009). Specifically, the study showed that the parietal activity involved in participant's judging an artwork beautiful is bilateral in female brains whereas it is lateralized in the right hemisphere in male brains. In our study, we screened participants based on their interest in art prior to the fMRI data collection. Thu,s the participants' degree of interest in art was controlled. To examine other sources of variation based on gender difference, we performed additional analyses on the fMRI data collected from the 11 female participants by excluding the data from the 4 males participants. Overall, the pattern of the results were consistent with the current results based on all 15 participants except minor differences probably due to the reduced statistical power. Therefore, we could infer that the inclusion of a small number of males was not the main cause for the current findings. These ancillary analyses, of course, could not reveal much about the potential gender difference in neural correlates of aesthetic judgment and emotion appraisal of art, which should be studied by testing males and females of a comparable sample size.

In conclusion, the present study identified both shared and differential neural networks involved in aesthetic judgment and emotion appraisal. The results suggest that those two core processes in experiencing art are closely related to each other, but not identical. This study also found brain areas involved in experiencing "sad but beautiful" paintings, which implies beauty and positive emotion do not always go hand in hand.

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1 차원고접수 : 2015. 03. 20
수정원고접수 : 2015. 04. 24
최종게재결정 : 2015. 04. 27

한국심리학회지 : 인지 및 생물
The Korean Journal of Cognitive and Biological Psychology
2015, Vol. 27, No. 2, 231-251

슬프지만 아름다운; 시각 예술의 미적 판단과 정서 평가에 대한 뇌 반응

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예술 감상은 인지적 과정과 정서적 과정을 포함한다. 그러나 지금까지의 신경미학 선행 연구에서 이 두 가지 과정과 그 신경 기반이 명확히 구별되지 않았다. 더욱이, 미적 경험은 종종 예술 작품이 지닌 긍정적 정서와 연관되는 콘텐츠, 혹은 예술 작품에 대한 긍정적 정서 평가와 혼재되어 왔다. 부정적 정서를 유발하는 예술 작품에 대한 미적 감상과 이에 수반되는 신경 활동에 대한 연구는 매우 드물다. 본 연구는 기능적자기공명영상을 활용하여 미적 판단에 관여하는 뇌 영역들이 정서 평가에 관여하는 영역들과 구별되는지 검토하고자 하였다. 또한 아름답지만 부정적 정서를 유발하는 예술작품의 감상에 관여하는 신경 기전에 대해서 탐구하고자 하였다. 연구 결과, 미적 판단과 정서 평가가 광범위한 신경네트워크를 공유함에도 불구하고, 전자가 내측 전두회, 후자가 중전두회, 피각, 중측두회, 미상핵 및 설전부를 포함하는 영역들과 차별적으로 연관됨을 확인하였다. 또한 “슬프지만 아름다운” 미술작품을 보거나 판단할 때, 뇌섬엽, 전측대상피질 및 전후중심회에서 뇌 활동이 증가됨을 발견하였다. 본 연구의 결과는 예술 감상을 구성하는 두 가지 핵심 과정들이 밀접한 상호연관성을 지니나 동일하지 않다는 것과, 아름다움의 경험이 항상 긍정적 정서를 동반하지 않는다는 것을 제안한다.

주제어 : 시각 예술, 감상, 미적 판단, 정서 평가, 기능적자기공명영상, 신경미학