Emotion and novelty processing in an implicit aesthetic experience of architectures: evidence from an event-related potential study

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The present study explored the implicit aesthetic processing of different architectures using an event-related potential method. Event-related potential data were acquired in a categorization task in which participants were asked to distinguish between two different categories of pictures of everyday life objects and the architectures as soon as possible. The architectural pictures included two categories: noted-architect-designed and ordinary architectures. A smaller P2 amplitude and a larger N2 amplitude were elicited by the master architects' works than those of ordinary architectures, which indicated that perceived positive emotion and novelty perception occurred in the aesthetic processing of architectures. Our results present two sensitive neural indicators, P2 and N2, to judge the delight and novelty qualities shown by the architecture, respectively. *NeuroReport* **26:279–284**

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Introduction

Nowadays, we are surrounded by a wide variety of architectures that are created by designers. At the same time, architectures can shape human experience and memory imperceptibly [1]. However, the mechanism of how an architecture influences the human experience is still not well understood [2]. When we walk by architectures, what feeling will be aroused? Why are some architectures attractive, but not others? As architectures play an important role in our daily life, it is important to understand the neural mechanism of the relationship between the architecture and the aesthetic experience, especially in a spontaneous manner.

Recent studies on this issue began to focus on the cognitive process of the experience using neuroscience approach. For example, Oppenheim *et al.* [3] carried out an event-related potentials (ERP) study, which discovered that high-ranking (classic) buildings elicited a lower N400 amplitude than low-ranking buildings. This finding indicated that neurophysiological correlates of building perception reflect an architectural rule system in the memory. From the neuroscientist's point of view, architectural experience is concerned with aesthetic processing, which shapes the beholder's experience of pleasure through visual perception of the harmony, symmetry and good proportions [2]. Armstrong and Detweiler-Bedell [4] reported that aesthetic pleasure involved both cognitive and emotional pleasure. Thus, architectural experience should be associated with cognitive and emotional processing.

Neuroaesthetics is an interdisciplinary research field that explores the neural bases of the aesthetic process [5]. A series of research have found neural mechanisms linked with pleasure underpinning our brain when viewing objects such as geometric graphs, paintings, faces and architectures. The brain areas engaged in the aesthetic experience include the medial orbitofrontal cortex, the subcallosal cingulate gyrus [6,7] and the bilateral insula [8], which are related to reward processing and emotional appraisal. Most existing studies have focused on the aesthetic experience in an explicit judgement or evaluation task [9]. However, in our daily life, aesthetic processing is not always induced externally, but occurred spontaneously instead. Wang *et al.* [10] found that beautiful pendants gave rise to more positive emotions than less beautiful ones in an implicit aesthetic experience. Previous evidence indicated that the aesthetic process involves emotional experiences both spontaneously and intentionally.

Novelty, which could induce motivational effects, was also considered an important factor for the success of an artwork to be appreciated [11]. Some studies have found an inverted-U-shaped relationship between novelty and aesthetic preference, and that a moderate novel design tends to be more attractive [12,13]. Besides, Berlyne [14] found that the interestingness and pleasantness increased in response to stimulus, which is in an appropriate range of novelty level. Thus, a novel and beautiful design can catch more interest and attention from beholders and induce a positive emotion. However, few studies have

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focused on the neural mechanism when dealing with the novelty embedded in an artwork, which contributes towards the perception of beauty.

As one of the most important artworks in our daily life, architecture not only plays a functional and utilitarian role but also possesses an aesthetic value on the basis of the ancient Roman architect Vitruvius' fundamental principles of architecture design including firmitas, utilitas and venustas meaning durable, useful and beautiful, respectively [2]. Besides, people are striving for novelty and original designs are highly valued [12], which indicates that an architect should design something new to attract beholders' attention and increase their interest. We believe that a good design of architecture, especially these ones designed by noted architects (e.g. Pritzker architecture prize winner), must conform to the above principles. In other words, these masterpieces should contain appropriate novel elements, but not too much or less, which can improve their intrinsic attractiveness as well as people's aesthetic preference towards them. However, there are still few studies exploring the neural activities of the underlying aesthetic experience of architectures with emotion and novelty processing. This work, we believe, should be essential for neuroaesthetics and architecture studies.

P2 is an early positive ERP component with a peak latency at about 200 ms after stimulus onset, and is referred to as an index reflecting the early automatic emotion processing in stimuli [15]. A body of ERP studies suggests that the amplitude of P2 induced by negative stimuli is larger than that induced by positive stimuli [16,17]. A recent ERP study showed that beautiful pendants can elicit a positive emotion reflected by a lower P2 amplitude [10]. N2 refers to the negative ERP component appearing between about 200 and 300 ms after stimulus onset. N2 elicited by stimuli in the frontocentral area is associated with the detection of novelty and a larger N2 indicates that more attention is allocated to the corresponding stimuli [18]. Several evidences indicated that novel stimuli such as photographs [19], or drawings [20] elicited a larger amplitude of N2.

In our study, we consider the appreciation of architectures as an aesthetic experience involving emotion and novelty processing, which can be reflected by changes in the amplitudes of P2 and N2. A task-irrelevant experimental paradigm similar to the one in Oppenheim and colleagues' research was used to study the spontaneous aesthetic processing of two categories of architectures: noted-architect-designed and ordinary architectures. We hypothesized that a designed master's architecture work should be appropriately novel to receive a higher aesthetic preference that attracts more attention from beholders and arouses more positive emotions compared with ordinary architecture, resulting in a larger amplitude of N2 and a lower amplitude of P2.

Methods

Participants

Eighteen right-handed participants (determined by the handedness questionnaire adapted from Oldfield (1971)'s study [21]) participated in the experiment. Data from one participant were excluded because of excessive recording artefacts. The remaining 17 participants (eight women) ranged in age from 20 to 27 years (mean age = 22.29, SD = 2.14), none of whom majored in architecture or had education in architecture or art-related fields beforehand. All participants reported normal or corrected-to-normal visual acuity and did not have any history of neurological or mental diseases. They provided informed consent and were paid for participation.

Experimental materials

The Pritzker Architecture Prize is awarded to only the best architect(s) in the world every year on the basis of the Vitruvius' fundamental principles and originality. Thus, we believed that architectures designed by noted architects who were awarded the Pritzker Architecture Prize should be suitable stimuli to test our hypothesis as these masterpieces are novel to an appropriate degree and more appealing than ordinary buildings in our daily life on the basis of identical authority evaluation. Thus, 40 architectural pictures were chosen as the candidate of noted-architect-designed architecture from the website of the Pritzker Architecture Prize. Another 40 architectural pictures that depicted ordinary buildings were chosen as the candidate of ordinary architecture from the online resources. All the pictures were processed by Adobe Photoshop 10.0 to be black-and-white and have the same luminance, shade and size. Thirty volunteers who had not participated in the later electrophysiological experiment rated the perceived beauty of the appearance of these 80 buildings using a seven-point Likert scale ranging from 1 (very ugly) to 7 (very beautiful) in a pilot study. Then, 20 candidate noted-architect-designed architectures at the top ranking of rating score were defined as noted-architect-designed architectures; another 20 candidate ordinary architectures at the bottom ranking of the rating score were defined as ordinary architectures. A paired t-test showed a significant difference in the means of beautiful levels between these two categories (high level = 4.9, low level = 3.39, $t = -9.239$, $P < 0.001$). We selected 40 pictures of everyday life objects (e.g. bags, umbrella) online that were processed in the same way as the architectural pictures.

Experimental procedure

All the stimuli were presented randomly twice in the experiment by E-prime software (Psychology Software Tools Inc., Pittsburgh, Pennsylvania, USA). Participants were comfortably seated in a sound-proof room facing the computer screen 1 m away, with a visual angle of $6.3° \times 6.3°$ to complete two blocks of 80 trials each. In each trial, a fixation cross was presented for 500 ms first,

Fig. 1

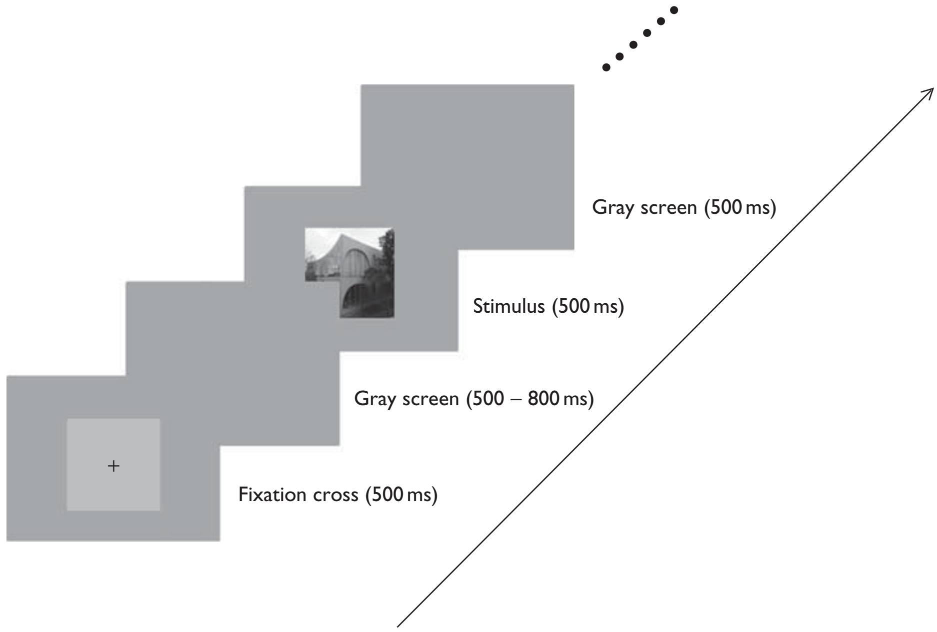


Illustration of the experiment paradigm applied.

and then a gray screen was shown for a random duration between 500 and 800 ms, followed by the picture with a 500 ms-presentation time. During this time, a modified categorization task from the study by Oppenheim and colleagues was used in which participants were asked to press a corresponding button with a left/right thumb on a keyboard to distinguish between the two different categories of pictures of everyday life objects and the architectures as soon as possible. Finger assignment was counterbalanced across participants. The participants did not know whether the architectures were noted-architects or ordinary, and thus they did not know anything about the aim of the experiment. Finally, another gray screen appeared for 500 ms before the next trial (Fig. 1). All the participants were allowed to familiarize themselves with the task before the experiment.

ERP data acquisition

The electroencephalogram (EEG) was recorded continuously (band pass 0.05–100 Hz, sampling rate 500 Hz) using a Neuroscan Synamp2 Amplifier (Scan 4.3.1; Neurosoft Labs, Inc., Sterling, Virginia, USA) by an electrode cap with 64 Ag/AgCl electrodes according to the standard international 10–20 system. The left mastoids served as a reference and the electrode on the cephalic location was used for ground. Vertical and horizontal electrooculograms were recorded with two pairs of electrodes, placed above and below the left eye, and at 1 cm from each eye's lateral canthi. Electrode impedance was maintained below 5 kΩ throughout the experiment.

ERP data analysis

We used the Scan 4.5 software (Compumedics NeuroScan Inc., Herndon, Virginia, USA) to preprocess the EEG data offline. The electrooculogram artefacts were corrected and then the EEG recordings were segmented into epochs of a 1000 ms period from 200 ms before onset of the picture to 800 ms after this onset with the first 200 ms prestimulus as a baseline. Trials containing amplifier clipping, bursts of electromyography activity or peak-to-peak deflection exceeding ± 80 μV were excluded before averaging. EEGs were rereferenced to the average of the left and the right mastoids and digitally filtered with a low-pass filter at 30 Hz (24 dB/Octave). Finally, the data were averaged separately for noted-architect-designed architecture and ordinary architecture pictures.

On the basis of visual inspection, the time window was 130–180 ms for P2 and 180–250 ms for N2 when analysing the mean amplitudes. As obvious frontal P2 activity was elicited when processing affective picture [22] and novelty-N2 often showed an anterior distribution [18], we selected the six electrodes (F3, FZ, F4, FC3, FCZ, FC4) in the frontal-central area for the analysis of both P2 and N2.

To test the hypotheses of this research, we used within-participant repeated-measure analysis of variance (ANOVA) to analyse the amplitudes of P2 and N2 with architecture type (two levels: noted-architect-designed vs. ordinary architecture) and electrode (six levels) as the two within-participant factors. The Greenhouse–Geisser correction was applied for the nonsphericity and multiple comparisons were corrected using the Bonferroni method where appropriate. Behavioural data (accuracy rates and response time) were analysed using paired t-tests. The statistical analyses were carried out using the SPSS statistical software (SPSS Inc., Chicago, Illinois, USA).

Results

Behavioural results

The paired t-test showed that the accuracy rate of distinguishing noted-architect-designed architecture from everyday life objects is significantly higher than that of distinguishing ordinary architecture ($t = 3.878$, $P = 0.001$, 97.29 ± 5.42 vs. $94.12 \pm 6.48\%$, respectively), whereas the response time of noted-architect-designed architecture was significantly shorter ($t = -2.865$, $P = 0.011$, 480.389 ± 55.536 vs. 490.162 ± 58.951 ms, respectively).

Event-related potential results

In the P2 analysis, the results of 2 (architecture type: noted-architect-designed vs. ordinary architecture) × 6 (electrodes) within-participant repeated-measure ANOVA showed significant main effects for architecture type [$F(1,16) = 11.141$, $P = 0.004$] and electrode [$F(5,80) = 7.913$, $P < 0.001$] on the P2 amplitude, but no significant interaction was found [$F(5,80) = 2.019$, $P = 0.085$]. Ordinary architecture elicited a larger amplitude of P2 than noted-architect-designed architecture. In the N2 analysis, the 2 (architecture type: noted-architect-designed vs. ordinary architecture) × 6 (electrodes) within-participant repeated-measure ANOVA showed the significant main effects for both the architecture type and the electrode [$F(1,16) = 5.178$, $P = 0.037$; $F(5,80) = 12.631$, $P < 0.001$, respectively]. The amplitude of N2 was larger for noted-architect-designed architecture than that for ordinary architecture. No significant interaction was found between architecture type and electrode [$F(5,80) = 2.049$, $P = 0.081$] (Fig. 2).

Discussion

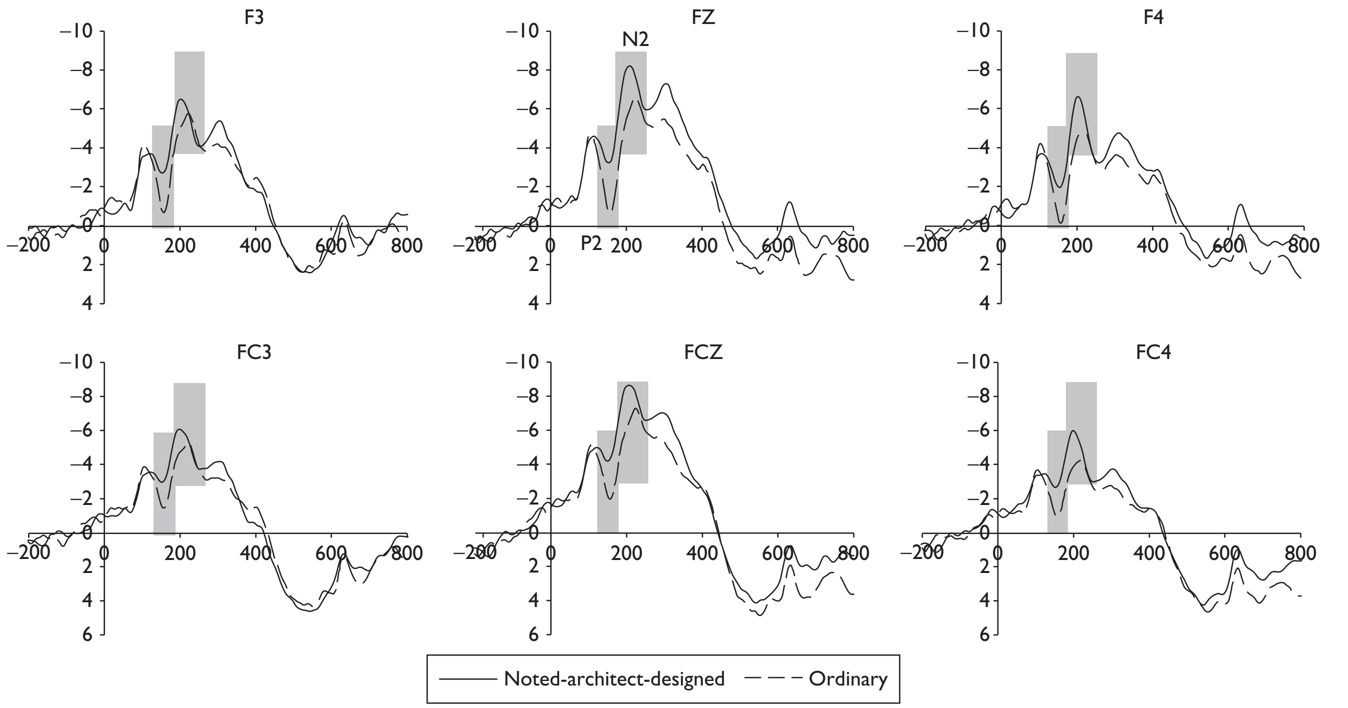
The discrepancies in ERP data in response to noted-architect-designed and ordinary architecture pictures with an unrelated task indicated that we can evaluate the architectures around us with a special aesthetics experience including emotion and novelty perception in an implicit manner. Beautiful architectures, designed by distinguished architects, elicited positive emotions in an early stage with a lower amplitude of P2 compared with the less beautiful ordinary architectures. The novelty effect of beautiful architectures on human aesthetic evaluation was reflected by the amplitude of N2, which looms larger in the noted-architect-designed architecture condition, reflecting more allocation of attention.

A previous study has shown that emotional processing existed at the early stage of aesthetic experience [10]. Our result is consistent with their finding of P2, which was elicited differently by beautiful and less beautiful pendants. Many previous ERP studies have provided evidence that emotional content in pictures (if it existed) was still evaluated even in an implicit nonemotional task and different emotions were reflected in the difference in P2 amplitude [16,17,23]. These findings supported the point that early emotional evaluation is an automatic process [24]. In a functional MRI study, viewing architectural pictures in an aesthetic judgement task can activate the medial orbitofrontal cortex and the subcallosal cingulate gyrus, which are associated with reward processing and emotional appraisal [6]. Combining the results from previous ERP and functional MRI studies with ours, the hypothesis that architectural experience involves emotional processing at the early stage of the spontaneous aesthetic evaluation and noted-architect-designed architecture will arouse a positive emotion with a lower amplitude of P2 was verified.

In contrast with the results of a previous study, we also found a significant difference in anterior N2 between noted-architect-designed architectures and ordinary architectures in the implicit aesthetic evaluation. Several studies attributed the modulations of N2 to the perceptual novelty or the mismatch to standard, and the anterior N2 in frontal or central scalp showed a larger amplitude in response to novel stimuli [19,20,25,26]. Our N2 component's scalp distribution is in agreement with the above findings. Novelty-N2 is indicative of the voluntary attention allocated to novel stimuli [18]. Generally, a well-known architect with rich experience and good knowledge of principles of architecture design (durable, useful, beautiful and originality) is more likely to embed some novel elements or original combination of ordinary elements into his/her works, which must be appropriate, novel and can induce beholder's more interest and positive emotion. These designs are highly aesthetically valued by beholders as they conform to human knowledge of architecture and meanwhile fulfill their pursuit of new things [27]. During the aesthetic experience, this novelty can be detected and perceived consciously in our brain because more attention resource is allocated to noted-architect-designed architectures reflected by the larger amplitude of N2.

Compared with Oppenheim's work [1,3], our stimuli are pictures of natural scenes whereas theirs are hand-drawn pictures. Vessel and Rubin's [28] study found that observer agreement in preferences ratings for real-world images is higher than that for abstract images. This suggests that aesthetic value is influenced by the semantic content of stimuli [28] and also by the semantic context [29]. Thus, the difference between the stimuli may result in distinct experience and aesthetic processing of the architectures, especially in an implicit evaluation. In our study, the semantic associations of the real buildings drove the participants to mainly focus on emotional and novelty perception related to an aesthetic experience rather than entail visual object model selection in an

Fig. 2



P2 and N2 were elicited by noted-architect-designed architectures (solid line) and ordinary architectures (dashed line), respectively. The time window for P2 is 130–180 ms and that for N2 is 180–250 ms.

implicit memory process, reflected in a different performance in ERPs.

Conclusion

Our ERP study put forward two sensitive measurements, P2 and N2, to judge the delight and novelty qualities of the architectures, respectively. Besides the emotional perception, the novelty is also processed by beholders in an implicit architectural experience. Beautiful architectures not only arouse positive emotion as reflected by a lower P2 amplitude but also elicit novelty evaluation by allocating more attention as reflected by a larger N2 amplitude. This study provided neural guidance for architectural design.

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Conflicts of interest

There are no conflicts of interest.

References

1 Oppenheim I, Vannucci M, Mühlmann H, Gabriel R, Jokeit H, Kurthen M, *et al.* Hippocampal contributions to the processing of architectural ranking. *Neuroimage* 2010; **50**:742–752.
2 Eberhard JP. Applying neuroscience to architecture. *Neuron* 2009; **62**:753–756.
3 Oppenheim I, Mühlmann H, Blechinger G, Mothersill IW, Hilfiker P, Jokeit H, *et al.* Brain electrical responses to high- and low-ranking buildings. *Clin EEG Neurosci* 2009; **40**:157–161.
4 Armstrong T, Detweiler-Bedell B. Beauty as an emotion: the exhilarating prospect of mastering a challenging world. *Rev Gen Psychol* 2008; **12**:305–329.
5 Zeki S. Art and the brain. *J Consciousness Stud* 1999; **6**:6–7.
6 Kirk U, Skov M, Christensen MS, Nygaard N. Brain correlates of aesthetic expertise: a parametric fMRI study. *Brain Cogn* 2009; **69**:306–315.
7 Kawabata H, Zeki S. Neural correlates of beauty. *J Neurophysiol* 2004; **91**:1699–1705.
8 Cupchik GC, Vartanian O, Crawley A, Mikulis DJ. Viewing artworks: contributions of cognitive control and perceptual facilitation to aesthetic experience. *Brain Cogn* 2009; **70**:84–91.
9 Höfel L, Jacobsen T. Electrophysiological indices of processing aesthetics: spontaneous or intentional processes? *Int J Psychophysiol* 2007; **65**:20–31.
10 Wang X, Huang Y, Ma Q, Li N. Event-related potential P2 correlates of implicit aesthetic experience. *Neuroreport* 2012; **23**:862–866.
11 Berlyne DE, Parham L. Determinants of subjective novelty. *Percept Psychophys* 1968; **3**:415–423.
12 Hekkert P, Snelders D, Wieringen PC. 'Most advanced, yet acceptable': typicality and novelty as joint predictors of aesthetic preference in industrial design. *Br J Psychol* 2003; **94**:111–124.
13 Hung W-K, Chen L-L. Effects of novelty and its dimensions on aesthetic preference in product design. *Int J Design* 2012; **6**:81–90.
14 Berlyne DE. Novelty, complexity, and hedonic value. *Percept Psychophys* 1970; **8**:279–286.
15 Spreckelmeyer KN, Kutas M, Urbach TP, Altenmüller E, Münte TF. Combined perception of emotion in pictures and musical sounds. *Brain Res* 2006; **1070**:160–170.

16 Carretié L, Mercado F, Tapia M, Hinojosa JA. Emotion, attention, and the 'negativity bias', studied through event-related potentials. *Int J Psychophysiol* 2001; **41**:75–85.
17 Huang YX, Luo YJ. Temporal course of emotional negativity bias: an ERP study. *Neurosci Lett* 2006; **398** (1–2):91–96.
18 Folstein JR, Van Petten C. Influence of cognitive control and mismatch on the N2 component of the ERP: a review. *Psychophysiology* 2008; **45**:152–170.
19 Thomas KM, Nelson CA. Age-related changes in the electrophysiological response to visual stimulus novelty: a topographical approach. *Electroencephalogr Clin Neurophysiol* 1996; **98**:294–308.
20 Czigler I, Balázs L. Age-related effects of novel visual stimuli in a letter-matching task: an event-related potential study. *Biol Psychol* 2005; **69**:229–242.
21 Oldfield RC. The assessment and analysis of handedness: the Edinburgh inventory. *Neuropsychologia* 1971; **9**:97–113.
22 Yuan J, Zhang Q, Chen A, Li H, Wang Q, Zhuang Z, Jia S. Are we sensitive to valence differences in emotionally negative stimuli? Electrophysiological evidence from an ERP study. *Neuropsychologia* 2007; **45**:2764–2771.
23 Feng C, Wang L, Liu C, Zhu X, Dai R, Mai X, Luo YJ. The time course of the influence of valence and arousal on the implicit processing of affective pictures. *PLoS One* 2012; **7**:e29668.
24 Zajonc RB. Feeling and thinking: preferences need no inferences. *Am Psychol* 1980; **35**:151.
25 Courchesne E, Hillyard SA, Galambos R. Stimulus novelty, task relevance and the visual evoked potential in man. *Electroencephalogr Clin Neurophysiol* 1975; **39**:131–143.
26 Daffner KR, Mesulam MM, Scinto LF, Calvo V, Faust R, Holcomb PJ. An electrophysiological index of stimulus unfamiliarity. *Psychophysiology* 2000; **37**:737–747.
27 Martindale C. *The clockwork muse: the predictability of artistic change*. New York: Basic Books; 1990.
28 Vessel EA, Rubin N. Beauty and the beholder: highly individual taste for abstract, but not real-world images. *J Vis* 2010; **10**:18.
29 Kirk U, Skov M, Hulme O, Christensen MS, Zeki S. Modulation of aesthetic value by semantic context: an fMRI study. *Neuroimage* 2009; **44**:1125–1132.