Trends in Neuroscience and Education 10 (2018) 8–18

Contents lists available at ScienceDirect

Trends in Neuroscience and Education

journal homepage: www.elsevier.com/locate/tine

The modulation of personal traits in neural responses during the aesthetic experience of mundane art

Yu-chu Yeh[a,b,*], Wei-Chin Hsu[c], Pei-Hsin Li[d]

[a] Institute of Teacher Education, National Chengchi University, No. 64, Zhinan Road, Section 2, Taipei 116, Taiwan
[b] Research Center for Research Center for Mind, Brain & Learning, National Chengchi University, No. 64, Zhinan Road, Section 2, Taipei 116, Taiwan
[c] Graduate Institute of Applied Science and Technology, National Taiwan University of Science and Technology, No.43, Section 4, Keelung Rd., Da'an Dist., Taipei 106, Taiwan
[d] Department of Education, National Chengchi University, No. 64, Zhinan Road, Section 2, Taipei 116, Taiwan

ARTICLE INFO

Keywords:
Aesthetic judgment
Aesthetic emotion
Aesthetic experience
Expertise
Design

ABSTRACT

To date, individual differences in the neuroaesthetics of mundane art are seldom studied. This study addresses group differences with regard to the neural mechanisms of aesthetic emotions and aesthetic judgments toward everyday designed products according to levels of everyday aesthetic experience and expertise in design. A fMRI experiment that included 26 college students was employed. The findings of this study suggest that rich everyday aesthetic experience elicits more brain activations in aesthetic judgments, and expertise in design elicits more brain activations in aesthetic emotions. Comparatively, rich everyday experience and expertise modulate the integration of external sensation and internal states, top-down attention, reward processing, and emotion regulation when viewing beautiful stimuli, whereas poor everyday experience and expertise modulate conscious assessment of self-relevant meaning as well as retrieval of negative memory and emotions when viewing ugly stimuli. These findings provide insights for enhancing aesthetic ability through daily life experience and instruction.

1. Introduction

Neuroaesthetics is a newly developed domain that focuses on understanding how the brain functions when engaged in aesthetics; it encompasses the perception, production, and response to art as well as interactions with stimuli that evoke an intense feeling [8]. Over the past decade, due to the development of neuroimaging techniques and collaborations across domains, the breadth of neuroaesthetics has been growing rapidly. Studies in various domains, such as painting, architecture, dance, and music, have been conducted to confirm the neural bases of aesthetic experience (AE) [6,7,10,13,41,43,46]. AE consists of two important outcomes, namely, aesthetic judgment and aesthetic emotion [31,34]. One of the major topics that researchers in neuroesthetics are interested in is how certain factors modulate neural activity during AE. A number of studies have shed light on this issue. For example, Reber, Schwarz, and Winkielman [40] suggested that AE, which is built upon biological and embodied mechanisms, is modulated by context, the individual's interest in the artwork, prior knowledge, and familiarity. Recently, Nadal and Skov [34] claimed that personal orientation toward an object is strongly influenced by experiences and beliefs. Therefore, the everyday experiences and expertise that contribute to the building of knowledge and tastes in aesthetics should be important modulating factors of AE. AE involves the production of aesthetic judgments and aesthetic emotions [8]. To date, although the study of neuroaesthetics is advancing, few neuroaesthetic studies have focused on products designed for everyday life. Design has become an essential component of our everyday life, and the ability of design is critical for professional success in the 21st century [38]. Because aesthetics is essential to product design, enhancing aesthetic experience of college students through everyday aesthetic practices should be a fundamental approach. This study focuses on two everyday aesthetic practices: everyday aesthetic experience that involves the aesthetic experience with regard to all types of designed products in daily life, and design expertise that involves the working experience in product design. Specifically, this study attempts to explore how everyday aesthetic experience and expertise in design modulate the neural mechanisms that influence AE outcomes (aesthetic judgment and aesthetic emotion) during the appreciation of designed products in a fMRI experimental design.

* Corresponding author at: Institute of Teacher Education, National Chengchi University, No. 64, Zhinan Road, Section 2, Taipei 116, Taiwan.
E-mail addresses: ycyeh@nccu.edu.tw (Y.-c. Yeh), weichinhsu@gmail.com (W.-C. Hsu), deanna0421@gmail.com (P.-H. Li).

https://doi.org/10.1016/j.tine.2017.12.002
Received 12 May 2017; Received in revised form 23 November 2017; Accepted 22 December 2017
Available online 29 December 2017
2211-9493/

1.1. Neural bases for AE

AE consists of two important interactive outcomes: aesthetic judgment and aesthetic emotion [31,34]. Such a two-component theory of AE has been supported by many behavioral and neuroimaging studies. For example, in a behavioral study that utilized designed products, Yeh [51] found that the perceived beauty of designed products was positively related to the aesthetic emotions of “happy/pleasant” and “relaxed/peaceful” but negatively related to those of “disgusting/hateful” and “terrible/fearful.” Such a finding not only illustrates the interactive relationship between aesthetic emotions and aesthetic judgements but also the close relationship between degrees of beauty and types of emotions. Along the same line, recent findings of neuroimaging studies have revealed that aesthetic judgment and aesthetic emotion share neural substrates [34], such as the anterior cingulate cortex (ACC), precuneus, and orbito-frontal cortex (OFC) [18,34,53]. Accordingly, AE comes to full fruition by inducing emotions in the individual and prompting an evaluative judgment [6].

Although recent studies of neuroaesthetics have been favorably received, they have mostly focused on aesthetic judgment, in that participants are usually asked to judge whether a visual stimulus is beautiful, neutral, or ugly [44,53]. Kawabata and Zeki [28] investigated nine correlates of the perception of beauty (beautiful, neutral or ugly) during the observation of different categories of paintings (landscapes, portraits, etc.); they found brain activations for judged-beautiful stimuli versus both neutral and ugly stimuli in the medial orbitofrontal cortex (mOFC). Bohrn, Altmann, Lubrich, Menninghaus, and Jacobs [5] found activations of the caudate and anterior cingulate (BA 32) when comparing “beautiful” to “not beautiful” judgements. In addition, using 300 pleasant, neutral, and unpleasant photographs from the International Affective Picture System as stimuli, Skov [44] asked participants to rate the pictures as beautiful, neutral, or ugly; he found that the beautiful-ugly contrast evoked brain areas involved in perceptual processing (i.e., the superior occipital gyrus and fusiform gyrus), reward processing (i.e., the orbitofrontal cortex and cingulate cortex), and executive processing (i.e., several prefrontal regions). Similarly, Pöppel et al. [39]. reported that aesthetic judgments activated the frontal network related to social cognition, namely the orbitomedial prefrontal cortex.

Three types of aesthetic emotions have been commonly compared in fMRI studies: negative, neutral, and positive emotions [19]. Whether there are specific aesthetic emotions has been a matter of debate. Some researchers have suggested that aesthetic emotions are similar to the fundamental emotions that occur when we react emotionally to a painting, sculpture, music, or a religious experience. Past studies have found that the amygdala, superior frontal gyrus, insula, bilateral postcentral gyri, temporoparietal, and prefrontal areas play important roles in the response to emotional stimuli and have suggested that different types of emotional stimuli may share or involve different neural mechanisms [19,25,27]. Moreover, Kreplin and Fairclough [30] reported that activation of medial BA 10 (rostral prefrontal cortex) was enhanced during the viewing of visual art that induced positive emotions. On the other hand, it is suggested that beauty itself is a kind of emotion, but unlike most emotions that lack concrete behavioral goals, such emotion reflects the mind's more abstract, overarching epistemic goals, and yield to understanding of an object [2]. Based on past findings, we suggest that aesthetic emotions and emotions in general share some neural substrates, but at the same time, aesthetic emotions involve unique neural substrates that are responsible for understanding, judging, and valuing an object.

1.2. The modulation of everyday experience and expertise during AE

As the key neurobiological mechanisms underlying the appreciation of aesthetics become clearer, one issue concerning neuroaesthetics stands out: What types of factors modulate the activity of the neural networks that underlie AE, and how is this modulation achieved [34]? According to the aesthetic triad theory [9], AE involves interactions between the sensory-motor, emotion–valuation, and meaning–knowledge neural systems. To date, the meaning–knowledge system to AE is less understood because its manifestations involve many brain functions and it is greatly influenced by personal traits and cultural factors [9]. It has been suggested that an aesthetic attitude leads us to process objects differently than when we approach them with a more casual, everyday attitude [31]. Therefore, everyday aesthetic experience should have influence on AE. Moreover, study findings showed that expertise influences aesthetic judgment [14]. Accordingly, individuals with different level of everyday experience and expertise may use different neural processes during AE.

AE is highly personally relevant and it involves the integration of external (sensory/somatic) sensations and internal (evaluative/emotional) states as an individual experiences an emotional connection to the stimuli [48]. In a study of emotional responses to art, Chatterjee found that the anterior medial temporal lobe [8], medial and orbitofrontal cortices, and subcortical structures mediate emotions in general and reward systems in particular. It is also revealed that emotional responses, especially negative ones, activated the precuneus which is related to both memory and attention [4]. Moreover, it has been found that ratings of subjective emotion were significantly correlated with activation of the ACC [20].

On the other hand, Kirk, Skov, Christensen, and Nygaard [29] found that expertise modulates brain areas (e.g. medial OFC and bilateral subcallosal cingulate gyrus) to both aesthetic processing and cognitive processing irrespective of aesthetic ratings; they suggested that experts integrate current input with prior knowledge to organize aesthetic judgments. In addition, Cupchik, Vartanian, Crawley, and Mikulis [14] demonstrated that when people viewed paintings and focused on their AE, anterior prefrontal regions, which are related to cognitive control, were strongly activated, whereas when people viewed paintings and focused on the depicted content, occipital regions, which are related to perceptual processing, were strongly activated.

Accordingly, everyday experience and expertise may modulate aesthetic emotions and judgments through the attention, cognitive control, memory, perceptual processing, and reward systems as well as through the creation of meaning. However, although both everyday experience and expertise contribute to the construction of the meaning-knowledge system, they may influence AE through the modulation of different neural circuits. While everyday experience may enhance the appreciation and preference of designed products, expertise may lead to more critical viewpoints toward beautifulness and greater sensitivity in emotions.

1.3. The present study

Although the findings described above have identified specific brains regions that are related to AE (including aesthetic judgments and emotions), most of the stimuli that were employed involved abstract art, rather than the mundane art (e.g. cup, chair, doorbell, etc.) that is closely related to our everyday life. Moreover, individual differences in the neural bases of the AE in designed products have been rarely studied, especially those focused on the AE of appreciating designed products with different levels of beauty (ugly, medium, and beauty). Two personal traits are included in this study to reveal such individual differences, namely, everyday aesthetic experience and expertise in design. In this study, everyday aesthetic experience refers to that involves aesthetic perceptions and analyses, aesthetic judgments and emotions, and everyday experience associations with regard to designed products [51]. Expertise in design refers to actual experience in design. Based on aforementioned literature review, this study seeks to explore how everyday aesthetic experience and expertise in design modulate the neural mechanisms that influence AE during the appreciation of designed products.

With a manner of exploratory study, we hypothesize that everyday

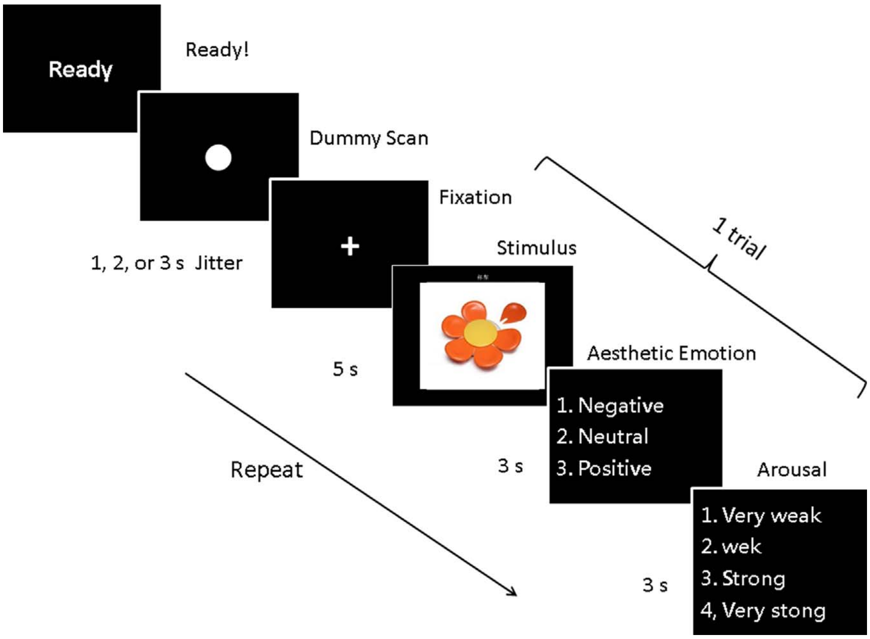

Fig. 1. Experimental design of the scan procedure.

aesthetic experience and expertise in design modulate the AE of appreciating designed products with different levels of beauty through shared as well as distinct neural circuits. More specifically, individuals with a higher level of everyday aesthetic experience and expertise in design may involve stronger neural activities relating to attention, cognitive control, memory, perceptual processing, and reward systems than those with a lower level of everyday aesthetic experience and expertise during the AE, especially when appreciating beautiful designed products.

2. Methods

2.1. Participants

Twenty-six college students (13 males and 13 females) were included in this study. The participants, aged 20–29 (23.27 ± 2.77 years), were pre-screened for a history of previous neurological or neuropsychological disorders. All participants were right-handed and had normal or corrected-to-normal vision. With a great variety of majors, none of the participants were art or design majors. The study was approved by a Research Ethics Committee in a university and written informed consent was obtained from all participants. Each participant received approximately $20 for participating.

2.2. Stimuli

Ninety pictures of everyday designed products were originally selected from 412 pictures in the database of "Aesthetic Pictures of Everyday Designed Products, APEDP" [52] The selected pictures included 30 pictures in each of the categories: beautiful, medium, and ugly, which have been validated by a previous study [52].

2.3. Instrumentation

The Inventory of Everyday Aesthetic Experience in Designed Products (IEAEDP) and the Inventory of Design Experience (IDE) were employed to test the participants' everyday aesthetic experience and expertise pertaining to product design [51]. Both inventories utilized 4-point Likert scales, with response options ranging from "never" to "always." With a total of 26 items, the IEAEDP included three factors: aesthetic perceptions and analyses (12 items), aesthetic judgments and emotions (11 items), and everyday experience associations (3 items). Examples for the three factors include "I can analyze the design styles of the product"; "I feel delighted when I see products with good design"; and "Familiar products can provoke memories of happiness in me." Exploratory factor analysis indicates that 49.10% of the total variance could be explained, with factor loadings that ranged from .400 to .846. The Cronbach's α coefficients were .946, .917, .893, and .749 for the IEAEDP and for the three factors listed above, respectively. The correlation coefficients for the three factors were .436∼.558, $p < .001$. Moreover, confirmatory factor analysis indicated that the IEAEDP had good construct validity; $\chi 2(N = 407) = 613.604$ ($p < .05$); goodness-of-fit (GFI) = .890, adjusted goodness-of-fit (AGFI) = .868, root-mean-square error of approximation (RMSEA) = .031, and standardized root-mean-square residual (SRMR) = .053; normed fit index (NFI) = .893, comparative fit index (CFI) = .939, incremental fit index (IFI) = .939, and relative fit index (RFI) = .878 [51].

The Inventory of Design Experience (IDE) included one factor with 7 items. Examples for the IDE include "I have worked for product design" and "I have participated in competitions related to creativity or design." Exploratory factor analysis indicated that 49.35% of the total variance could be explained, with factor loadings that ranged from .613 to .805. The Cronbach's α coefficient was .822 [51].

2.4. Design and procedures

The fMRI experiment employed an event-related paradigm. After the participants filled out the consent form and provided the required personal information, a brief introduction and a practice session followed. The participants that required vision correction used either MRI-compatible contact lenses or MRI-compatible plastic goggles; they reported no difficulty viewing stimuli or hearing instructions during the fMRI scan. The experiment consisted of two runs, and each run included 45 trials. In each trial, the participants were first presented with "ready" and a dummy scan waiting for fMRI trigger. Then, a stimulus was presented for 5 s, with randomly jittered inter-trial intervals of 1, 2, or 3 s of fixation. Finally, the participants were requested to rate their aesthetic emotion (1 = negative, 2 = neutral, or 3 = positive) (see Fig. 1) within 3 s. During the rating, the fingers used for the button-press responses (1: index finger; 2: middle finger; 3: ring finger) were counterbalanced across subjects and runs, and 30 pictures for the each of the categories of aesthetic judgment (ugly, medium, and beautiful)

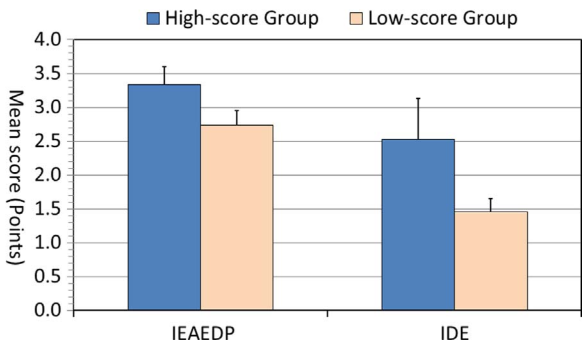

Fig. 2. Means and standard deviation of different groups in IEAEDP and IDE.

were also randomly distributed in each run. The participants took a 2-min break between the two runs in the scanner to avoid exhaustion. Each run took approximately 7 min and 36 s; it took approximately 17 min and 12 s to complete the experiment.

Comparatively, the timing of measuring aesthetic emotional state may be more important than aesthetic judgment. Moreover, we did not try to scan the participants' brains while they were rating emotional state or making aesthetic judgement. Instead, we focused on understanding how participants' brains may function differently when they were watching different types of stimuli (e.g. beautiful, medium, and ugly) perceived by themselves. Therefore, to avoid exhaustion from too many ratings in fMRI scans, post-scan of aesthetic judgment and emotion ratings of arousal were conducted immediately after the fMRI scan. However, the participants were informed at beginning that they would rate the beautifulness and emotional arousal of each stimuli at the end. The ratings of aesthetic judgment were: 1 = ugly, 2 = medium, 3 = beautiful. The ratings of emotional arousal were: 1 = very weak; 2 = weak; 3 = strong; 4 = very strong. Moreover, the IEAEDP and the IDE was administered followed the post-scan ratings.

2.5. Data acquisition and image analyses

fMRI data were acquired on a 3 T Siemens with a 32-channel head coil, and the visual stimuli were displayed via a Hitachi CP-SX635 projector. Functional images were obtained with a T2*-weighted gradient echo planner imaging sequence (voxel size, $4 \times 4 \times 3\ mm^3$). Each volume contained 34 3-mm-thick transverse slices that were oriented parallel to the anterior and posterior commissure (AC-PC) line and covered the whole brain (TR = 2000 ms, TE = 24 ms, flip angle = 90°, FOV = 256 mm, 64 × 64 matrix, and in-plane resolution = $4.0 \times 4.0\ mm^2$). Moreover, high-resolution T1-weighted structural images were acquired using a 3D MPRAGE pulse sequence: TR = 1560 ms, TE = 3.30 ms, flip angle = 15.0°, 256 × 256 voxel matrix, FOV = 256 mm, 192 contiguous axial slices, thickness = 1.0 mm, and in-plane resolution = $1.0 \times 1.0\ mm^2$. In this study, the first two TRs in each functional run were discarded to avoid T1 equilibrium effects. Each functional run acquired 228 volumes.

Data analysis was performed using SPM8. At the single-participant level, a general linear model was applied to the fMRI time series, where stimulus onset was convolved with SPM8's canonical hemodynamic response function. Slice timing correction and realignment of DICOM images were performed first. Then, co-registered images were normalized to the standard Montreal Neurological Institute EPI template. Furthermore, to remove low-frequency artifacts, statistical analyses were performed on spatially smoothed data using an 8-mm full-width-at-half-maximum (FWHM) Gaussian kernel with a high-pass filter (128-s cutoff period). Contrasts of interest obtained from the first-level parameter estimates were then used in the group-level analyses, in which a voxel threshold of $p < .05$ for family wise error rate (FWE corrected) and a cluster threshold of $p < .05$ (FWE corrected) were employed. To investigate the group differences of everyday aesthetic experience (high to low and low to high) and expertise in design (high to low and low to high) with regard to brain activation during AE (aesthetic judgment and aesthetic emotions), two-sample *t*-tests and a significance level of $p < .005$ (FWE corrected) were employed. For multiple comparisons, all brain areas reported as activated were at the voxel level with a cluster size greater than or equal to 10 voxels.

3. Results

3.1. Behavioral data

The correlation between the scores of IEAEDP and IDE were .491 (p = .011), suggesting everyday aesthetic experience and expertise in design, although positive related, are not highly related. In both followed behavioral and fMRI data analyses, we separately used the medium score of the IEAEDP and IDE as the cut-off point and divided the participants into the low versus the high score group. See Fig. 2 for the means and standard deviations of different groups in IEAEDP and IDE. As for the grouping of IEAEDP, the cut-off point was 3.00. Both the high-score group and the low-score group comprised 13 participants. In addition, there was a significant difference in experience of taking aesthetic related courses (50.0% in the high-score group vs. 7.1% in the low-score group), $\chi^2 = 6.032$, $p = .014$. For the grouping of IDE, the cut-off point was 1.86. The high-score group comprised 12 participants and the low-score group was consisted of 14 participants. The unevenly grouping was due to the same scores of two participants in the cut-off point. There was no significant difference in experience of taking aesthetic related courses (30.8% in the high-score group vs. 7.7% in the low-score group), $\chi^2 = 2.229$, $p = .135$.

Based on the participants' subjective rating, the averaged trials of aesthetic judgment for the low everyday-experience group were: beautiful = 48.08, medium = 18.92, and ugly = 23.00; the averaged trials of aesthetic judgment for the high everyday-experience group were: beautiful = 44.69, medium = 18.77, and ugly = 26.54; the averaged trials of aesthetic judgment for the low design-expertise group were: beautiful = 48.43, medium = 17.86, and ugly = 23.71; and the averaged trials of aesthetic judgment for the high design-expertise group were: beautiful = 44.83, medium = 18.08, and ugly = 27.08. On the other hand, the averaged trials of aesthetic emotion for the low everyday-experience group were: positive = 35.62, neutral = 27.42, and negative = 25.31; the averaged trials of aesthetic emotion for the high everyday-experience group were: positive = 36.69, neutral = 26.15, and negative = 25.30; the averaged trials of aesthetic emotion for the high everyday-experience group were: positive = 36.69, neutral = 26.15, and negative = 25.30; the averaged trials of aesthetic emotion for the low design-expertise group were: positive = 35.64, neutral = 26.36, and negative = 26.57; and the averaged trials of aesthetic emotion for the high everyday-experience group were: positive = 36.69, neutral = 26.15, and negative = 25.30. These averaged trials were employed in the contrasts of conditions in the subsequent GLM analyses.

To further understand the relationship between aesthetic judgments and emotions, we first multiplied each score of aesthetic emotion (1 = negative, 2 = neutral, or 3 = positive) by the score of emotional arousal (1 = very weak; 2 = weak; 3 = strong; 4 = very strong) to calculate the weighted aesthetic emotion of each stimulus; then, we analyzed the correlations between aesthetic judgments, original emotions, and the weighted aesthetic emotions. With a total of 1170 ratings for the 90 pictures, the correlation coefficients within groups showed that aesthetic judgments and aesthetic emotions were highly correlated. However, the correlations between aesthetic judgments and original emotions tend to be stronger than those between aesthetic judgments and weighted emotions in high everyday-experience and high design-expertise group. Specifically, the correlation coefficients were (1) .72 l vs. .716 ($ps < .001$) in low everyday-experience group; (2) .693 vs. .603 ($ps < .001$) in high everyday-experience group; (3) .727 vs. .721 ($ps < .001$) in low design-expertise group; and (4) .683 vs. .587

($ps < .001$) in high design-expertise group.

Interestingly, the correlations between the rating of "beautiful" and "negative emotion" did not differ in low everyday-experience group and in high everyday-experience group, $r(12) = -.382$ and $-.349$, $ps > .05$, respectively. However, the correlation between the rating of "beautiful" and "negative emotion" in low design-expertise group was stronger than that in high design-expertise group, $r(12) = -.567$ ($p = .034$) and $r(12) = -.338$ ($p = .283$), respectively. Moreover, the correlations between the rating of "ugly" and "negative emotion" did not differ in low everyday-experience group and in high everyday-experience group, $r(12) = -.578$ ($p = .038$) and $r(12) = -.597$ ($p = .031$), respectively. However, the correlations between the rating of "ugly" and "negative emotion" in low design-expertise group was stronger than that in high design-expertise group, $r(12) = -.739$ ($p = .003$) and $r(12) = -.618$ ($p = .032$), respectively.

3.2. Influences of everyday aesthetic experience on AE during the fMRI scan

To understand how the levels of everyday aesthetic experience modulate the neural responses to AE during the fMRI scans, we analyzed the following six contrasts with regard to aesthetic judgments for conditions of high-to-low everyday experience and low-to-high everyday experience based on participants' subjective rating: beautiful to medium, ugly to medium, beautiful to ugly, beautiful, medium, and ugly. We also analyzed the following six contrasts with regard to aesthetic emotions for conditions of high-to-low everyday experience and low-to-high everyday experience by two-sample *t*-tests: positive emotion to negative emotion, negative emotion to neutral emotion, positive emotion to neutral emotion, positive emotion, negative emotion, and neutral emotion (see Table 1 for significant contrasts).

With regard to the high to low contrasts in aesthetic judgments, three out of the six contrasts were significant. The significant contrasts and activated brain regions were as follows: (1) beautiful to medium: left anterior cingulate (BA 32), $p = .005$; (2) ugly to medium: right AC (BA 32), $p = .018$; and (3) beautiful to ugly: left precentral gyrus (BA 6), $p = .037$ (see Table 1 and Fig. 3).

With regard to the low to high contrasts in aesthetic judgments, three out of the six contrasts were significant. The significant contrasts and activated brain regions were as follows: (1) medium stimuli: left cingulate gyrus (BA 32), $p = .019$; and (2) ugly: right precentral gyrus (BA 4), $p = .010$, and (3) left medial frontal gyrus (BA 6), $p = .047$ (see Table 1 and Fig. 3).

We also compared brain activations for the three types of aesthetic emotions: positive, neutral, and negative. The only region that showed significant brain activation for positive emotions for the contrast between the low everyday experience group and the high everyday experience group was the right postcentral gyrus (BA 2), $p = .013$ (see Table 1 and Fig. 4).

3.3. Influences of expertise in design on AE during the fMRI scan

To understand how the levels of expertise in design modulate the neural responses to AE during the fMRI scans, we analyzed the same contrasts as those used to evaluate the interactions between everyday experience and AE.

With regard to high to low contrasts in aesthetic judgments, only the beautiful to medium beautiful contrast was significant; the activated brain region was the left lentiform nucleus ($p = .004$). With regard to the low to high contrasts in aesthetic judgments, two contrasts among the six were significant. The significant contrasts and activated brain regions were as follows: (1) ugly to medium: left insula (BA 13), $p = .007$; (2) ugly: right inferior frontal gyrus (BA 45), $p = .001$ (see Table 2 and Fig. 5).

With regard to the high to low contrasts in aesthetic emotions, three contrasts were significant. The significant contrasts and activated brain regions were as follows: (1) positive to neutral: right inferior frontal gyrus (BA 10), $p = .004$; (2) negative to neutral: left medial frontal gyrus (BA 6), $p = .013$; and (3) positive to negative: inferior parietal lobule (BA 40), $p = .022$ (see Table 2 and Fig. 6).

With regard to the low to high contrasts in aesthetic emotions, two contrasts were significant. The significant contrasts and activated brain regions were as follows: (1) neutral: right cingulate gyrus (BA 31), $p = .012$; and (2) negative: right inferior frontal gyrus (BA 45), $p = .016$ (see Table 2 and Fig. 6).

4. Discussion

4.1. The relationship between aesthetic emotions and aesthetic judgements

The main goal of this study was to explore whether everyday aesthetic experience and expertise in design modulate the activity of the neural networks underlying the AE (aesthetic judgments and aesthetic emotions) of designed products and how this modulation is achieved. The results from the behavioral data of this study suggest that aesthetic emotions and aesthetic judgements are positively related. Such findings are in line with arguments that cognition is usually characterized by a feeling [42] as well as with arguments that aesthetic judgments and aesthetic emotions are interactive [2,16,53]. Recent fMRI research [52] has also revealed that aesthetic emotions and aesthetic judgements share some neural substrates. Accordingly, aesthetic emotions and aesthetic judgements are interactive during the appreciation of designed products.

Moreover, recent studies have found that emotional arousal plays a critical role in aesthetic responses [3,36] and have suggested that

Table 1
Activated regions for contrasts between everyday aesthetic experience and AE.

Condition	Regions	Side	BA	Voxels	Z Max	MNI Coordinate			p
						X	Y	Z	
Aesthetic judgments (High EAE to low EAE)									
B-M	Anterior cingulate	L	32	314	3.94	−16	30	26	.005
U-M	Anterior cingulate	R	32	462	3.52	4	42	20	.018
B-U	Precentral gyrus	L	6	222	3.27	−34	−6	28	.037
Aesthetic judgments (Low EAE to high EAE)									
M	Cingulate gyrus	L	32	424	3.49	−6	12	46	.019
U	Precentral gyrus	R	4	301	3.73	38	−18	38	.010
U	Medial frontal gyrus	L	6	437	3.18	−6	−12	64	.047
Aesthetic emotions (Low EAE to high EAE)									
P	Postcentral gyrus	R	2	243	3.55	66	−22	30	.013

Note. MNI = Montreal Neurological Institute; B = beautiful; U = ugly; M = medium; P = positive emotion; L = left; R = right; BA = Brodmann's area; Voxels = number of voxels in the cluster; only clusters with an extent threshold of $p < .05$, corrected for the whole brain and a size of 10 voxels or greater are presented; threshold of $p < .05$, FWE (familywise error rate) corrected.

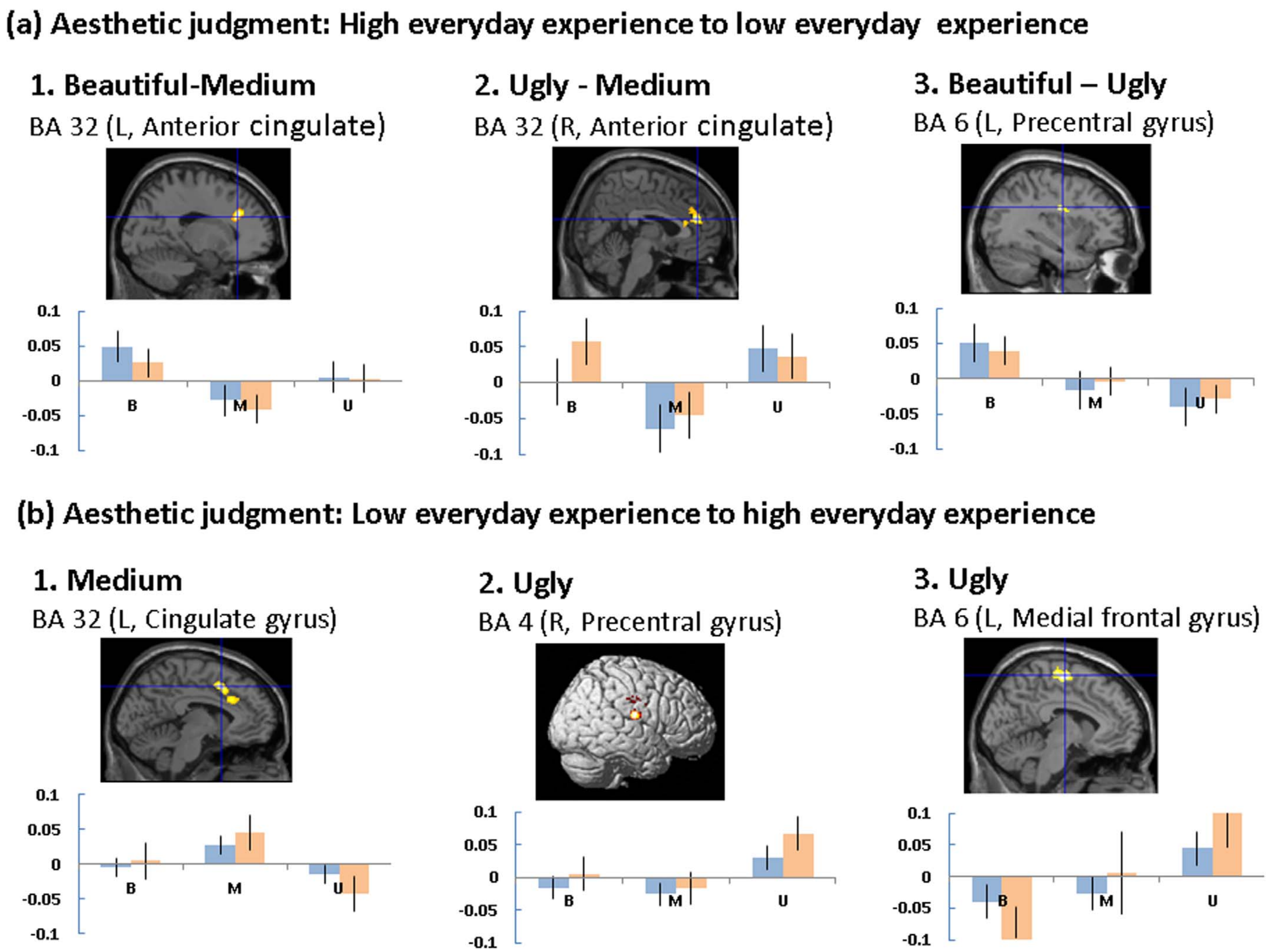

Fig. 3. Brain Regions Showing Activation for Contrasts of Aesthetic Judgments × Levels of EAE. Significant activations at a $p < .05$ FWE-corrected level. Bar-charts show beta values for regions of interests (ROIs). Blue bar represents High everyday experience; orange bar represents low everyday experience. All comparisons were significant. The MNI coordinates for distinct regions can be found in Table 1. L = left; R = right.

Fig. 4. Brain regions Showing Activation for Contrasts of Aesthetic Emotions × Levels of EAE. Significant activations at a $p < .05$ FWE-corrected level. Bar-charts show beta values for regions of interests (ROIs). Blue bar represents High everyday experience; orange bar represents low everyday experience. All comparisons were significant. The MNI coordinates for distinct regions can be found in Table 1. L = left; R = right.

identifying the factors that influence emotional arousal is critical and challenging for neuroaesthetics [34]. We therefore included emotional arousal in the behavioral measures to support the findings of the fMRI analyses. Analyses of correlations between aesthetic judgments, original emotions, and weighted emotions suggest that participants with richer everyday aesthetic experience and expertise in design, especially those with richer expertise in design, tend to be more critical to beautifulness as well as tend have a higher level of threshold in emotional arousal as compared to their counterparts.

4.2. How everyday aesthetic experience modulates the neural responses to AE

The fMRI data of this study suggest that the neural responses to AE differ between participants with varied everyday aesthetic experience and expertise for designed products. However, there were both shared and unique neural mechanisms between the groups with different levels of everyday aesthetic experience and expertise in design. Specifically, in both the high and the low everyday aesthetic experience groups, the left (anterior) cingulate (BA 32) was activated when the participants made aesthetic judgments. The result is in line with past findings [9,11,14] and suggest that the left cingulate cortex (BA 32) is, in general, related

Table 2
Activated regions for contrasts between expertise in design and AE.

Condition	Regions	Side	BA	Voxels	Z Max	MNI Coordinate			P
						X	Y	Z	
Aesthetic judgments (High expertise to low expertise)									
B-U	Lentiform nucleus	L		220	3.96	−26	2	20	.004
Aesthetic judgment (Low expertise to high expertise)									
U-M	Insula	L	13	424	3.80	−28	26	18	.007
U	Inferior frontal gyrus	R	45	248	3.98	58	24	16	.001
Aesthetic emotions (High expertise to low expertise)									
P-N	Inferior frontal gyrus	R	10	375	3.97	46	42	0	.004
Neg-N	Medial frontal gyrus	L	6	500	3.65	−2	−20	66	.013
P-Neg	Inferior parietal lobule	L	40	255	3.40	−40	−60	42	.022
Aesthetic Emotions (Low expertise to high expertise)									
N	Cingulate gyrus	R	31	297	3.69	14	−14	46	.012
Neg	Inferior frontal gyrus	R	45	266	3.59	56	26	16	.016

Note. MNI = Montreal Neurological Institute; B = beautiful; U = ugly; M = medium; P = positive emotion; N = neutral emotion; Neg = negative emotion; L = left; R = right; BA = Brodmann's area; Voxels = number of voxels in the cluster; only clusters with an extent threshold of $p < .05$, corrected for the whole brain and a size of 10 voxels or greater are presented; threshold of $p < .05$, FWE (familywise error rate) corrected.

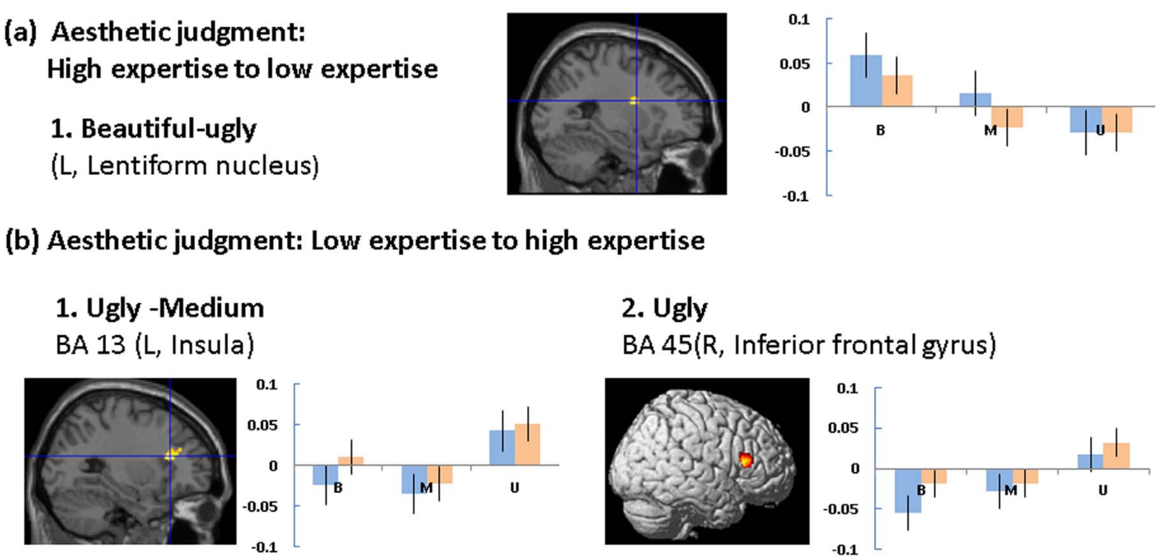

Fig. 5. Brain Regions Showing Activation for Contrasts of Aesthetic Judgments × Levels of expertise in design. Significant activations at a $p < .05$ FWE-corrected level. Bar-charts show beta values for regions of interests (ROIs). Blue bar represents High expertise; orange bar represents low expertise. All comparisons were significant. The MNI coordinates for distinct regions can be found in Table 2. L = left; R = right.

to aesthetic judgments regardless of individual differences. The results of this study also suggest that the aesthetic process of those with a high level of everyday aesthetic experience involves implicit activity in the motor system of the left precentral gyrus (BA 6) when viewing beautiful designed products. The results here are in line with Zhang's [54] finding that beautiful judgments of pictographs elicit strong activation of motor-related areas, which is implicated in the generation of embodied approach and motivation for beauty. AE involves visuo-spatial coding and motor mapping, and motor system is fundamental to visuomotor transformations [16]. Moreover, the subtle motor engagement during appreciating visual art represents an embodied element of an individual's empathetic responses [47]. Accordingly, people with rich everyday aesthetic experience may be more motivated and empathetic toward visual arts as well as have better competences in processing visual-spatial coding and visuomotor transformation through the modulation of motor systems.

Moreover, this study found that, compared to participants with a low level of everyday aesthetic experience, participants with a high level of everyday aesthetic experience was more prone to activate the right anterior cingulate (BA 32) when viewing ugly pictures. The result here is consistent with findings that experts show a distinctive downward shift in the identification of familiar art [24]. On the other hand, when the participants with a low level of everyday aesthetic experience viewed ugly stimuli, the motor areas of the right precentral gyrus (BA 4) and left medial frontal gyrus (BA 6) were also activated. Moreover, compared to the participants with a high level of everyday aesthetic experience, the participants with a low level of everyday aesthetic experience had the right postcentral gyrus activated when they experienced positive emotions. These findings are in line with arguments that the medial frontal gyrus modulates cognitive and semantic integration [14] and that AE involves interactions among sensory-motor, emotion–valuation, and meaning–knowledge circuitry [31]. Moreover, the postcentral gyrus is related to the recognition of the shape, size, and texture of objects [17]. Therefore, it is possible that people with a low level of everyday aesthetic experience tend to appreciate an object based on its external features, which brings about positive emotions.

The integrated findings suggest that rich everyday aesthetic experience facilitates the formation of connections between stimuli and existing knowledge as well as descending cognitive control through activation of the left anterior cingulate which further increases the preference for beautiful products. On the other hand, poor everyday

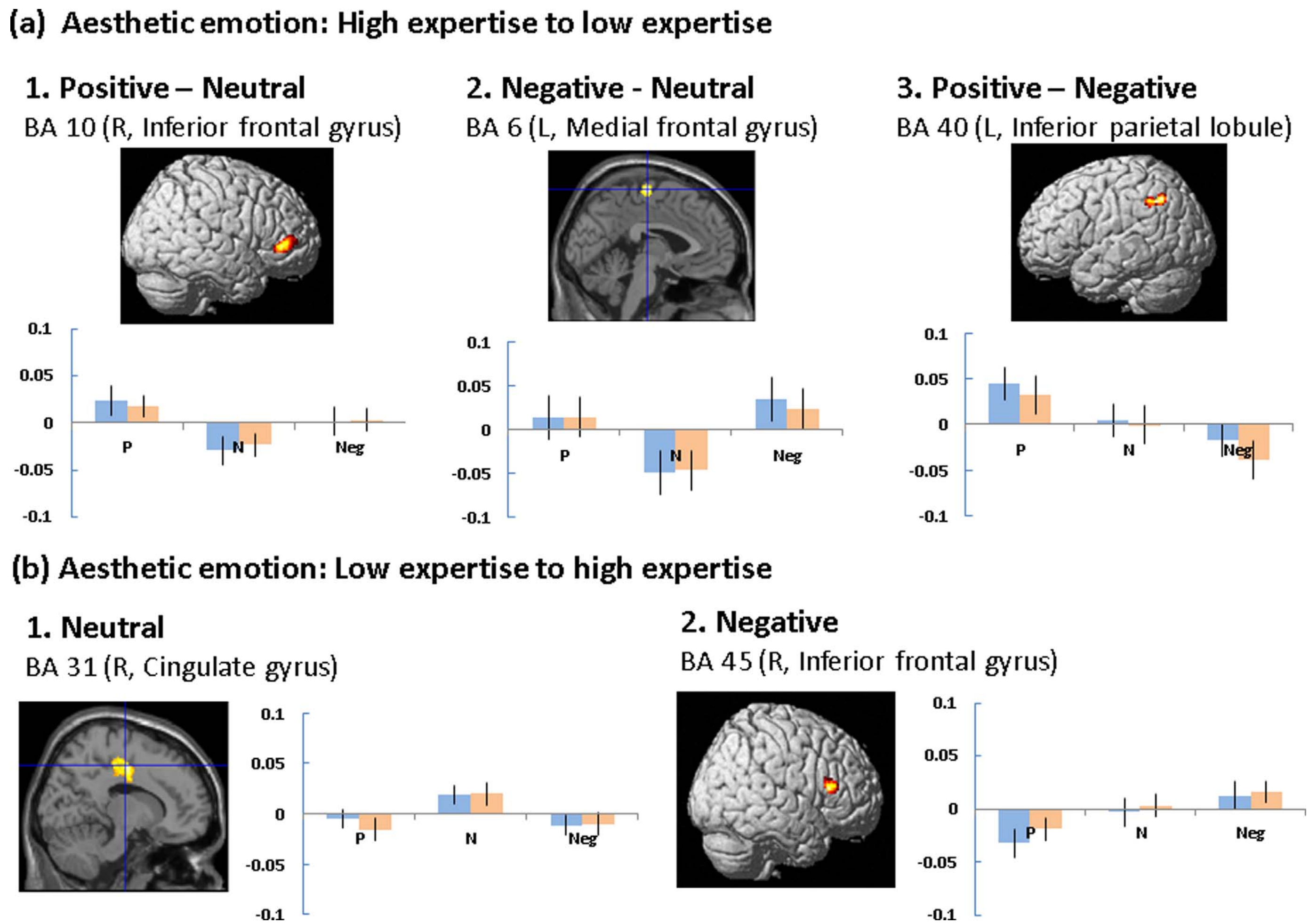

Fig. 6. Brain Regions Showing Activation for Contrasts of Aesthetic Emotions × Levels of expertise in design. Significant activations at a $p < .05$ FWE-corrected level. Bar-charts show beta values for regions of interests (ROIs). Blue bar represents High expertise; orange bar represents low expertise. All comparisons were significant. The MNI coordinates for distinct regions can be found in Table 2. L = left; R = right.

aesthetic experience may lead to stronger responses to ugly designed products; however, when they appreciate ugly designed product with positive emotions, the AE process is modulated by motor system, such as the right precentral gyrus and left medial frontal gyrus.

4.3. How expertise in design modulates the neural responses to AE

While the comparisons of everyday aesthetic experience revealed more brain activation for contrasts of aesthetic judgments, those of expertise in design revealed more brain activation for contrasts of aesthetic emotions. Interestingly, rich expertise in design facilitated activation in the left lentiform nucleus when beautiful stimuli were viewed. The result lends support to the argument that the implicit perception of beauty and attractiveness involves the putamen, a subcortical reward region that is part of the lentiform nucleus [26,33,50] as well as that the putamen is related to aesthetic judgments [26], affective motor planning [26], and continuous affective evaluation [47]. In other words, emotional and reward processing may guide motivation and decision making and, further, influence aesthetic judgments through putamen [54]. Moreover, in accordance with past findings [11,39], the findings reported here suggest that the inferior frontal gyrus and insular cortex modulate the judgment of ugly stimuli in people with poor expertise in design. In addition, the insula plays a critical role in emotional processing [12,45] and is related to conscious evaluation during AE [47]. Therefore, people with poor expertise in design are prone to be influenced by emotion when assessing ugly stimuli. However, OFC which is widely accepted as a crucial node of aesthetic judgment in abstract arts [24,34] was not activated in our analyses. Past studies seldom employ everyday designed products as stimuli. Our findings may indicate that appreciation of abstract arts and mundane arts goes through some different cognitive processes, which requires further studies to confirm.

With respect to aesthetic emotions, the findings in this study suggest that positive emotions may be elicited in people with rich expertise in design through the function of inferior frontal gyrus (R, BA 10) and inferior parietal lobules (L, BA 40). BA 10 has been found to be related to the subjective self or personal entity [1,15], and it plays an important role in the maintenance of attention on external stimuli and it is related to internal self-awareness during emotional regulation [30]. Accordingly, AE is of high personal importance; this importance results in the integration of external sensations and internal states as an individual experiences an emotional connection to the arts [48]. In addition, the findings suggest that the inferior parietal cortex plays an important role in top-down attention in the automatic regulation of responses to emotional stimuli [25].

On the other hand, the activation of the cingulate gyrus (R, BA 31) and inferior frontal gyrus (R, BA 45) in the participants with poor expertise in design when they were experiencing negative emotions are in line with the finding that the evaluation of emotional states involves the posterior and anterior cingulate cortex, medial frontal gyrus, and inferior frontal gyrus and that these areas are functionally associated for accessing interceptive information and underlie the subjective

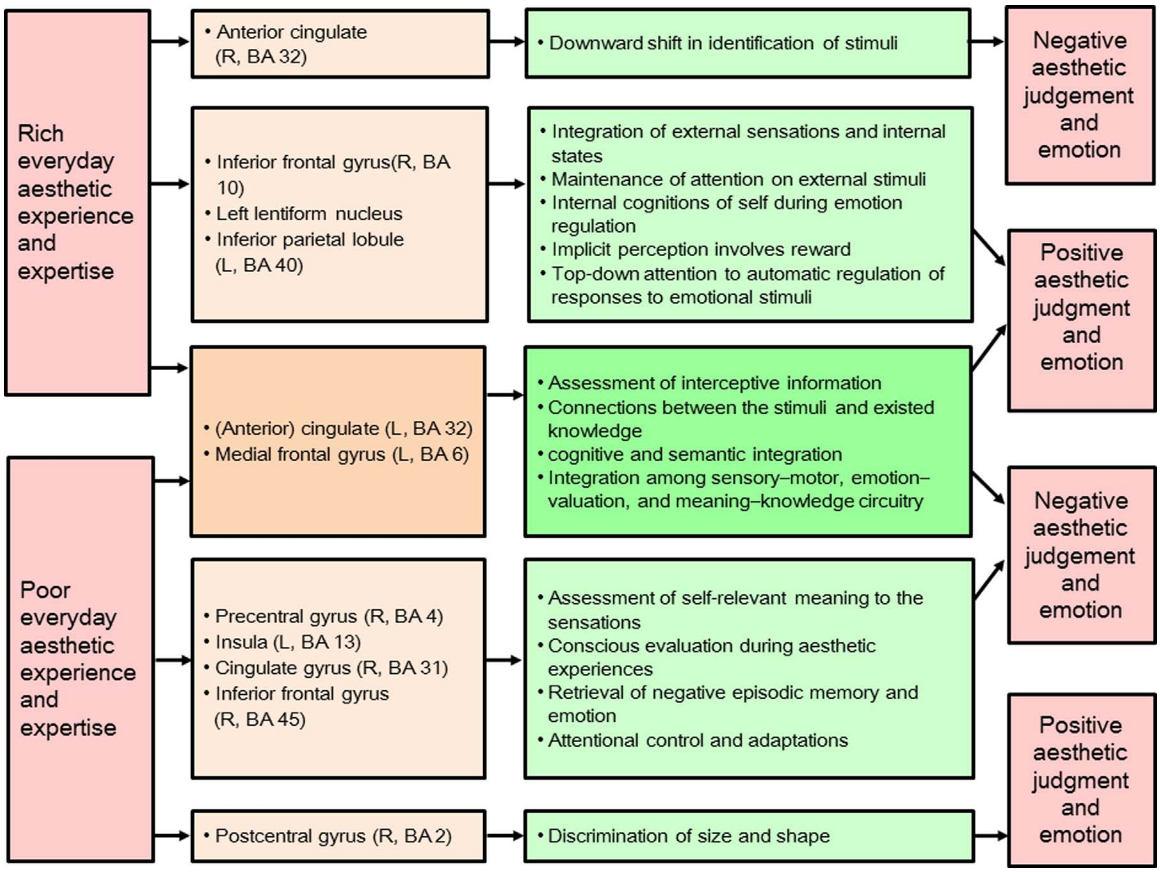

Fig. 7. An Integrative Model of the AE of Designed Products and the Underlying Neural Mechanisms.

experience of emotional states [45]. BA 31 provides a pre-potent signal that prepares for withdrawal responses [49], and the posterior cingulate is related to the retrieval of emotion-laden episodic memories [22]. The right inferior frontal gyrus has also been suggested to play a crucial role in attentional control and adaptations to respond to currently relevant and salient stimuli with inhibitory control [23]. In other words, ugly products that elicit negative episodic memories and emotion may lead to the instinctual avoidance of looking at such objects followed by aesthetic appraisals through the function of the RIFG and cingulate gyrus.

Analyses of behavioral data found that the averaged trials of “beautiful” in the high design-expertise was lower than that in the low design-expertise (44.83 vs. 48.43) and the correlation between aesthetic judgments and weighted emotions in the high design-expertise was lower than that in the low design-expertise (.587 vs. .721). These results suggest that rich expertise in design results in a more critical viewpoint when assessing beautiful stimuli through the application of higher standards of aesthetic judgment. However, the weaker correlation between the rating of “ugly” and “negative emotion” in high design-expertise group than that in low design-expertise group suggests that rich expertise in design contribute to a more open-minded and self-absorbed attitude towards stimuli that provoke negative emotions. The seemingly contradictory findings here are in line with the dissociation theory of aesthetic enjoyment, which suggests that individuals with the capacity to enter states of absorption are able to deactivate displeasure circuits and therefore enjoy negative emotion [21]. In other words, rich expertise in design may contribute to the activation of the lentiform nucleus and right inferior frontal gyrus, which enhances attention, the integration of information, and positive emotion, thereby deactivating negative emotions toward ugly stimuli.

4.4. An integrative model of AE in designed products

Taken together, the findings of this study support our hypothesis and suggest that there are shared neural mechanisms between the AE of college students with different levels of everyday aesthetic experience and expertise in design. In addition to the common neural mechanisms (BA 32 and BA 6), college students with rich everyday aesthetic experience and expertise in design had more brain activations when viewing beautiful stimuli, whereas their counterparts had more brain activations when viewing ugly stimuli (see Fig. 7).

Overall, the findings of this study support the idea that context and knowledge affect the neural responses of individual AE, which may further influence individual taste [9]. The findings are also consistent with the proposal that AE involves the integration of sensory and emotional reactions, which are modulated by their personal relevance [35]. Moreover, the brain areas that were activated suggest that AE involves interactions between sensory-motor, emotion–valuation, and meaning–knowledge circuitry [9]. In other words, controlled cross-modal neural processes are required for aesthetic emotions and aesthetic judgments [6], and these aesthetic processes involve attention, implicit reward, memory retrieval, the making of meaning, knowledge integration, and emotional regulation.

5. Conclusions

The AE of designed products results from interplay between brain structures that underlie complex perceptions, memories, emotions, and cognition of presented stimuli. These processes, however, are modulated by personal traits such as everyday aesthetic experience and expertise in design. The findings of this study reveal that aesthetic judgments and aesthetic emotions are interactive, and the activation of common neural substrates (left BA 32 and BA6) indicates that AE involves interactions between sensory-motor, emotion–valuation, and meaning–knowledge circuitry. However, rich everyday aesthetic experience elicits more brain activations in aesthetic judgments, and expertise in design elicits more brain activations in aesthetic emotions. Comparatively, rich everyday aesthetic experience and expertise in design result in more brain activations (right BA 10, left lentiform nucleus, and left BA 40) related to integration of external sensation and internal states, maintenance of attention, and emotional regulation when viewing beautiful stimuli, whereas poor everyday aesthetic experience and expertise in design result in more brain activations (right BA 4, BA 31, BA45, and left BA13) related to conscious assessment of self-relevant meaning as well as retrieval of negative memory and emotions when viewing ugly stimuli.

The majority of past studies on neuroaesthetics have focused on exploring the underlying neural mechanisms of AE across participants rather than on individual differences. This study addressed group differences with regard to the neural mechanisms of aesthetic emotions and aesthetic judgments toward designed products according to levels of everyday aesthetic experience and expertise in design. The findings of this study suggest that different types and various degrees of personal traits affect AE through the modulation of both shared and unique neural circuits. Everyday aesthetic experience and expertise in design carry different effects on aesthetic judgments and emotions. Accordingly, enhancing both the personal traits should bring about a better effect in enhancing aesthetic ability than just focusing on enhancing one of them.

6. Limitations and suggestions

Many researchers have proposed specific stages of AE [32,37]. Due to the poor time resolution of MRI, individual differences in the neural mechanisms underlying specific aesthetic process have not been identified. Further studies can combine fMRI with ERP techniques to map out the processes as well as their underlying neural mechanisms. Moreover, whether there are cause-and-effect or interactive relationships between aesthetic judgments and aesthetic emotions could be examined. Such studies would help identify the critical components of AE and its interactive relationships, which would contribute to effective instruction for aesthetics.

Moreover, experimental instruction with regard to AE and posttest-pretest fMRI contrasts can be conducted to accumulate evidence on how instruction changes neural circuits. Finally, the findings of this study provide insight into how personal traits modulate neural mechanisms and influences AE in mundane arts; aesthetic experience can be strengthened through daily life experience. Notably, the findings of this study suggest that taking aesthetic related courses, although contributes to everyday aesthetic experiences, does not enhance expertise of product design. Instead, practical working experience is closely related to the accumulation of expertise in product design. Accordingly, further studies or training aimed at enhancing aesthetic experience can encourage both theoretical learning and practical training, and further, strengthen the neural mechanisms that contribute to positive aesthetic judgments and emotions.

Acknowledgment

This study was supported by the Ministry of Science and Technology in Taiwan (Contract Nos. NSC 101–2420-H-004–014-MY2, and MOST 103–2511-S-004 – 002-MY3).

Conflicts of interest

None.

References

[1] J.M. Amting, S.G. Greening, D.G. Mitchell, Multiple mechanisms of consciousness: the neural correlates of emotional awareness, J. Neurosci. 30 (2010) 10039–10047, http://dx.doi.org/10.1523/JNEUROSCI.6434-09.2010.
[2] T. Armstrong, B. Detweiler-Bedell, Beauty as an emotion: the exhilarating prospect of mastering a challenging world, Rev. Gen. Psychol. 12 (4) (2008) 305–329.
[3] M. Bertamini, A. Makin, G. Rampone, Implicit association of symmetry with positive valence, high arousal and simplicity, Iperception 4 (2013) 317–327.
[4] A.J. Blood, R.J. Zatorre, P. Bermudez, A.C. Evans, Emotional responses to pleasant and unpleasant music correlate with activity in paralimbic brain regions, Nat. Neurosci. 2 (1999) 382–387, http://dx.doi.org/10.1038/7299.
[5] I.C. Bohrn, U. Altmann, O. Lubrich, W. Menninghaus, A.M. Jacobs, When we like what we know - a parametric fMRI analysis of beauty and familiarity, Brain Lang. 124 (2013) 1–8, http://dx.doi.org/10.1016/j.bandl.2012.10.003.
[6] E. Brattico, M. Pearce, The neuroaesthetics of music, Psychol. Aesthetics Creat. Arts 7 (2013) 48–61, http://dx.doi.org/10.1037/a0031624.
[7] B. Calvo-Merino, C. Urgesi, G. Orgs, S.M. Aglioti, P.H aggard, Extrastriate body area underlies aesthetic evaluation of body stimuli, Exp. Brain Res. 204 (2010) 447–456, http://dx.doi.org/10.1007/s00221-010-2283-6.
[8] A. Chatterjee, Neuroaesthetics: a coming of age story, J. Cogn. Neurosci. 23 (2011) 53–62, http://dx.doi.org/10.1162/jocn.2010.21457.
[9] A. Chatterjee, O. Vartanian, Neuroaesthetics, Trends Cogn. Sci. 18 (2014) 370–375, http://dx.doi.org/10.1016/j.tics.2014.03.003.
[10] J.F. Christensen, B. Calvo-Merino, Dance as a subject for empirical aesthetics, Psychol. Aesthetics Creat. Arts 7 (2013) 76–88, http://dx.doi.org/10.1037/a0031827.
[11] T. Costa, M. Crini, Basic emotions: differences in time sequence and functional imaging with low resolution brain electrical tomography (LORETA), Nat. Preced (2011).
[12] A.B. Craig, How do you feel now? The anterior insula and human awareness, Nat. Rev. Neurosci. 10 (2009) 59–70.
[13] E.S. Cross, L.F. Ticini, Neuroaesthetics and beyond: new horizons in applying the science of the brain to the art of dance, Phenomenol. Cogn. Sci. 11 (2012) 5–16.
[14] G.C. Cupchik, O. Vartanian, A. Crawley, D.J. Mikulis, Viewing artworks: contributions of cognitive control and perceptual facilitation to aesthetic experience, Brain Cogn. 70 (2009) 84–91.
[15] B.T. Denny, H. Kober, T.D. Wager, K.N. Ochsner, A meta-analysis of functional neuroimaging studies of self- and other judgments reveals a spatial gradient for mentalizing in medial prefrontal cortex, J. Cogn. Neurosci. 24 (2012) 1742–1752.
[16] C. DiDio, G. Vittorio, Neuroaesthetics: a review, Curr. Opin. Neurobiol. 19 (2009) 682–687, http://dx.doi.org/10.1016/j.conb.2009.09.001.
[17] B. Estañol, J.F. Baizabal-Carvallo, H. Sentíes-Madrid, A case of tactile agnosia with a lesion restricted to the post-central gyrus, Neurol. India 56 (2008) 471–473.
[18] J. Fan, X. Gu, X. Liu, K.G. Guise, Y. Park, L. Martin, A. deMarchena, C.Y. Tang, M.J. Minzenberg, P.R. Hof, Involvement of the anterior cingulate and frontoinsular cortices in rapid processing of salient facial emotional information, Neuroimage 54 (2011) 2539–2546.
[19] P. Fusar-Poli, A. Placentino, F. Carletti, P. Landi, P. Allen, S. Surguladze, F. Benedetti, M. Abbamonte, R. Gasparotti, F. Barale, J. Perez, P. McGuire, P. Politi, Functional atlas of emotional faces processing: a voxel-based meta-analysis of 105 functional magnetic resonance imaging studies, J. Psychiatry Neurosci. 34 (2009) 418–432.
[20] A.S. Garrett, R.J. Maddock, Separating subjective emotion from the perception of emotion-inducing stimuli: an fMRI study, Neuroimage 33 (2006) 263–274.
[21] S. Garrido, E. Schubert, Adaptive and maladaptive attraction to negative emotions in music, Music. Sci. 17 (2013) 147–166.
[22] H. Gündel, M.F. O'Connor, L. Littrell, C. Fort, R.D. Lane, Functional neuroanatomy of grief: an fMRI study, Am. J. Psychiatry 160 (2003) 1946–1953.
[23] A. Hampshire, S.R. Chamberlain, M.M. Monti, J. Duncan, A.M. Owen, The role of the right inferior frontal gyrus: inhibition and attentional control, Neuroimage 50 (2010) 1313–1319.
[24] G. Harsanyi, C.C. Carbon, Matching style and content in art perception, Percept. ECVP Abstr. 39 (2010) 115.
[25] S. Hwang, S.F. White, Z.T. Nolan, S. Sinclair, R.J.R. Blair, Neurodevelopmental changes in the responsiveness of systems involved in top down attention and emotional responding, Neuropsychologia 62 (2014) 277–285.
[26] T. Ishizu, S. Zeki, The brain's specialized systems for aesthetic and perceptual judgment, Eur. J. Neurosci. 37 (2013) 1413–1420.
[27] P.H. Janak, K.M. Tye, From circuits to behaviour in the amygdala, Nature 517 (2015) 284–292.
[28] H. Kawabata, S. Zeki, Neural correlates of beauty, J. Neurophysiol. 91 (2004) 1699–1705.
[29] U. Kirk, M. Skov, M.S. Christensen, N. Nygaard, Brain correlates of aesthetic expertise: a parametric fMRI study, Brain Cogn. 69 (2009) 306–315.

nonlinear response to facial attractiveness, Social. Neurosci. 5 (3) (2010) 320–334.
[34] M. Nadal, M. Skov, Introduction to the special issue: toward an interdisciplinary neuroaesthetics, Psychol. Aesthet., Creat. Arts 7 (2013) 1–12.
[35] S. Nieminen, E. Istók, E. Brattico, M. Tervaniemi, The development of the aesthetic experience of music: preference, emotions, and beauty, Music. Sci. 16 (2012) 372–391, http://dx.doi.org/10.1177/1029864912450454.
[36] K. Okanoya, Learning, epigenetics, and computation: an extension on Fitch's proposal, Phys. Life Rev. 11 (2014) 389–390, http://dx.doi.org/10.1016/j.plrev.2014.07.004.
[37] M.J. Parsons, How We Understand Art: A Cognitive Developmental Account of Aesthetic Experience, Cambridge University Press, New York, NY, 1987.
[38] D.H. Pink, A Whole New Mind Moving from the Information Age to the Conceptual Age, Riverhead Books, New York, 2005.
[39] E. Pöppel, M. Avram, Y. Bao, V. Graupmann, E. Gutyrchik, A. Lutz, M. Park, M. Reiser, E. Russell, S. Silveira, L. Smigielski, C. Szymanski, Y. Zaytseva, Sensory processing of art as a unique window into cognitive mechanisms: evidence from behavioral experiments and fMRI studies, Procedia - Soc. Behav. Sci. 86 (2013) 10–17.
[40] R. Reber, N. Schwarz, P. Winkielman, Processing fluency and aesthetic pleasure: is beauty in the perceiver's processing experience? Personal. Soc. Psychol. Rev. 8 (2004) 364–382.
[41] M. Reimann, J. Zaichkowsky, C. Neuhaus, T. Bender, B. Weber, Aesthetic package design: a behavioral, neural, and psychological investigation, J. Consum. Psychol. 20 (2010) 431–441.
[42] T. Roald, S. Køppe, Sense and subjectivity. Hidden potentials in psychological aesthetics, J. Theor. Philos. Psychol. 35 (2015) 20–34, http://dx.doi.org/10.1037/a0038435.
[43] V. Salimpoor, R. Zatorre, Neural interactions that give rise to musical pleasure, Psychol. Aesthet., Creat. Arts 7. 1 (2013) 62–75.
[44] M. Skov, The pleasure of art, in: M.L. Kringelbach, K.C. Berridge (Eds.), Pleasures of the Brain, Oxford University Press, Cambridge, MA, 2010, pp. 270–283.
[45] Y. Terasawa, H. Fukushima, S. Umeda, How does interoceptive awareness interact with the subjective experience of emotion? An fMRI study, Hum. Brain Mapp. 34 (2013) 598–612.
[46] B. vanBuren, B. Bromberger, D. Potts, B. Miller, A. Chatterjee, Changes in painting styles of two artists with Alzheimer's disease, Psychol. Aesthet., Creat. Arts 7 (2013) 89–94.
[47] O. Vartanian, M. Skov, Neural correlates of viewing paintings: evidence from a quantitative meta-analysis of functional magnetic resonance imaging data, Brain Cogn. 87 (2014) 52–56.
[48] E.A. Vessel, G.G. Starr, N. Rubin, The brain on art: intense aesthetic experience activates the default mode network, Front. Hum. Neurosci. 6 (2012) 1–17, http://dx.doi.org/10.3389/fnhum.2012.00066.
[49] B.A. Vogt, Submodalities of emotion in the context of cingulate subregions, Cortex 59 (2014) 197–202.
[50] T. Wang, L. Mo, C. Mo, L.H. Tan, J.S. Cant, L. Zhong, G. Cupchik, Is moral beauty different from facial beauty? Evidence from an fMRI study, Soc. Cogn. Affect. Neurosci. 10 (2014) 814–823.
[51] Y.C. Yeh, Cognitive Processes and Neural Mechanisms of Aesthetic Experience and Creativity in Designed Products (NSC 101-2420-H-004-014-MY2), Ministry of Science and Technology of the Republic of China in Taiwan, Taipei, 2013.
[52] Y.C. Yeh, C.W. Lin, W.C. Hsu, W.J. Kuo, Y.C. Chan, Associated and dissociated neural substrates of aesthetic judgment and aesthetic emotion during the appreciation of everyday designed products, Neuropsychologia 73 (2015) 151–160.
[53] S. Zeki, J.P. Romaya, D.M.T. Benincasa, M.F. Atiyah, The experience of mathematical beauty and its neural correlates, Front. Hum. Neurosci. 8 (2014) 68.
[54] W. Zhang, S. Lai, X. He, X. Zhao, S. Lai, Neural correlates for aesthetic appraisal of pictograph and its referent: an fMRI study, Behav. Brain Res. 305 (2016) 229–238.