Neurosci Bull June 1, 2014, 30(3): 441–450. http://www.neurosci.cn
DOI: 10.1007/s12264-013-1401-4


·Original Article·

# Neural responses to cartoon facial attractiveness: An event-related potential study

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## ABSTRACT

Animation creates a vivid, virtual world and expands the scope of human imagination. In this study, we investigated the time-courses of brain responses related to the evaluation of the attractiveness of cartoon faces using the event-related potential (ERP) technique. The results demonstrated that N170 amplitude was higher for attractive than for unattractive cartoon faces in males, while the opposite was found in females. Facial attractiveness notably modulated the late positive component (LPC), which might reflect the task-related process of aesthetic appraisal of beauty. The mean LPC amplitude in males was significantly higher for attractive cartoon faces than for unattractive faces, while the LPC amplitude in females did not significantly differ between attractive and unattractive cartoon faces. Moreover, the paint mode (computer graphics, gouache, and stick figure) modulated the early encoding of facial structures and the late evaluative process. The early modulation effect by paint mode may be related to the spatial frequency of the pictures. The processing speed and intensity in females were both higher than those in males. In conclusion, our study, for the first time, reported ERP modulation based on the assessment of cartoon facial attractiveness, suggesting the facilitated selection of attractiveness information at the early stage, and that the attentional enhancement of attractive faces at the late stage only exists in males. This suggests that men's brains are hard-wired to be sensitive to facial beauty, even in cartoons.

**Keywords:** facial attractiveness; cartoon face; event-related potential; gender difference; late positive component; N170; vertex positive potential

## INTRODUCTION

One common feature of cartoon images is their attractiveness. Facial attractiveness is very important in cartoon character design and has engaged the attention of many researchers, since it plays a key role in social and affective behavior[1]. Researchers have found that averageness, symmetry, and sexual dimorphism are the three major factors influencing the assessment of facial attractiveness, while features such as size, skin health and color, proportions, and other factors play a relatively less important role[2]. Studies on the facial attractiveness of cartoons have not yet been reported, even though cartoon pictures and videos have been used as measuring tools in some psychological studies[3, 4]. Considering that children are often deeply absorbed in the cartoon world for hours[5, 6], assessment of the facial attractiveness of cartoons will have an impact on their future social development. In this study, we investigated the neural responses to cartoon facial attractiveness.

Attractiveness assessment of cartoon faces may share neural pathways with that of real faces in early processing, but differ in the late processing pathway[7]. Cognitive neuroscientists have attempted to explore whether the patterns of activity in the brain differ when processing cartoon and real faces. A functional magnetic resonance imaging (fMRI) study found that the fusiform face area appears to be optimally tuned to the broad category of faces, including those of cats, cartoons, and humans[8]. Chen *et al.* (2010)[9] found that adaptation to cartoon faces with large eyes significantly shifted participants' preferences for human faces with larger eyes, indicating a common representation for both cartoon and real faces. However, as face-processing goes on, the patterns of activity in the brain may differ between cartoon and real faces. Our previous face-recognition experiments found no significant difference in the amplitudes of N170 and the vertex-positive potential (VPP) between real and cartoon faces during the early facial structural encoding stage. The late positive component (LPC) for real faces was, however, significantly higher than that for cartoon faces during the late stage of face processing, which may reflect a difference in the motivational significance of real and cartoon faces[7]. Further, developmental changes occur in the processing of cartoon and real figures by children and adults. The medial prefrontal cortex (mPFC) is activated in 10-year-old children when they watch videos of real people and cartoon characters, while the mPFC in adults is activated by videos of real people, but not cartoon characters[10].

The ERP provides a useful technique for investigating the brain mechanisms of processing cartoon facial attractiveness. The N170 is involved in the analysis of facial configuration, free from the influence of sex, age, and race[11]. The VPP is also involved in early face cognition, and might be a polarity reversal of the N170 in the frontal area[12]. The LPC is closely correlated with the evaluation of facial attractiveness. Elevated LPC activity has been found in response to attractive *versus* non-attractive faces, possibly reflecting task-related evaluative processes[13]. Interestingly, the LPC has a higher response to beloved faces than those of regular friends and strangers[14], and a higher response to erotic than non-erotic pictures[15]. The LPC is also modulated by two dimensions of emotion, valence (negative to positive) and arousal (calm to excited), in affective processing[16, 17]. Recent studies have suggested that facial attractiveness processing affects not only the LPC, but also early components, such as the N170 (manifested by a significantly higher amplitude for liked than disliked faces)[18], early frontal positivity (60–100 ms, in the right frontal areas showing significant differences among high-, average- and low-attractiveness faces)[19], early posterior negativity (230–280 ms; elicited by attractive as opposed to non-attractive target faces)[20], the P2 (~250 ms at Pz, showing higher amplitude to high-beauty faces than to average- and low-beauty faces)[13], and an early component at ~150 ms (enhanced amplitude for attractive and non-attractive faces relative to faces of intermediate attractiveness).

Since cartoons are works of art, the influence of expression techniques on attractiveness should also be considered. As suggested by animation experts with over 10 years of experience in cartoon education, we decided to investigate first how the paint mode affects the processing of cartoon facial attractiveness. In animation creation, faces are commonly drawn using three paint modes: computer graphics (CG), gouache (G) and stick-figure (SF)[21]. CG has become a booming mainstream technology, as digital and film techniques are widely used to produce vivid pictures. Pictures in G mode are between opaque and translucent, which may produce gorgeous, soft, bright, vigorous, and other artistic effects in color. G mode is also widely used in children's picture-books. SF, with a high degree of generality and identification, is often used in the early stages of animation.

Males and females differ in evaluating facial attractiveness (e.g. men are more attentive to cues such as facial beauty)[22]; and the latency of N170 and VPP in females is shorter than that in males in cartoon facial processing[7], so gender was investigated as a between-group factor. For simplicity, the sex of cartoon characters was not taken into consideration in this research, since it is hard to differentiate the sex of animal cartoons when their headdresses are removed. The facial expression and gaze-direction of the cartoon stimuli should also be controlled, because they affect the appraisal of facial attractiveness[23].

The primary aim of the present study was to investigate whether cartoon faces of varying attractiveness in different paint modes would elicit different ERP waveforms. N170, VPP, and LPC were chosen to investigate the time-course of responses related to the process of cartoon facial attractiveness evaluation, and the influence of paint mode on cartoon facial beauty assessment. Gender, brain region, and hemispheric differences were also considered. Based on previous studies[7, 20, 24], we hypothesized that facial attractiveness processing would affect not only the late ERP components, but also the early components, i.e.

attractive cartoon faces would elicit a larger N170, VPP, and LPC than unattractive cartoon faces. Females might have an advantage of speed over males in processing cartoon facial attractiveness. Paint mode closely related to cartoon facial attractiveness would have an impact on LPC amplitude. The cartoon face is a type of stimulus lying between an artistic portrait and a real face, therefore research on the neural underpinnings of the evaluation of cartoon facial attractiveness will enrich our understanding of the brain mechanisms of face processing.

## METHODS

### Participants

Twenty-four right-handed students from Zhejiang Normal University not majoring in animation (12 females and 12 males, 21.3 ± 1.5 years) were recruited. Exclusion criteria were a history of psychiatric or neurological disease. All participants had normal or corrected-to-normal vision and gave written informed consent prior to the experiments. The study was approved by the Ethics Committee of Zhejiang Normal University, and conducted in accordance with the Declaration of Helsinki. Familiarity rating of the cartoon stimuli by the participants after ERP experiments showed good control over familiarity (2.04 ± 0.20; rated from 1 to 3: 1-unfamiliar, 2-generally familiar, 3-very familiar).

### Stimuli

One hundred and fifty pictures of clear, colored, and symmetrical cartoon faces with a direct gaze were used as stimuli. Human and anthropomorphic cartoon faces were in equal proportions, since both are widely used in animations. These pictures were assessed by 53 students (28 females and 25 males, different from the 24 participants) on three dimensions of emotion (intensity, arousal, and dominance; rated from 1 to 9), attractiveness (rated from 1 to 9), and emotional valence (1-positive, 2-neutral, 3-negative). The mean scores on intensity, arousal, dominance and emotional valence were 5.04 (SD, 2.49), 5.23 (2.44), 5.07 (2.44), and 1.86 (0.70), suggesting that the cartoon pictures were well controlled for facial expression. Correlation analysis showed that arousal and attractiveness were highly correlated ($r$ = 0.862, $P$ <0.001). This high correlation may be attributed to the fact that highly-attractive cartoon faces automatically attract attention, thus causing high arousal. The attractiveness of the 150 pictures was scored into three levels: high, medium, and low, and the values were: high, 7.24 (SD, 2.50); medium, 5.54 (2.95); and low, 4.16 (3.18). These results ensured good discrimination of the stimuli.

Each CG face was transformed into a G copy with Adobe Photoshop, and an SF copy by tracing its outline with gel ink pens on paper then digitizing it with a camera. To minimize the interference of color, the outline of each SF face was painted in the main color of the original CG face using Photoshop (Fig. 1). There were a total of 450 pictures [150 pictures × 3 types (CG, G and SF)]. All faces were in full frontal view and displayed on a white background.

The cartoon faces included the features of hair and ears, but not the neck. Spectacles or jewelry were not featured. The pictures were adjusted to the same height (400 pixels) and brightness, but the widths were not unified because each face had a different left-right dimension (average ~400 pixels). All stimuli were presented in the center of a 14.1-inch monitor, at a viewing distance of 60 cm, resulting in a visual angle of 10.7° in the vertical and 6.3°–22.7° in the horizontal directions. The presentation software was Stim2 (NeuroScan, Charlotte, NC).


**Fig. 1. Examples of cartoon faces in different paint modes.**

### Experimental Procedure

Each cartoon face was presented for 1 000 ms, followed by an inter-stimulus interval of 1 800–2 000 ms (randomized, blank screen). The response keys were counterbalanced across participants, that is, half were instructed to press the "F" key (as accurately and quickly as possible) if he/she considered the cartoon face was attractive, and press the "J" key if unattractive; and the other half were instructed in the reversed response pattern. Participants were required to focus on judging the attractiveness of the face, and had to respond within 1 000 ms. Each participant practiced this task for 30 trials before starting the experiment. The ERP experiment had three blocks separated by two 5-min breaks. Each block was composed of 150 trials. Trials were presented randomly and distributed equally over the three blocks.

After the ERP experiment, a behavioral experiment was performed, in which the participants were asked to evaluate the attractiveness of each cartoon face using a scale from 1, 'not attractive at all' to 5, 'highly attractive'. Participants were asked to ignore all the background information on the cartoon faces and only focus on their attractiveness. Familiarity rating of the cartoon stimuli was also conducted.

### EEG Recording and Data Analysis

EEG was recorded continuously *via* a 32-channel electrode cap with a frontal ground (NeuroScan). The online reference electrode was the right mastoid and the average mastoids reference was derived off-line. The electrode impedance was maintained below 5 kΩ. EEG was amplified with a DC-70 Hz bandpass and continuously sampled at 1 000 Hz/channel. The artifact correction procedure provided with Scan 4.3 (NeuroScan) was used to remove blink artifacts. Trials with incorrect responses (failure to react within 1 000 ms) and with a voltage exceeding ±80 μV were excluded from the ERP averages. The average numbers of valid trials for CG, G, and SF were 140.4 (SD, 4.85), 143.0 (5.07), and 137.8 (6.24). The data were re-filtered off-line with a low-pass filter of 30 Hz. The ERP waveforms were time-locked to the onset of the stimulus and the average epoch was 2 200 ms, including a 200-ms pre-stimulus baseline.

The latencies and peak amplitudes of N170 (at T5/T6) and VPP (at Cz), as well as the average amplitudes of LPC (at F3/Fz/F4, C3/Cz/C4, and P3/Pz/P4, 400–600 ms) were measured[14, 20, 22, 24, 25]. The time-course of ERPs related to the assessment of cartoon facial attractiveness was explored by repeated-measures ANOVA with the following factors: paint mode (CG/G/SF in N170, VPP, and LPC analysis), gender (male/female in N170, VPP, and LPC analysis), attractiveness (attractive/unattractive in N170, VPP, and LPC analysis) (the evaluation of facial attractiveness varies among individuals[26]; a cartoon face is more like an artistic portrait and its assessment probably shows more individual difference, so classification of attractive or unattractive was done based on the participants' own choices instead of the original picture types), region (frontal/central/parietal in LPC analysis only) and hemisphere (left/right in N170 analysis only). The behavioral data were analyzed using a repeated-measures ANOVA with factors of paint mode and gender. Significance levels for ERP data were reported after adjustment for violations of the sphericity assumption using the Greenhouse-Geisser method, where warranted.

## RESULTS

### Behavioral Data in ERP Experiment

Accuracy and reaction time (RT) were analyzed with 2 (participant gender: male, female) × 2 (stimulus category: attractive, unattractive) × 3 (paint mode: CG, G, SF) repeated-measures ANOVA. The overall response rate was high (mean 0.978) and no significant main or interaction effects were found. Likewise, RTs showed no significant differences among the stimulus categories (means: attractive 616.1 ms, unattractive 622.1 ms) and paint modes (means: CG 617.0 ms, G 615.7 ms, SF 624.5 ms), and between male and female participants (means: male 637.4 ms, female 600.8 ms, $P = 0.164$).

Attractiveness rates recorded during the appraisal process in ERP experiments were also analyzed with 2 (participant gender: male, female) × 3 (paint mode: CG, G, SF) repeated-measures ANOVA. Attractiveness rates were well balanced in the genders and paint modes (means: total, 48.71%; gender: male, 48.83%, female 48.58%; paint mode: CG, 46.97%; G, 51.29%; SF, 47.85%) and no significant main or interaction effects were found.

### Time-course of the Neural Processing of Cartoon Facial Attractiveness

#### N170

The differences in N170 latency between genders and among paint modes were significant. N170 latency was shorter for females *vs* males [$F(1, 22) = 7.24$, $P < 0.05$, Table 1]. N170 latency was shorter for G [158.4 (SD, 18.67) ms] than for CG [161.3 (18.13) ms], and SF [166.2 (20.42)] $F(1.42, 31.33) = 15.61$, $P < 0.001$. For N170 amplitude, a significant interaction of gender × attractiveness was found [$F(1, 22) = 8.13$, $P < 0.01$]. Simple effect analysis reflected a larger amplitude for attractive cartoon faces [–3.41 (SD, 3.35) μV] than unattractive cartoon faces [–3.06 (2.92) μV] in males [$F(1, 142) = 8.24$, $P < 0.01$]; and a smaller amplitude for attractive cartoon faces [–5.25 (6.71) μV] than unattractive cartoon faces [–5.47 (7.23) μV] in females [$F(1, 142) = 4.40$, $P < 0.05$] (Fig. 2). No other differences were significant.

#### VPP

The difference in VPP latency between genders was significant, with a shorter latency for females [$F(1, 22) = 7.31$, $P < 0.05$] (Table 1). The main effect of paint mode in VPP latency was significant [$F(2, 44) = 103.24$, $P < 0.001$], with a shorter latency for G [152.5 (SD, 8.94) ms] than for CG [158.4 (10.21) ms] and for SF [165.6 (11.80) ms]. There were no significant differences in VPP amplitude between genders, paint modes, and other comparisons. The reported effects of early frontal positivity in frontal sites and early posterior negativity in temporal and occipital sites with real faces were not found in the processing of cartoon facial attractiveness (Fig. 2).

#### LPC

In the time-window from 400 to 600 ms, ANOVA revealed significant main effects of attractiveness [$F(1, 70) = 4.05$, $P < 0.05$], gender [$F(1, 70) = 5.84$, $P < 0.05$] (Table 1), and region [$F(1.32, 91.72) = 92.44$, $P < 0.001$]. Multiple comparison tests showed a larger positivity for the attractive than the unattractive cartoon faces; a more pronounced positivity for females than males; and the mean LPC amplitude increased significantly from the anterior to the posterior regions (Fig. 2). ANOVA also revealed two significant interactions: paint mode × gender [$F(1, 140) = 4.38$, $P < 0.05$] and attractiveness × gender [$F(1, 70) = 10.26$, $P < 0.01$].

The results of simple effect analysis showed that the LPC mean amplitude in females was significantly larger than in males for the different paint modes [CG, $F(1, 430) = 36.59$, $P < 0.001$; G, $F(1, 430) = 23.82$, $P < 0.001$; SF, $F(1, 430) = 7.15$, $P < 0.01$]. Besides, both males and females showed significant differences in the mean LPC amplitudes among the CG, G, and SF modes [females, $F(2, 860) = 4.33$, $P < 0.05$; males, $F(2, 860) = 7.80$, $P < 0.001$]. Further, there was larger positivity for females [attractive: 12.86 (SD, 5.53) μV; unattractive: 13.25 (6.19) μV] than males [attractive: 11.37 (6.55) μV; unattractive: 9.66 (5.05) μV] in processing both attractive and unattractive cartoon faces [attractive: $F(1, 646) = 9.77$, $P < 0.01$; unattractive: $F(1, 646) = 65.35$, $P < 0.001$]. The mean LPC amplitude for attractive cartoon faces in males was significantly larger than for unattractive faces, $F(1, 646) = 47.15$, $P < 0.001$; but no significant difference was found in females (Fig. 2).

The topographies of the ERP curves (250–400 ms and 400–600 ms) were characterized by LPC-typical parietocentral positivities, indicating a wide scalp distribution of the attractiveness evaluation effect (Fig. 3).

### Behavioral Responses after ERP Experiments

Paint mode significantly influenced the cartoon facial

**Table 1. Latency and amplitude of ERP components in different genders during cartoon facial attractiveness evaluation (SD in parentheses)**

| | N170 | | VPP | | LPC | |
|---|---|---|---|---|---|---|
| | Male | Female | Male | Female | Male | Female |
| Latency (ms) | 169.4 (17.02) | 154.5 (18.60) | 163.4 (11.2) | 154.2 (10.1) | — | — |
| Amplitude (μV) | −3.23 (3.14) | −5.36 (6.95) | 15.07 (4.2) | 17.85 (8.0) | 10.44 (6.06) | 13.01 (5.97) |

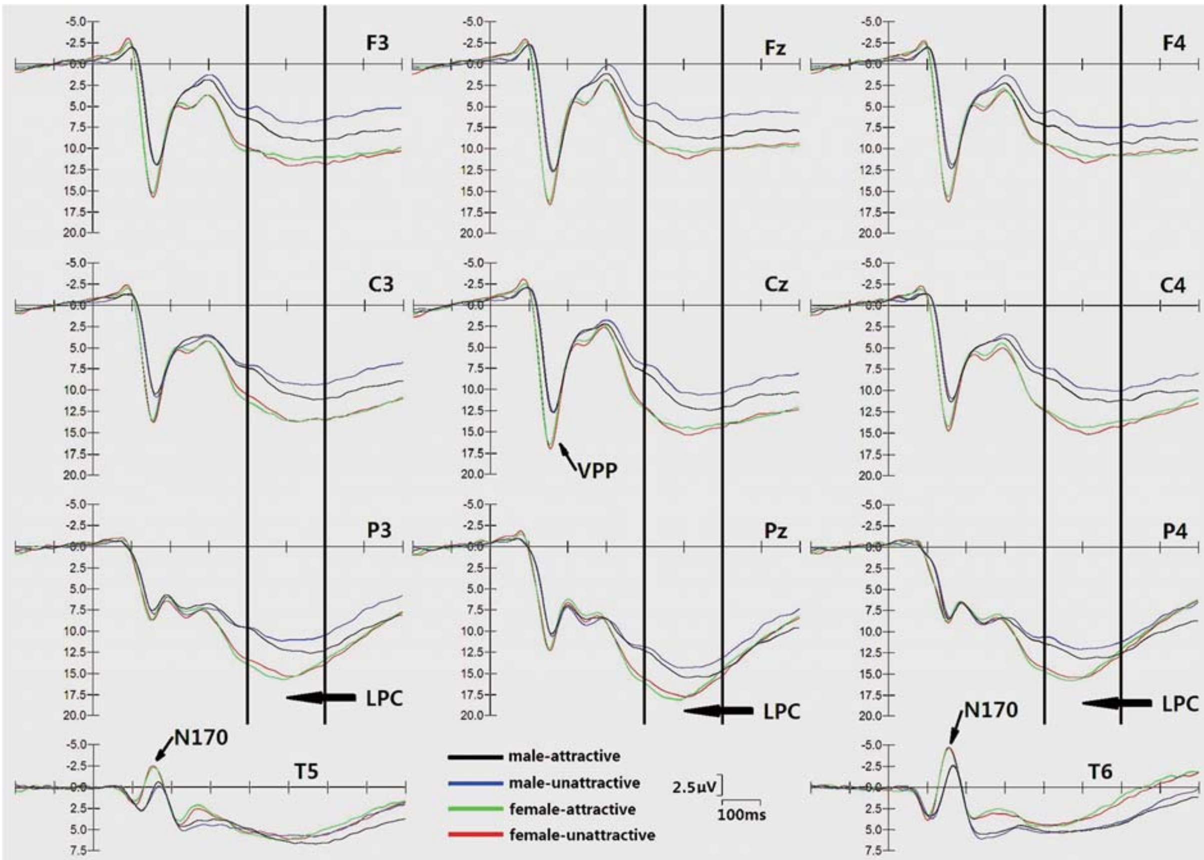


**Fig. 2.** **Grand-average ERP responses to attractive and unattractive cartoon faces in both genders during the evaluation of attractiveness.**

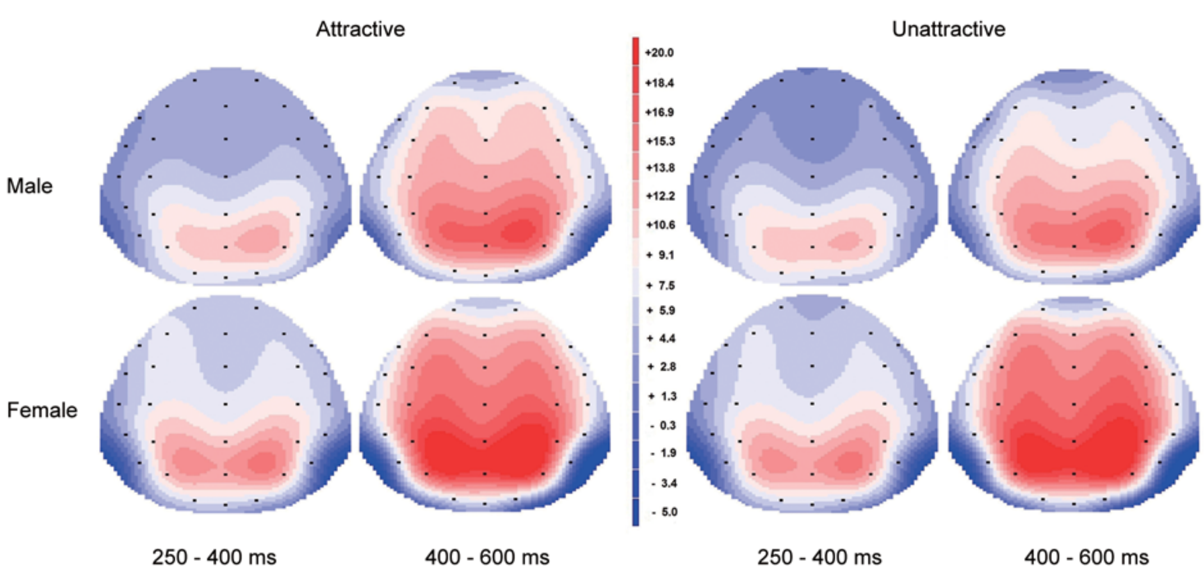


**Fig. 3.** **Scalp topographic maps for the 250–400 ms and 400–600 ms time-windows of the LPC effect in both genders during the evaluation of cartoon facial attractiveness.**

attractiveness scores [$F$(1.97, 1423.64) = 184.82, $P$ < 0.05]: the mean score for the CG mode [3.02 (1.13)] was significantly higher than those for the G [2.65 (1.10)] and SF modes [2.52 (1.10)] ($P$ <0.01). The difference in facial attractiveness scores between the genders was also significant, with higher scores for females [$F$(1, 4348) = 11.81, $P$ <0.01]. A significant interaction of gender × paint mode was found in the attractiveness evaluation [$F$(2.00, 8675.72) = 45.29, $P$ <0.001]. Simple effect analysis reflected higher scores for CG [3.04 (1.13)] than G [2.69 (1.09)] and SF [2.36 (1.14)] in males [$F$(2, 8696) = 200.54, $P$ <0.001] and higher scores for CG [3.01 (1.13)] than G [2.61 (1.11)] and SF [2.68 (1.05)] in females [$F$(2, 8696) = 97.54, $P$ <0.001].

## DISCUSSION

To our knowledge, this is the first investigation of the neural responses to cartoon facial attractiveness and the influence of paint mode.

### Time-Course of ERPs Associated with Cartoon Facial Attractiveness Assessment

The pattern of ERP responses showed a robust effect of attractiveness on late cartoon face processing (400–600 ms). The LPC amplitudes for attractive cartoon faces were significantly higher than those for unattractive cartoon faces in different parts of the brain. This late modulation is consistent with the results of previous studies[20, 22, 24, 25] using real faces. Changes of LPC are thought to be related to the pleasure of stimuli, facial appearance, and relationship with the subject[13, 14, 19, 24]. But a previous study suggested that the elevated LPC magnitude might be a response to a general aesthetic appraisal of beauty (or symmetry), rather than facial attractiveness *per se*, as found for abstract patterns by Hofel and Jacobsen (2007) in an ERP study that found a right-lateralized late effect after 500 ms[27]. Because LPC activity reflects task-related, evaluative processes, and our task was to explicitly assess cartoon facial attractiveness, we considered this elevated LPC to be related to the evaluation of facial beauty. Thus, the mean LPC amplitude at the Pz electrode (where the value was highest) was taken as a specific electrophysiological indicator of cartoon facial attractiveness.

The main effect of attractiveness on early cartoon face processing was not significant as shown in the N170 and VPP. But the interaction between gender and attractiveness showed that N170 amplitude was larger for attractive than for unattractive cartoon faces in males. This reflected men's facilitated selection of attractiveness information at the early stage, which may be attributed to the fact that men are more attentive to cues like facial beauty[22].

### Effects of Paint Mode on Cartoon Facial Attractiveness Processing

Spatial frequency, a feature of visual stimuli, affects the early components of ERP[28]. The cartoon faces drawn in CG mode were similar to broadband frequency faces, while those drawn in G mode were similar to low spatial frequency faces, and finally, the faces drawn in SF mode were similar to high spatial frequency faces (Fig. 1). The results showed that the N170 and VPP latencies evoked by SF cartoon faces were significantly longer than that by G cartoon faces. The significantly longer N170 latency evoked by high spatial frequency faces than low spatial frequency faces is consistent with the report by Shi *et al.* (2010)[29]. This is likely because the high-frequency spatial information carries partial details, which require fine processing after the large-scale processing of low-frequency spatial information. Another study also found that the influence of spatial frequency on face classification is mainly reflected in the N170 amplitude[30]. But such an amplitude difference was not found in this study. Thus, early ERP components related to encoding face configuration, like N170 and VPP, were influenced by paint mode.

Our behavioral results also demonstrated that the main effects of paint mode were significant. The scores for CG were higher than those for the other two paint modes. This reflected a preference for the CG cartoon faces, which may be due to their richness of hue and color brilliance.

### Effects of Gender on Processing Cartoon Facial Attractiveness

The latency of N170 and VPP in males was significantly longer than that of females, while the amplitudes of N170, VPP, and LPC in males were lower than in females. These findings are in accord with our previous study[31] and Gai's study[32]. The tendencies of VPP and N170 were consistent, which may be due to the fact that VPP and N170 are "both sides" of the same source in the brain[12]. All the above results suggested that females have higher processing speed and intensity for cartoon faces than males. Gender differences in the assessment of facial attractiveness may be based on brain activity differences between genders[22, 33-36]. For instance, fMRI studies reveal sex differences in the recruitment of the orbitofrontal cortex during facial attractiveness assessment[37, 38].

Furthermore, the interaction between gender and attractiveness found for LPC also supported the gender difference hypothesis, as the mean LPC amplitude for attractive cartoon faces in males was significantly larger than that for unattractive faces, while no significant difference was found in females. As LPC reflected attentional engagement in facial attractiveness assessment, this suggests that men's brains are hard-wired to be more attentive to facial beauty, even in cartoons.

### Differences in the Processing of Cartoon Facial Attractiveness among Different Brain Areas

Explicit aesthetic judgment is associated with distributed neural structures. The fusiform face area, the lateral occipital cortex, and the medially adjacent regions are activated automatically by beauty and may serve as a neural trigger for the pervasive effects of attractiveness[39]. Activation within the reward system, including the orbitofrontal cortex, nucleus accumbens, ventral striatum, anterior cingulate cortex, and amygdala, may reflect the emotional valence attached to attractive faces[19, 37, 40]. The dorsolateral and medial prefrontal cortex might be involved in the judgment of facial beauty, and parietal circuits may reflect attentional engagement with attractive faces[39]. These findings help us to understand the neural mechanism underlying facial attractiveness assessment. However, these results were mainly obtained through brain imaging techniques with limited temporal resolution. In this experiment, the average reaction time was 612.9 ms, that is, most participants finished the facial attractiveness judgment task within 600 ms[39]. Therefore we studied the timing of assessing cartoon facial attractiveness using the ERP, although its spatial resolution is not adequate for accurate signal localization.

Differences in the N170 latency and amplitude between the hemispheres were not significant. The N170 did not show a pattern of hemispheric dominance, with the right N170 mean amplitude a little higher than the left. Judgment of cartoon facial attractiveness affected the LPC with a central-right deviation pattern on the brain surface (Fig. 3), and the mean LPC amplitude was highest in the parietal lobe. The processing intensity of cartoon facial attractiveness was highest in the parietal region, decreasing slightly from posterior to anterior. This observation supports the hypothesis that subcortical structures under the right posterior parietal lobe play an important role in face processing[41]. Our ERP results suggest that the central and right parietal lobe or structures under it play a role in the assessment of cartoon facial attractiveness. This parietal-central-distributed LPC may reflect attentional engagement in the assessment of facial attractiveness[39].

### Research Prospect

In the recent literature, researchers have begun to focus on the internal features of the face and their impact on attractiveness, such as facial proportions and skin color[42, 43]. Three-dimensional images have also been used to study preferences for sex-typical bodily characteristics[44]. The use of animated videos eliminate the possibility of position-dependent, retinotopic adaptation and more closely simulate realistic situations[45]. The findings of these studies suggest that the effects of additional factors, such as the proportions, skin color, texture, and the use of dynamic or three-dimensional cartoon faces, should be considered in future studies of the neuronal processes underlying facial attractiveness. Furthermore, the integration of fMRI and ERP methods[46, 47] will help to obtain high spatiotemporal maps of cartoon facial attractiveness processing in the human brain.

## CONCLUSIONS

In summary, the LPC, which is the ERP component associated with facial attractiveness assessment in real faces, was also notably influenced by the evaluation of cartoon facial attractiveness. This probably reflects a similar task-related evaluative process for both real and cartoon faces. The highest mean amplitude of the LPC was in the parietal lobe, which indicates that the parietal lobe or structures under it may operate in attentional engagement for the assessment of both real and cartoon facial attractiveness. Facilitated selection of attractiveness information at the early stage, and attentional enhancement of attractive faces at the late stage, which occur for real faces, only existed in males when assessing cartoon faces. This may be because men are more attentive to cues like facial beauty. The processing speed and intensity of cartoon faces in females were both higher than those in males, similar to results with real faces, and this may be based on brain activation differences between the genders. Paint mode modulated the early encoding of facial structures and the late evaluative processing of faces in the assessment of cartoon facial attractiveness. The early modulation effect of paint mode may be related to the spatial frequency of pictures, while the differences in LPC are probably induced by the differences of hue and the brightness of pictures in different paint modes.

**ACKNOWLEDGEMENTS**

This work was supported by the New Talent Program of Zhejiang Province, China (2013R404046). We thank Prof. Yiping Du for modification of the English language.

Received date: 2013-04-17; Accepted date: 2013-08-22

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