Lip color affects ERP components in temporal face perception processing

Hideaki Tanaka[1],*

[1] *Department of Psychology, Faculty of Psychology, Otemon Gakuin University, Nishiai, 567-0009 Ibaraki, Osaka, Japan*

*Correspondence: tanahide@otemon.ac.jp (Hideaki Tanaka)

This brief report investigates the relationship between the lip color of women's faces and the latency and amplitude of the P1, N170, and early posterior negativity of event-related potential components. To show different color lipsticks affect face perception processing, we used EEG to observe these event-related potential components in 19 participants exposed to visual stimuli under four conditions: red lips, yellow lips, blue lips, and no-makeup. The results indicate a significantly higher attractiveness score for red lips than the other three conditions and a significantly shorter P1 peak latency for red lips than blue lips or no-makeup. This may reflect that red lips attract attention more than blue or natural lips in the early stages of face processing. The results indicate that the peak of early posterior negativity for red lips occurred significantly longer than for yellow lips, blue lips, or no-makeup. Early posterior negativity amplitudes were significantly larger to red lips than blue lips or no-makeup. These results may indicate that, at later stages of face processing, the high attractiveness of red lips is associated with slower and careful processing. In contrast, blue lips, which have a low attractiveness score, are processed speedily and carelessly. These present results suggest a novel possibility that P1 and early posterior negativity can be used as a biomarker for temporal face perception processing of facial attractiveness in the human brain.

Keywords

Early posterior negativity; N170; P1; Event-related potential; Lip color; Temporal face perception processing, EEG

1. Introduction

Event-related brain potentials (ERPs) have been recorded in response to various aspects of facial perception, from which face-sensitive P1, N170, and early posterior negativity (EPN) components have been identified. P1 consists of a sharp positive increase in the ERP, appearing about 100 ms after human faces presentation. The P1 component is reported to relate the perception of low-level visual features of the human face, such as color [1–6]. Previous studies reported that P1 has a medial or lateral-occipital scalp distribution [2, 7–14]. Moreover, the neural generators in the human brain of P1 are indicated to lie adjacent to the occipital face area (OFA) [15, 16].

The N170 has been related to face perception and structural encoding of human faces [8, 17, 18]. This component comprises a sharp increase in ERP negativity, which is maximal close to 170 ms after presentation of the human faces and distributed over the posterior temporal region of the human scalp [17, 19–22]. N170 amplitude is larger for human faces than other objects, including hands, cars, houses, furniture, plane figures, solid figures, and scrambled faces [7, 17, 18, 23–25]. The generators of N170 have been indicated to be located in the fusiform face area (FFA) in human brains [16, 26]. Rossion and Caharel [3] reported that processing of faces represented by both P1 and N170 components can be functionally differed, with P1 relating low-level visual features and N170 reflecting the high-level perception of human faces. In particular, the N170 component is related to changes in facial perception resulting from cosmetic makeup [27, 28], suggesting its usefulness to investigate the effect of red lipstick on face perception.

The EPN component is sensitive to the emotional content of faces [29, 30]. In addition, a larger EPN amplitude is reported for faces perceived to be attractive relative to those perceived to be unattractive [31]. The EPN is observed between 150 and 350 ms after stimulus onset and is usually distributed across the posterior temporal scalp [29, 32, 33].

Haxby *et al.* [34] suggested a cortical model of the neural system for face perception in human brains. Pitcher *et al.* [15] subsequently modified Haxby's cortical model by adding temporal information from intracranial ERP studies [35–38]. In the latter model [15], early stages of face processing occur in three regions of the occipitotemporal visual cortex, specifically the OFA, FFA, and superior temporal sulcus. Meanwhile, later stages of face processing occur in other regions (e.g., amygdala, insula, limbic system, and auditory cortex) and the above three regions: OFA, FFA, and superior temporal sulcus.

The P1 and N170 neural generators are reported in the OFA [15, 16] and FFA [16, 26]. Therefore, these components may reflect the early stages of face processing. At later stages, both models [15, 34] assume interactions between the three regions of the occipitotemporal visual cortex (OFA, FFA, and superior temporal sulcus) and the other regions above (amyg-

dala, insula, and limbic system). Therefore, because the limbic system processes emotions in the later stages of face processing [34], the emotion sensitive-EPN component reflects these later stages.

DaSilva *et al.* [39] suggested the significance of the mouth in facial processing. Expressions featuring teeth (open mouth) elicited significantly larger N170 amplitudes relative to expressions without teeth (close mouth) [39]. Pesciarelli *et al.* [40] reported significantly larger N170 amplitudes for the mouth relative to the eyes in upright faces. Krautheim *et al.* [41] showed that lip-protrusion was processed in the superior temporal cortices, the temporal-occipital junctions, the postcentral gyri, and the left fusiform gyrus in the human brain. Cortical models for face perception processing [15, 34] indicated superior temporal sulcus in the human brain perception of lip movement. Tanaka [27] showed that facial cosmetics exert a greater influence on mouth processing than the eyes by N170 amplitudes. Combined with these previous findings [15, 27, 34, 39–41], it may be presumed that the mouth compared to the eyes, exert a greater influence on face perception processing. Therefore, these previous studies [15, 27, 34, 39–41] support the notion that lip color affects face-sensitive event-related potential components.

The purpose of our work is to examine the relationship between lip color and P1, N170, and EPN during women's face perception. Specifically, Tanaka [27] reported that a Lipstick condition (red lip painting) elicited a larger N170 amplitude than a no-makeup condition. N170 would be particularly sensitive to lip color but did not examine whether lip colors other than red affect ERP components (P1, N170, and EPN). We compared face-sensitive ERP components (P1, N170, and EPN) were compared for four lip color conditions (red lips, yellow lips, blue lips, and no-makeup). Since the P1 and N170 components reflect early stages of face processing and the EPN component reflects later stages of face processing [15, 34], P1 and N170 were predicted to be sensitive to the red lips condition, and that the emotion sensitive-EPN would be sensitive to both the red (enhanced EPN amplitude) and blue lips condition (reduced EPN amplitude). Moreover, Leder *et al.* [42] showed that the more attractive the face became, the longer it looked. Therefore, attracting attention by changing facial attractiveness using different color lipsticks lip color may affect the emotion sensitive-EPN peak latency.

2. Materials and methods

2.1 Participants

Nineteen healthy, right-handed, East Asian participants (men, n = 11, women, n = 8; mean age (standard deviation: SD) = 21.1 (1.08) years, age range = 18–23 years) participated. According to the Declaration of Helsinki, all participants had a normal or corrected-to-normal vision and provided written informed consent. The ethics committee of Otemon Gakuin University provided ethical approval, and participants were recruited from the student population at Otemon Gakuin University.

2.2 Stimuli

The stimuli of eight young, adult East Asian women's faces were unfamiliar to all participants. The faces were collected from the Internet[1] and faces had neutral expressions. In total, 32 faces were made with each of the eight model faces presented in four conditions: red lips (wearing red lipstick), yellow lips (wearing yellow lipstick), blue lips (wearing blue lipstick), and no-makeup (no lipstick applied).

Each face stimulus was digitally edited to lip color and reconstructed from the original using the YouCan Makeup on an iPad (http://jp.perfectcorp.com/#ymk) (Fig. 1A, [27]). No-makeup faces were used for adaptation stimulus and were presented before each target stimulus (red lips, yellow lips, blue lips, and no-makeup) to compare adaptation stimulus and each target stimulus. Furthermore, an iPad also digitally edited each face image to the same hairstyle and hair color (black). Finally, all face stimuli were presented in the same orientation on a background of the white color screen by Adobe Photoshop 12.

All face stimuli had the same visual angle of $3.4° × 4.0°$ (horizontal × vertical) and were presented as a front-facing view equalized for mean luminance (luminance values = 7.7 cd/m^2) (Fig. 1A). All faces were presented at the center of a 22-inch cathode ray tube (CRT) monitor (Mitsubishi, Diamondtron M2, RDF223G, Chiyoda, Tokyo, Japan). This CRT monitor had a screen resolution of 1280 × 1024 and a refresh rate of 100 Hz and was placed 80 cm in front of the participants.

We used faces with neutral expressions because N170 is affected by emotional expression [43–48]. However, previous studies reported larger N170 amplitudes of other-race facial stimuli than own-race facial stimuli [49, 50]. All face stimuli were of East Asian women only, and all participants were recruited from East Asian people. Furthermore, because N170 amplitude varies by the face viewpoint [18, 51], all faces were presented in a front-facing view. Similarly, because Tanaka [52] reported that a change in hair length influences N170 latency, we presented faces with the same hair length, same hairstyle and hair color (black) for all conditions to all participants. Finally, Russell [53] reported that enhanced luminance contrast between facial features (lips and eyes) and facial skin increases attractiveness and femineity of women's faces but decreases the attractiveness and masculinity of men's faces. Therefore, we used only women's faces as a stimulus.

2.3 Experimental procedure and attractiveness scores

All participants were seated comfortably 80 cm in front of a 22-inch CRT monitor which faces were presented by a Multi Trigger System (Medical Try System, Kodaira, Tokyo, Japan). Each trial comprised as follow: (i) a fixation mark (+) was presented for 500 ms after a white color screen as an in-
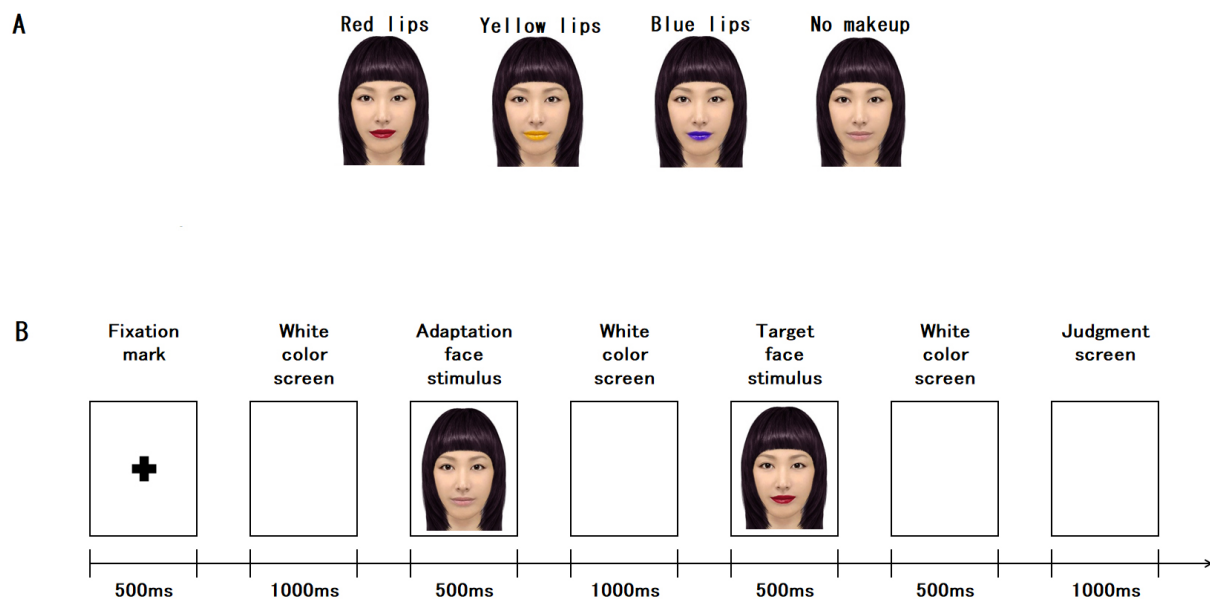
Fig. 1. Example of stimuli and the single trial. (A) Examples of four face stimuli. (B) Timeline of the single trial. This figure has been modified from Tanaka [27].

terval of 1000 ms was presented; (ii) an adaptation face stimulus (no-makeup) was presented for 500 ms after a white color screen as an interval of 1000 ms was presented; (iii) a target face stimulus (red lips, yellow lips, blue lips, or no-makeup) was presented for 500 ms after a white color screen as an interval of 500 ms was presented; and (iv) a judgment screen was presented for 1000 ms (Fig. 1B). The inter-trial interval varied randomly between 500–1500 ms.

On the judgment screen, participants rated all face stimuli for attractiveness. Attractiveness was assigned a number, defined as an attractiveness score: 1 = very unattractive; 2 = unattractive; 3 = attractive; and 4 = very attractive. All participants were instructed to compare the adaptation face and the target face and rate the attractiveness. Participants responded by pressing one button corresponding to 1, 2, 3, and 4 with their index finger of the right hand to show the attractiveness score. Reaction times (RTs) were measured from beginning with the onset of the judgment screen to finishing when participants had responded with a button press.

Furthermore, responses <250 ms or >1000 ms were excluded from the average RTs. After 10 practice trials, all participants performed by three blocks of 100 trials (300 trials total). Four target face stimuli (red lips, yellow lips, blue lips, or no-makeup) were presented with equal probability in random order. The adaptation and target faces belonging to the same person were presented in each trial.

2.4 Electrophysiological recording and analysis

Electroencephalography (EEG) and electrooculography (EOG) data were recorded with a 128-channel Sensor Net and the standard EGI Net Station 5.2.01 package (GES300, Electrical Geodesic, Inc., Eugene, USA). Moreover, EEG data were obtained with Ag/AgCl electrodes according to the 10-5 system [54, 55]. The 128 electrodes were referenced to Cz and next re-referenced offline to the common average. Electrodes for EOG recording are placed above, below, and at the outer canthi of both eyes. EEG and EOG recording had been set a band-pass filter at 0.01–30 Hz, and electrode impedance maintained <5 kΩ. EEG and EOG signals were recorded with a sampling rate of 500 Hz. For artifact rejection, all trials where both the vertical and horizontal EOG voltages >140 μV during the period from 500 ms before to 1000 ms after stimulus presentation were excluded from the averages. Moreover, the average number of trials to evoke all ERP waveforms after artifact rejection was 65 in the four lip conditions (red lips, yellow lips, blue lips, and no-makeup).

Stimulus-locked ERPs were obtained separately for each of the four target faces (red lips, yellow lips, blue lips, or no-makeup) from 200 ms before to 400 ms after stimulus presentation. Baseline corrected using the 200 ms pre-stimulus window. For P1 analyses, electrode sites O1 and O2 were analyzed. The positive peak of the ERP in the window from 60 ms to 110 ms after stimulus presentation was defined as P1 latency and amplitude. For N170 and EPN analyses, electrode sites P7, PO7, PO8, and P8 were analyzed. The negative peak of the ERP in the window from 110–180 ms after stimulus presentation was defined as N170 latency and amplitude; the negative peak of the ERP in the window from 200–300 ms after stimulus presentation was defined as the EPN latency and amplitude. The mean RTs and mean ERP latencies and amplitudes (peak-to-peak) were calculated for each participant for each stimulus type by manual inspection. The mean ERP latencies, the average of 19 max points for each ERP latencies in each of the above time windows, was calculated.
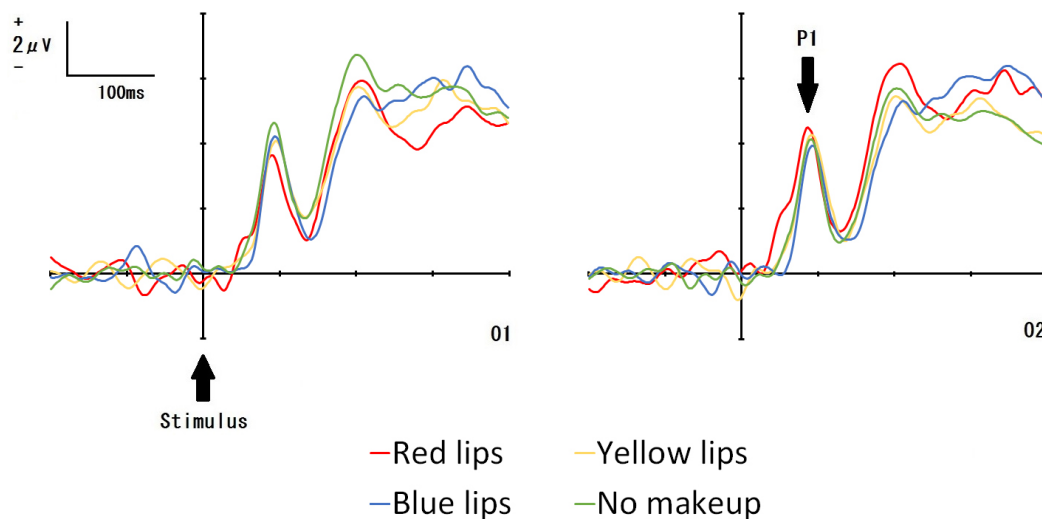
Fig. 2. Stimulus-locked average event-related potential (ERP) waveforms (P1 component) at O1 and O2 for each condition.

Table 1. Mean attractiveness scores and mean reaction times (ms) for the four lip conditions.

	Red lips		Yellow lips		Blue lips		No-makeup	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Attractiveness scores	3.24	0.64	1.65	0.50	1.46	0.52	2.78	0.64
Reaction times	348.12	68.54	345.01	58.15	360.83	76.01	376.11	79.41

2.5 Statistical analysis

The attractiveness scores and RTs were analyzed with a one-way repeated-measures analysis of variance (ANOVA) for the four lip conditions as the main effect (red lips, yellow lips, blue lips, or no-makeup). Moreover, to test for a participant-gender effect of the facial attractiveness ratings, the attractiveness scores were also analyzed with two-way (4 $\times$ 2) repeated-measures ANOVA across the four lip conditions and participant-gender (men, women) as the main effect. P1 latency and amplitude were analyzed with two-way (4 $\times$ 2) repeated-measures ANOVA across the four lip conditions and two electrodes (O1, O2) as the main effect. N170 and EPN latencies and amplitudes were analyzed with three-way (4 $\times$ 2 $\times$ 2) repeated-measures ANOVA across the four lip conditions, two hemispheres (left, right), and two electrodes (P7 vs. PO7, PO8 vs. P8) as the main effect. Next, we performed multiple comparisons with the Bonferroni correction if there were significant main effects. ANOVAs of ERPs data were analyzed with Greenhouse-Geisser corrections applied to *p* values.

3. Results

3.1 Attractiveness scores and behavioral performance

Table 1 shows the mean attractiveness scores and RTs for the four lip conditions (red lips, yellow lips, blue lips, and no-makeup). A significant main effect was observed for lip condition on the attractiveness score ($F(3, 54) = 50.09$, $p < 0.0001$, $\eta_p^2 = 0.74$). Multiple comparisons with the Bonferroni correction indicated significantly higher attractiveness scores for red lips than no-makeup ($p < 0.01$). In contrast, the attractiveness scores for no-makeup were significantly higher than for yellow lips ($p < 0.0001$) and blue lips ($p < 0.0001$). Moreover, the attractiveness scores (mean $\pm$ standard deviation) in each participant-gender for the four lip conditions are as follow: The mean attractiveness scores of red lips condition was 3.09 ± 0.71 in men while it was 3.43 ± 0.46 in women. The mean attractiveness scores of yellow lips condition were 1.51 ± 0.44 in men while it was 1.84 ± 0.52 in women. The mean attractiveness scores of blue lips condition were 1.48 ± 0.58 in men while 1.44 ± 0.42 in women. The mean attractiveness scores of no-makeup conditions were 2.82 ± 0.67 in men while 2.72 ± 0.58 in women. A significant main effect was observed for lip condition on the attractiveness score ($F(3, 51) = 48.92$, $p < 0.0001$, $\eta_p^2 = 0.74$). However, there was no significant effect of participant-gender ($F(1, 17) = 0.57$, $p = 0.46$, $\eta_p^2 = 0.03$) or a lip condition $\times$ participant-gender interaction ($F(3, 51) = 0.90$, $p = 0.417$, $\eta_p^2 = 0.05$) on the attractiveness score. Multiple comparisons with the Bonferroni correction indicated significantly higher attractiveness scores for red lips than no-makeup ($p < 0.01$). In contrast, the attractiveness scores for no-makeup were significantly higher than for yellow lips ($p < 0.001$) and blue lips ($p < 0.001$).

A significant main effect was also detected for lip condition on RTs ($F(3, 54) = 3.17$, $p = 0.039$, $\eta_p^2 = 0.15$). However, there was no significant effect of multiple comparisons with Bonferroni correction.

Table 2. Mean P1 latency (ms) and amplitude (μV) for all conditions at two electrode sites.

Electrode	Red lips		Yellow lips		Blue lips		No-makeup	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
P1 latency								
O1	92.21	13.04	94.95	16.86	97.37	11.52	96.53	13.39
O2	86.74	14.34	92.00	13.78	94.11	10.81	96.32	15.74
P1 amplitude								
O1	5.51	2.79	5.67	3.07	5.35	2.85	5.41	3.02
O2	6.25	3.84	5.91	2.91	5.06	2.66	5.16	3.09

Table 3. Mean N170 latency (ms) and amplitude (μV) for all conditions at four-electrode sites.

Electrode	Red lips		Yellow lips		Blue lips		No-makeup	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
N170 latency								
P7	140.42	10.91	141.58	14.53	144.00	13.87	136.21	12.61
PO7	139.47	12.68	139.89	13.24	141.16	12.84	135.68	14.91
PO8	134.84	14.74	134.95	14.15	140.95	14.92	128.11	15.33
P8	134.11	12.82	136.42	12.42	138.63	16.31	129.89	14.65
N170 amplitude								
P7	4.33	2.69	3.84	2.37	3.88	2.78	4.22	2.79
PO7	4.85	3.13	4.67	2.87	4.78	2.98	5.06	3.12
PO8	5.96	3.47	6.10	3.01	5.10	3.09	5.76	2.76
P8	5.40	3.08	5.66	2.76	4.89	2.16	5.03	2.27

3.2 P1 latency and amplitude

Fig. 2 showed ERP waveforms for the four lip conditions. An increased positive component lasted from 60 ms to 110 ms after face onset for each condition. This positive component was identified as P1. Table 2 shows the mean P1 peak latency for the four lip conditions at two electrode sites.

There was a significant main effect of lip condition on P1 latency ($F(3, 54) = 2.86$, $p = 0.05$, $\varepsilon = 0.75$, $\eta_p^2 = 0.14$). However, there was no significant effect of electrode ($F(1, 18) = 2.62$, $p = 0.123$, $\varepsilon = 1.00$, $\eta_p^2 = 0.14$) or a lip condition $\times$ electrode interaction ($F(3, 54) = 1.09$, $p = 0.349$, $\varepsilon = 0.72$, $\eta_p^2 = 0.06$) on P1 latency. Multiple comparison with Bonferroni correction indicated a significantly shorter P1 peak latency for red lips than for blue lips and no-makeup ($p < 0.05$). In contrast, there was no significant main effect of lip condition and electrode and lip condition $\times$ electrode interaction on P1 amplitude (peak-to-peak) (Table 2).

3.3 N170 latency and amplitude

Fig. 3 shows ERP waveforms for the four lip conditions. For each condition, an increased negative component was evident between 110 ms to 180 ms after the onset of the face stimulus. This negative component was identified as N170.

Table 3 shows the mean N170 peak latency for each lip condition of four electrode sites. There were significant main effects of lip condition ($F(3, 54) = 5.35$, $p = 0.007$, $\varepsilon = 0.74$, $\eta_p^2 = 0.23$) and hemisphere ($F(1, 18) = 4.95$, $p = 0.039$, $\varepsilon = 1.00$, $\eta_p^2 = 0.22$) on N170 latency. However, there was no significant main effect of electrode on N170 latency ($F(1, 18) = 2.44$,

$p = 0.136$, $\varepsilon = 1.00$, $\eta_p^2 = 0.12$). Moreover, there were no significant interactions between any two variables (lip condition $\times$ hemisphere, lip condition $\times$ electrode, hemisphere $\times$ electrode), or between all three variables (lip condition $\times$ hemisphere $\times$ electrode) (all $p > 0.05$). The N170 peak for no-makeup occurred significantly earlier than for yellow lips and blue lips ($p < 0.05$). The N170 peak also was earlier in the right hemisphere than in the left ($p < 0.05$).

Table 3 also shows the mean N170 amplitude (peak-to-peak) for four lip conditions of four electrode sites. There was a significant main effect of hemisphere on N170 amplitude ($F(1, 18) = 5.88$, $p = 0.026$, $\varepsilon = 1.00$, $\eta_p^2 = 0.25$). However, there were no significant main effects of lip condition ($F(3, 54) = 1.24$, $p = 0.305$, $\varepsilon = 0.90$, $\eta_p^2 = 0.06$) or electrode ($F(1, 18) = 0.94$, $p = 0.346$, $\varepsilon = 1.00$, $\eta_p^2 = 0.05$) on N170 amplitude. In addition, there were no significant interactions between lip condition $\times$ hemisphere or lip condition $\times$ electrode, or between all three variables (all $p > 0.05$). However, there was a significant interaction of hemisphere $\times$ electrode on N170 amplitude ($F(1, 18) = 6.20$, $p = 0.023$, $\varepsilon = 1.00$, $\eta_p^2 = 0.26$). Simple effect analyses showed that the N170 amplitude of P8 was significantly larger than of P7.

3.4 EPN latency and amplitude

For each condition, an increased negative component was evident between 200 ms to 300 ms after the onset of the face stimulus (Fig. 3). This negative component was identified as EPN. Table 4 shows the mean EPN peak latency for each lip condition of four-electrode sites. There were significant

Table 4. Mean early posterior negativity (EPN) latency (ms) and amplitude (μV) for all conditions at four-electrode sites.

Electrode	Red lips		Yellow lips		Blue lips		No-makeup	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
EPN latency								
P7	277.89	29.30	245.37	24.98	249.26	20.20	262.32	25.19
PO7	277.89	31.88	250.21	20.24	242.74	16.25	260.42	26.35
PO8	260.11	18.43	243.79	17.33	246.32	19.63	244.74	16.38
P8	264.32	17.56	243.89	18.24	242.21	19.70	241.68	17.79
EPN amplitude								
P7	3.23	2.74	2.24	1.37	2.12	1.57	2.44	2.07
PO7	3.81	2.34	2.47	1.16	1.82	1.46	2.43	1.83
PO8	3.30	2.04	2.71	1.86	1.70	1.60	2.01	1.71
P8	2.92	1.38	2.27	1.51	1.47	1.23	1.83	1.30

main effects of lip condition ($F(3, 54) = 17.68$, $p < 0.0001$, $\varepsilon = 0.83$, $\eta_p{}^2 = 0.50$) and hemisphere ($F(1, 18) = 12.35$, $p = 0.002$, $\varepsilon = 1.00$, $\eta_p{}^2 = 0.41$) on EPN latency. However, there was no significant main effect of electrode on EPN latency ($F(1, 18) = 0.23$, $p = 0.638$, $\varepsilon = 1.00$, $\eta_p{}^2 = 0.01$). In addition, there were no significant interactions between any two variables or between all three variables (all $p > 0.05$). The peak of EPN for red lips occurred significantly later than for yellow lips, blue lips, and no-makeup ($p < 0.05$). The EPN peak also was earlier in the right hemisphere than in the left ($p < 0.05$).

Table 4 also shows the mean EPN amplitude (peak-to-peak) for each lip condition of four electrode sites. There was a significant main effect of lip condition on EPN amplitude ($F(3, 54) = 7.49$, $p < 0.001$, $\varepsilon = 0.85$, $\eta_p{}^2 = 0.29$). In contrast, there were no significant main effects of hemisphere ($F(1, 18) = 0.82$, $p = 0.376$, $\varepsilon = 1.00$, $\eta_p{}^2 = 0.04$) or electrode ($F(1, 18) = 1.08$, $p = 0.312$, $\varepsilon = 1.00$, $\eta_p{}^2 = 0.06$) on EPN amplitude. In addition, there were no significant interactions between any two variables, or between all three variables (all $p > 0.05$). The EPN amplitude for red lips was significantly larger than that for blue lips and no-makeup ($p < 0.05$).

4. Discussion

The relationship between lip colors and three ERP components (P1, N170, and EPN) investigated women's face perception. Face-sensitive ERP components (P1, N170, and EPN) across four lip color conditions (red lips, yellow lips, blue lips, and no-makeup) were compared with the attractiveness scores and RTs. The results demonstrated that the attractiveness scores for red lips were significantly higher than for no-makeup; those for no-makeup were significantly higher than for yellow lips and blue lips. These differences were further reflected in the ERP components.

The P1 peak for red lips occurred significantly shorter than for blue lips and no-makeup. Moreover, the N170 peak for no-makeup occurred significantly earlier than for yellow lips and blue lips, while the N170 peak latency was significantly earlier in the right hemisphere than in the left. Meanwhile, N170 amplitude was significantly larger at P8 than at P7. Furthermore, the EPN peak for red lips showed a signif-

icantly longer latency than for yellow lips, blue lips, and no-makeup, while EPN peak latency was significantly earlier in the right hemisphere than in the left. In addition, EPN amplitude was significantly larger in response to red lips than to blue lips and no-makeup. Therefore, in the early stages of face processing, as red lips are very attractive, they attract the participants' attention. This is reflected in a significantly shorter P1 peak latency for red lips than for blue lips and no-makeup, significantly lower attractiveness scores. Compared to [27] that P1 amplitude was unaffected by single color lipstick, the present results suggest a novel possibility that P1 can be used as a biomarker for face perception processing of facial attractiveness by various colors lipsticks. In addition, previous studies [56, 57] indicated that the P1 component is related to the positive, rewarding value of stimuli. This may be reflected in a significantly shorter P1 peak latency for red lips, with high attractiveness scores a positive, rewarding value. However, there was no P1 peak latency difference between yellow lips and red lips. It may be because the contrast difference in lip colors also affects P1 peak latency.

At later stages of face processing, red lips' enhanced facial attractiveness is reflected in the significantly longer latency of the emotion sensitive-EPN peak latency for the red lips condition than that for yellow lips, blue lips, and no-makeup had significantly lower attractiveness scores. Leder *et al.* [42] showed that the more attractive the face became, the longer it looked. Our results may suggest that red lips are slowly and carefully processed at later stages of face processing due to their high attractiveness. In contrast, blue lips are processed speedily and carelessly due to their low attractiveness. The amplitude of the emotion sensitive-EPN component was also significantly larger in response to red lips than to blue lips and no-makeup. These results are consistent with those suggesting that larger EPN amplitudes are observed for attractive faces [31]. These results also support cortical models that suggest the temporal processing of human faces [15, 34]. The EPN component may be sensitive to the emotional content of human faces, reflecting an interaction between the FFA and limbic system, which processes the emotional content of human faces in the later stages of face processing [34]. However,
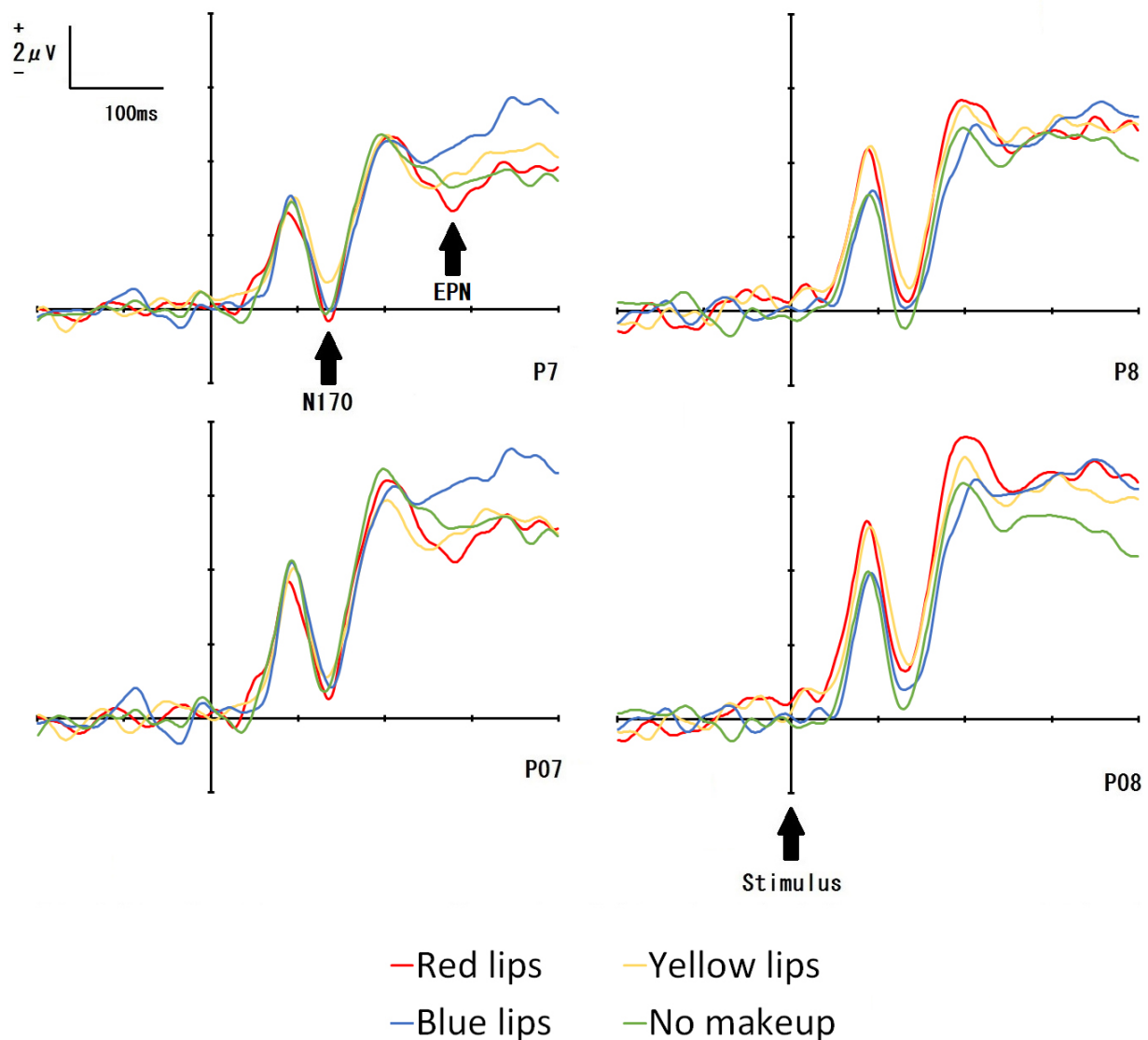
Fig. 3. Stimulus-locked average event-related potential waveforms (N170 and early posterior negativity [EPN] components) at P7, P8, PO7, and PO8 for each condition.

because the task structure will draw the participants' attention to lip colors, this may affect facial processing and produce a pseudo-attraction for lips. To correctly interpret the present results, it is important to note that explicit characteristics of the current experiment may have created a pseudo-attention to lip colors that may not be observed in less biased circumstances.

Although we investigated the relationship between facial attractiveness and face-sensitive ERP components (P1, N170, and EPN), the present results show an indirect correlation between behavioral and neural measures and not a direct causational relationship. In addition, eight different pictures were used. For all 300 trials, each face was presented at least 10 times in total. Therefore, after so many repetitions, faces might become familiar. It may be presumed that this higher than the usual number of repetitions can affect the results obtained.

tained.

Tanaka [27] showed that a lipstick condition (red lips) elicited a significantly larger N170 amplitude than a no-makeup condition. However, N170 amplitude did not differ significantly between an eye shadow condition and the no-makeup condition [27]. In contrast, in the current results, the N170 amplitude for red lips did not differ significantly from the other three conditions (yellow lips, blue lips, and no-makeup). Tanaka manipulated a wider region of the face (including the eyes and mouth), while only a local region was manipulated (the mouth) [27]. Therefore, these inconsistencies in N170 amplitude results may reflect differences in experimental procedures.

Our results demonstrated that the N170 peak for no-makeup occurred significantly shorter than yellow and blue lips. In no-makeup stimuli, the light lip color had low con-

trast, while the deep lip colors in yellow and blue lips had high contrast. Only the no-makeup condition had a light lip color, making it conspicuous among the four conditions. Therefore, it is possible that, in the early stages of face processing, the light lip color in no-makeup attracted more attention from participants than the deep lip colors in yellow and blue lips. In addition, Zhang et al. [58] showed that the repeated high attractive faces tended to elicit a larger N170 amplitude. In contrast, there was no significant difference in N170 amplitude between four lip conditions (red lips, yellow lips, blue lips, and no-makeup). Zhang et al. [58] used gray-scaled faces stimuli, and it may also be presumed that differential contrast of faces stimuli and our results affect inconsistency of N170 amplitude results.

Our results demonstrated that N170 peak latency was significantly earlier in the right hemisphere than in the left, similar to the findings of [52]. Moreover, previous functional magnetic resonance imaging (fMRI) studies reported that N170 neural generators were located in the FFA [16, 26] and the middle and posterior fusiform gyri [59]. Several studies [60–63] have highlighted that processing of face perception is dominant in the FFA in the right hemisphere in humans. In particular, Gao et al. [59] showed larger current density reconstruction (CDR) values in the posterior fusiform gyri and FFA in response to faces than houses, which were also larger on the right hemisphere than on the left. Chance et al. [63] had found that the fusiform gyrus for the right hemisphere of the human brain relative to the left hemisphere contained narrower minicolumns and smaller pyramidal neurons. Taken together, the previous studies [52, 59–63] and the present results support a dominance of face processing in the right brain hemisphere in humans.

As previous studies showed that facial expression processing occurred earlier (N170 and EPN, 150–290 ms post-stimulus onset) than facial attractiveness processing (P3b, 400–700 ms) [64], that high attractive faces increased significantly larger EPN. Larger late positive potentials (LPP) [65], facial attractiveness should also be investigated using other ERP components. We investigated the relationship between the lip color of women's faces and cortical models that suggest temporal processing of human faces [15, 34]. However, we used ERP techniques only. The role of lip color in facial perception should be investigated using additional neuroimaging techniques such as fMRI or magnetoencephalography.

Furthermore, Ikeda et al. [66], facial skin radiance affects facial attractiveness and affective impressions of women's faces. For example, if lips, eyes, and facial skin were simultaneously modified by cosmetic makeup, what effect does this multiplex cosmetic makeup have on facial attractiveness? Together with Ikeda et al.'s [66] results indicate that further research is needed to investigate the relationship between facial attractiveness and ERP components in the multiplex effect of cosmetic makeup on face perception. In addition, Zaki et al. [67] indicated that participants first rated facial attractiveness and subsequently changed their second ratings to conform

to those of other participants. Therefore, further research is needed to investigate facial attractiveness from social processing.

5. Conclusions

The attractiveness scores were significantly higher for red lips than the other three lip conditions. Moreover, the P1 peak for red lips occurred with significantly shorter latency than for blue lips and no-makeup. The EPN peak for red lips also occurred significantly longer than for yellow lips, blue lips, and no-makeup. In contrast, the EPN amplitude was significantly larger in response to red lips than blue lips and no-makeup. These results suggest that red lips attract the participants' attention in the early stages of face processing due to their high attractiveness, which is reflected in the P1 peak latency. The results may also indicate that in later stages of facial processing, the attractiveness of red lips is slowly and carefully processed. In contrast, blue lips are less attractive and, therefore, processed more quickly and carelessly. These present results suggest a novel possibility that P1 and EPN can be used as a biomarker for temporal face perception processing of facial attractiveness in the human brain.

Abbreviations

ERP, event-related potential; EPN, early posterior negativity; OFA, occipital face area; FFA, fusiform face area; fMRI, functional magnetic resonance imaging; CDR, current density reconstruction.

Author contributions

HT conceived and designed the experiments; HT performed the experiments; HT analyzed the data; HT contributed materials; HT wrote the paper.

Ethics approval and consent to participate

I was obtained with the written informed consent of all participants. The ethics committee of Otemon Gakuin University provided ethical approval, and participants were recruited from the student population at Otemon Gakuin University. The ethics code number was 2017017.

Conflict of interest

The author declares no conflict of interest.

References

[1] Dering B, Martin CD, Moro S, Pegna AJ, Thierry G. Face-sensitive processes one hundred milliseconds after picture onset. Frontiers in Human Neuroscience. 2011; 5: 93.

[2] Luo S, Luo W, He W, Chen X, Luo Y. P1 and N170 components distinguish human-like and animal-like makeup stimuli. Neuroreport. 2013; 24: 482–486.

[3] Rossion B, Caharel S. ERP evidence for the speed of face categorization in the human brain: Disentangling the contribution of low-level visual cues from face perception. Vision Research. 2011; 51: 1297–1311.

[4] Susac A, Ilmoniemi RJ, Pihko E, Nurminen J, Supek S. Early dissociation of face and object processing: a magnetoencephalographic study. Human Brain Mapping. 2009; 30: 917–927.

[5] Tarkiainen A, Cornelissen PL, Salmelin R. Dynamics of visual feature analysis and object-level processing in face versus letter-string perception. Brain. 2002; 125: 1125–1136.

[6] Thierry G, Martin CD, Downing P, Pegna AJ. Controlling for interstimulus perceptual variance abolishes N170 face selectivity. Nature Neuroscience. 2007; 10: 505–511.

[7] Eimer M. Does the face-specific N170 component reflect the activity of a specialized eye processor? Neuroreport. 1998; 9: 2945–2948.

[8] Eimer M. Effects of face inversion on the structural encoding and recognition of faces. Evidence from event-related brain potentials. Brain Research. Cognitive Brain Research. 2000; 10: 145–158.

[9] Goffaux V, Gauthier I, Rossion B. Spatial scale contribution to early visual differences between face and object processing. Brain Research. Cognitive Brain Research. 2003; 16: 416–424.

[10] Herrmann MJ, Ehlis A, Muehlberger A, Fallgatter AJ. Source Localization of Early Stages of Face Processing. Brain Topography. 2005; 18: 77–85.

[11] Itier RJ. N170 or N1? Spatiotemporal differences between Object and Face Processing Using ERPs. Cerebral Cortex. 2004; 14: 132–142.

[12] Itier RJ, Taylor MJ. Source analysis of the N170 to faces and objects. Neuroreport. 2004; 15: 1261–1265.

[13] Liu J, Harris A, Kanwisher N. Stages of processing in face perception: an MEG study. Nature Neuroscience. 2002; 5: 910–916.

[14] Okazaki Y, Abrahamyan A, Stevens CJ, Ioannides AA. The timing of face selectivity and attentional modulation in visual processing. Neuroscience. 2008; 152: 1130–1144.

[15] Pitcher D, Walsh V, Duchaine B. The role of the occipital face area in the cortical face perception network. Experimental Brain Research. 2011; 209: 481–493.

[16] Sadeh B, Podlipsky I, Zhdanov A, Yovel G. Event-related potential and functional MRI measures of face-selectivity are highly correlated: a simultaneous ERP-fMRI investigation. Human Brain Mapping. 2010; 31: 1490–1501.

[17] Bentin S, Allison T, Puce A, Perez E, McCarthy G. Electrophysiological Studies of Face Perception in Humans. Journal of Cognitive Neuroscience. 1996; 8: 551–565.

[18] Eimer M. The face-specific N170 component reflects late stages in the structural encoding of faces. NeuroReport. 2000; 11: 2319–2324.

[19] Bentin S, Deouell LY. Structural encoding and identification in face processing: ERP evidence for separate mechanisms. Cognitive Neuropsychology. 2000; 17: 35–55.

[20] Chen J, Liu B, Chen B, Fang F. Time course of amodal completion in face perception. Vision Research. 2009; 49: 752–758.

[21] Peng M, De Beuckelaer A, Yuan L, Zhou R. The processing of anticipated and unanticipated fearful faces: an ERP study. Neuroscience Letters. 2012; 526: 85–90.

[22] Ran G, Zhang Q, Chen X, Pan Y. The effects of prediction on the perception for own-race and other-race faces. PLoS ONE. 2014; 9: e114011.

[23] Eimer M, McCarthy RA. Prosopagnosia and structural encoding of faces. NeuroReport. 1999; 10: 255–259.

[24] George N, Evans J, Fiori N, Davidoff J, Renault B. Brain events related to normal and moderately scrambled faces. Brain Research. Cognitive Brain Research. 1996; 4: 65–76.

[25] Tanaka H. Face-sensitive P1 and N170 components are related to the perception of two-dimensional and three-dimensional objects. Neuroreport. 2018; 29: 583–587.

[26] Puce A, Allison T, Gore JC, McCarthy G. Face-sensitive regions in human extrastriate cortex studied by functional MRI. Journal of Neurophysiology. 1995; 74: 1192–1199.

[27] Tanaka H. Facial cosmetics exert a greater influence on processing of the mouth relative to the eyes: evidence from the N170 event-related potential component. Frontiers in Psychology. 2016; 7: 1359.

[28] Tagai K, Shimakura H, Isobe H, Nittono H. The light-makeup advantage in facial processing: Evidence from event-related potentials. PLoS ONE. 2017; 12: e0172489.

[29] Schindler S, Zell E, Botsch M, Kissler J. Differential effects of face-realism and emotion on event-related brain potentials and their implications for the uncanny valley theory. Scientific Reports. 2017; 7: 45003.

[30] Schupp HT, Ohman A, Junghöfer M, Weike AI, Stockburger J, Hamm AO. The facilitated processing of threatening faces: an ERP analysis. Emotion. 2004; 4: 189–200.

[31] Werheid K, Schacht A, Sommer W. Facial attractiveness modulates early and late event-related brain potentials. Biological Psychology. 2007; 76: 100–108.

[32] Wierzchoń M, Wronka E, Paulewicz B, Szczepanowski R. Post-decision wagering affects metacognitive awareness of emotional stimuli: an event-related potential study. PLoS ONE. 2016; 11: e0159516.

[33] Xu M, Li Z, Diao L, Fan L, Yang D. Contextual Valence and Sociality Jointly Influence the Early and Later Stages of Neutral Face Processing. Frontiers in Psychology. 2016; 7: 1258.

[34] Haxby, Hoffman, Gobbini. The distributed human neural system for face perception. Trends in Cognitive Sciences. 2000; 4: 223–233.

[35] Allison T. Electrophysiological Studies of Human Face Perception. i: Potentials Generated in Occipitotemporal Cortex by Face and Non-face Stimuli. Cerebral Cortex. 1999; 9: 415–430.

[36] Barbeau EJ, Taylor MJ, Regis J, Marquis P, Chauvel P, Liegeois-Chauvel C. Spatio temporal Dynamics of Face Recognition. Cerebral Cortex. 2008; 18: 997–1009.

[37] McCarthy G, Puce A, Belger A, Allison T. Electrophysiological studies of human face perception. II: Response properties of face-specific potentials generated in occipitotemporal cortex. Cerebral Cortex. 1999; 9: 431–444.

[38] Puce A, Allison T, McCarthy G. Electrophysiological studies of human face perception. III: Effects of top-down processing on face-specific potentials. Cerebral Cortex. 1999; 9: 445–458.

[39] DaSilva EB, Crager K, Geisler D, Newbern P, Orem B, Puce A. Something to sink your teeth into: the presence of teeth augments ERPs to mouth expressions. NeuroImage. 2016; 127: 227–241.

[40] Pesciarelli F, Leo I, Sarlo M. Implicit processing of the eyes and mouth: evidence from human electrophysiology. PLoS ONE. 2016; 11: e0147415.

[41] Krautheim JT, Steines M, Dannlowski U, Neziroğlu G, Acosta H, Sommer J, et al. Emotion specific neural activation for the production and perception of facial expressions. Cortex. 2020; 127: 17–28.

[42] Leder H, Mitrovic A, Goller J. How Beauty Determines Gaze! Facial Attractiveness and Gaze Duration in Images of Real World Scenes. i-Perception. 2016; 7: 2041669516664355.

[43] Batty M, Taylor MJ. Early processing of the six basic facial emotional expressions. Brain Research. Cognitive Brain Research. 2003; 17: 613–620.

[44] Blau VC, Maurer U, Tottenham N, McCandliss BD. The face-specific N170 component is modulated by emotional facial expression. Behavioral and Brain Functions. 2007; 3: 7.

[45] Caharel S, Courtay N, Bernard C, Lalonde R, Rebaï M. Familiarity and emotional expression influence an early stage of face process-

ing: an electrophysiological study. Brain and Cognition. 2005; 59: 96–100.

[46] Eger E, Jedynak A, Iwaki T, Skrandies W. Rapid extraction of emotional expression: evidence from evoked potential fields during brief presentation of face stimuli. Neuropsychologia. 2003; 41: 808–817.

[47] Framorando D, Moses E, Legrand L, Seeck M, Pegna AJ. Rapid processing of fearful faces relies on the right amygdala: evidence from individuals undergoing unilateral temporal lobectomy. Scientific Reports. 2021; 11: 426.

[48] Leppänen JM, Kauppinen P, Peltola MJ, Hietanen JK. Differential electrocortical responses to increasing intensities of fearful and happy emotional expressions. Brain Research. 2007; 1166: 103–109.

[49] Stahl J, Wiese H, Schweinberger SR. Learning task affects ERP-correlates of the own-race bias, but not recognition memory performance. Neuropsychologia. 2010; 48: 2027–2040.

[50] Wiese H, Kaufmann JM, Schweinberger SR. The neural signature of the own-race bias: evidence from event-related potentials. Cerebral Cortex. 2014; 24: 826–835.

[51] Caharel S, Collet K, Rossion B. The early visual encoding of a face (N170) is viewpoint-dependent: a parametric ERP-adaptation study. Biological Psychology. 2015; 106: 18–27.

[52] Tanaka H. Length of Hair Affects P1 and N170 Latencies for Perception of Women's Faces. Perceptual and Motor Skills. 2018; 125: 1011–1028.

[53] Russell R. Sex, beauty, and the relative luminance of facial features. Perception. 2003; 32: 1093–1107.

[54] Jurcak V, Tsuzuki D, Dan I. 10/20, 10/10, and 10/5 systems revisited: their validity as relative head-surface-based positioning systems. NeuroImage. 2007; 34: 1600–1611.

[55] Oostenveld R, Praamstra P. The five percent electrode system for high-resolution EEG and ERP measurements. Clinical Neurophysiology. 2001; 112: 713–719.

[56] Schacht A, Adler N, Chen P, Guo T, Sommer W. Association with positive outcome induces early effects in event-related brain potentials. Biological Psychology. 2012; 89: 130–136.

[57] Zahedi A, Łuczak A, Sommer W. Modification of food preferences by posthypnotic suggestions: an event-related brain potential study. Appetite. 2020; 151: 104713.

[58] Zhang Y, Luo N, Hong FF, Yang CH, Xie YF, Wu JY, et al. Attractiveness-related recognition bias captures the memory of the beholder. Journal of Integrative Neuroscience. 2020; 19: 629–639.

[59] Gao C, Conte S, Richards JE, Xie W, Hanayik T. The neural sources of N170: Understanding timing of activation in face-selective areas. Psychophysiology. 2019; 56: e13336.

[60] Chance SA. The cortical microstructural basis of lateralized cognition: a review. Frontiers in Psychology. 2014; 5: 820.

[61] Kanwisher N, McDermott J, Chun MM. The fusiform face area: a module in human extrastriate cortex specialized for face perception. The Journal of Neuroscience. 1997; 17: 4302–4311.

[62] Puce A, Allison T, Asgari M, Gore JC, McCarthy G. Differential Sensitivity of Human Visual Cortex to Faces, Letterstrings, and Textures: a Functional Magnetic Resonance Imaging Study. The Journal of Neuroscience. 1996; 16: 5205–5215.

[63] Chance SA, Sawyer EK, Clover LM, Wicinski B, Hof PR, Crow TJ. Hemispheric asymmetry in the fusiform gyrus distinguishes Homo sapiens from chimpanzees. Brain Structure and Function. 2013; 218: 1391–1405.

[64] Calvo MG, Gutiérrez-García A, Beltrán D. Neural time course and brain sources of facial attractiveness vs. trustworthiness judgment. Cognitive, Affective, & Behavioral Neuroscience. 2018; 18: 1233–1247.

[65] Han S, Liu S, Gan Y, Xu Q, Xu P, Luo Y, et al. Repeated exposure makes attractive faces more attractive: Neural responses in facial attractiveness judgement. Neuropsychologia. 2020; 139: 107365.

[66] Ikeda H, Saheki Y, Sakano Y, Wada A, Ando H, Tagai K. Facial radiance influences facial attractiveness and affective impressions of faces. International Journal of Cosmetic Science. 2021; 43: 144–157.

[67] Zaki J, Schirmer J, Mitchell JP. Social Influence Modulates the Neural Computation of Value. Psychological Science. 2011; 22: 894–900.