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Odors modulate self face perception and frontal ERP responses

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The face is crucial for social interactions, as it conveys various personal characteristics and influences social judgments. Although previous studies have demonstrated that odors can modulate facial perception and evaluation, these investigations largely focused on others' faces (other-face). The neural mechanisms underlying self-face perception remain less explored. This study examined how odors differing in pleasantness modulate self-face perception and associated neural responses measured via event-related potentials (ERPs). Thirty-one healthy participants (14 women, 17 men) evaluated their self-faces after exposure to a neutral odor (lavender), an unpleasant odor (isovaleric acid), or solvent control (control). Exposure to isovaleric acid, compared with air and lavender, significantly reduced self-face attractiveness and preference ratings. Beyond these behavioral effects, we observed odor-related modulation of ERP amplitude and latency across multiple time windows, and Positive potential (PP) amplitude in the 300–600 ms interval was positively associated with self-face preference and attractiveness. These neural responses correlated with subjective self-evaluations, highlighting a critical period for affective self-assessment influenced by olfactory stimuli. These results suggest that odors modulate self-face perception and frontal ERP responses. Our findings suggest that everyday olfactory environments subtly shape self-perception, underscoring the broader impact of odors on social and psychological functioning.

Keywords ERP, Odor, Self-face, Self-face evaluation, Self-face processing

In human society, the face plays a crucial role in social interaction, conveying key genetic, biological, and psychological characteristics, such as identity[1], gender[2], age[3], ethnicity[4], sear physical health[5,6], and emotional state[7]. Moreover, the face transmits critical social information, including first impressions[8], sexual orientation[9], attractiveness[5,10,11], and personality traits[12]. Given its importance in social communication, understanding how external factors influence face perception has become a significant research interest[13–15].

Olfactory stimuli represent one type of external factor known to modulate face perception. Prior studies have demonstrated that odor stimuli can alter hedonic evaluations of faces, affecting perceived attractiveness, social judgments, and preferences[16–22]. Pleasant odors typically enhance positive evaluations, while unpleasant odors tend to elicit negative evaluations[19]. The neural mechanisms underlying these effects involve key brain regions such as the medial prefrontal cortex (mPFC) and the orbitofrontal cortex (OFC), which are crucial for emotional processing and cross-modal integration between olfactory and visual stimuli[23–27]. Interestingly, the OFC also plays a pivotal role in processing reward stimuli and facial attractiveness[28,29].

Despite the substantial research on odor and face perception, most studies have focused on evaluating other-faces. The neural mechanisms underlying self-face perception, however, differ significantly from those involved in other-face perception[30,31]. Recent research has begun to explore how odors influence self-face evaluation, suggesting potential cross-modal interactions between olfactory and visual processing. For example, Davies-Owen et al. (2024) found enhanced neural responses to self-face stimuli under pleasant odor conditions, while Callara et al. (2022) showed that emotional odors modulate the late positive potential (LPP) component during face processing. However, the effects of odor stimuli—particularly those differing in pleasantness—on the neural correlates of self-face perception remain insufficiently explored.

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Odor stimuli, particularly those low in pleasantness, are known to affect emotional states by engaging brain regions such as the amygdala, part of the primary olfactory cortex, which is involved in both olfactory and emotional processing[23,32]. Given the amygdala's known role in self-face processing, odor-induced changes in emotional state are likely to influence neural responses to one's own face[30,33]. Previous studies have suggested that body odor can influence self-face perception, underscoring a potential connection between olfactory stimuli and self-related evaluations[30]. Nevertheless, studies exploring neurological changes specifically associated with unpleasant odor stimuli and self-face perception are limited.

Event-related potentials (ERPs), measured through electroencephalography (EEG), provide a means to capture rapid neural dynamics in face perception due to their millisecond-level temporal resolution[34,35]. Face-related ERP research commonly examines components such as P1, N170, P200, N250, P300, N400, and LPP, each reflecting distinct stages of facial information processing.

The P1 component, peaking around 110 ms, reflects early visual encoding in the occipital cortex[34,36]. Although the P1 responds robustly to face stimuli in general, previous studies have reported no significant differences between self- and other-face conditions[37]. Around 170 ms after stimulus onset, the fusiform gyrus and fusiform face area are primarily engaged in the structural encoding of facial features, and neural responses at this stage differ significantly between self- and other-faces[38]. Processing around 250 ms is considered self-face specific[39] and is also associated with personal identity recognition within the fusiform face area[37,39].

Each of these components corresponds to progressively higher levels of cognitive and affective processing, including early visual encoding, emotional enhancement, and affective evaluation[40,41]. ERP components within the 300–600 ms time window are particularly sensitive to stimulus pleasantness and self-relevance, reflecting evaluative processes related to attractiveness and preference[42,43]. From approximately 600 ms onward, emotion-related face processing relies on previously encoded perceptual and affective information, supporting later judgments of preference or attractiveness toward one's own face[16,44,45].

Considering the gaps identified above, this study investigates how different odor conditions, specifically a neutral odor (lavender) and an unpleasant odor (isovaleric acid), modulate self-face perception and associated neural responses measured by ERP. Previous studies have suggested that odor effects on perception may reflect both pleasantness and arousal[18,46], because direct measures of arousal were not collected. By combining behavioral ratings with ERP analysis, we sought to clarify the timing and neural localization of odor-related changes in self-face perception. Taken together, this work advances our understanding of how odor pleasantness modulates self-perception, offering a basis for future investigations into olfactory influences on self-related cognition.

Methods

Participants

We recruited 39 healthy adults (20 women, 19 men) from the Daegu Gyeongbuk Institute of Science and Technology for this study. Eight participants were excluded from the final analysis due to incomplete questionnaire data or compromised olfactory function. This resulted in a final cohort of 31 healthy adults (14 women, 17 men), with a mean age of 20.65 years (SD = 1.90). Before participation, all individuals provided written informed consent. All experimental protocols adhered strictly to relevant guidelines and regulations. Participants were screened to ensure they had no history of neurological or psychiatric disorders and possessed normal or corrected-to-normal vision and olfactory capabilities. Olfactory function was rigorously assessed using the Sniffin' Sticks test kit (Burghardt, Wedel, Germany), which evaluated odor threshold, discrimination, and identification abilities, as previously described[47]. This study received approval from the Institutional Review Board Ethics Committee of Daegu Gyeongbuk Institute of Science and Technology (DGIST-181210-HR-024-02).

Olfactory stimuli

In this study, we investigated the neural responses to three distinct olfactory conditions. Our experimental odors included a neutral, herbal, and floral scent (lavender [L]), an unpleasant, pungent, and sweaty odor (isovaleric acid [IVA]), and a control condition consisting of only the solvent (solvent control). For precise delivery, the lavender oil (CAS: 61718, Sigma-Aldrich, St. Louis, USA) was prepared at a concentration of 0.05%, while the isovaleric acid (CAS: 503-74-2, Sigma-Aldrich, St. Louis, USA) was diluted to 0.01%. The solvent used was mineral oil (CAS: M5904, Sigma-Aldrich, St. Louis, USA). Each 1 ml odor solution was housed in a glass bottle within a custom-built olfactometer. These bottles were connected via silicone tubing to the olfactometer's delivery channels. Odor presentation was synchronized with the participant's respiratory cycle: a controlled airflow (3.9 L/min) delivered the odor through a mask during inhalation, with respiration continuously monitored using a respiratory belt. The odor was routed through the olfactometer as the participant exhaled, ensuring precise timing with the respiratory cycle.

Visual stimulus

To create our visual stimuli, we photographed each participant's face, ensuring a neutral facial expression, using a digital camera (SONY FDR-AXP35, Sony, Japan) within the experimental room. All participants provided explicit consent for the use of their facial images in this study. Critically, participants were not privy to their own images during the experiment. For standardization, each facial image was cropped into an oval shape, encompassing the region from the forehead to the chin. Image brightness was then uniformly increased by 30% using Microsoft PowerPoint, and all photographs were resized to a consistent dimension. Prior to EEG recording, participants were simply informed that the visual stimuli were derived from their own faces; they were blind to any subsequent image manipulation during the study.

Experimental scheme

Our study employed a priming paradigm, a modification of the procedure described by Cook et al. (2015), designed to investigate the cross-modal effects of olfactory stimuli on visual processing. This approach has been successfully utilized in prior research to elucidate such interactions[19,46,48,49].

Participants underwent three sets of EEG recordings. In each set, an olfactory prime (either solvent control, lavender [L], or isovaleric acid [IVA]) was presented, immediately followed by the visual target: their own face (Fig. 1). Participants were informed about the general experimental procedure and EEG recording precautions prior to participation, but remained naive to the specific modifications their facial images underwent. Each participant was randomly assigned to one of the three odor conditions for each set, with 25 trials conducted per set. Specifically, set 1 involved lavender priming, set 2 utilized isovaleric acid, and Set 3 served as an air-only control, with the self-face visual stimuli following each prime (Fig. 1A). A post-test survey was administered immediately after the first EEG recording set. To ensure a sufficient number of epochs for ERP analysis, additional EEG recording sets, identical in procedure but without the survey, were conducted on the subsequent two days. During EEG acquisition, participants were seated before a 24-inch monitor displaying stimuli via Microsoft PowerPoint. The trial sequence was as follows (Fig. 1B): a white cross on a black screen for 5 s (fixation and baseline), followed by a black background for the duration of one respiratory cycle (odor condition period). The self-face stimulus was then presented for 500 milliseconds, succeeded by a 5-second black background (resting period). Before each EEG set, participants were given 1–2 min to stabilize their mood. Crucially, during the odor condition period, olfactory stimuli were delivered via the olfactometer for a single respiratory cycle, with the participant's breathing continuously monitored by a respiratory belt.

This figure illustrates the experimental and EEG recording trial procedure. Participants underwent three sets of EEG recordings, with each set consisting of 25 trials. These sets were repeated over three days. During the experiment, participants provided ratings for both odor characteristics and self-face perception. Throughout each EEG recording trial, a self-face picture was presented on the monitor screen. The sequence of events within a trial was as follows: a fixation cross for 5 s, followed by odor presentation during one respiratory cycle, then a self-face visual stimulus for 500 milliseconds, and finally, a black screen for 5 s. The odor conditions included: "Air" (solvent only, mineral oil), "L" (lavender), and "IVA" (isovaleric acid).

Survey ratings

Following each EEG recording session, we administered a survey to capture participants' subjective perceptions of odor characteristics and their self-face ratings (Fig. 1A). Participants evaluated their experiences using a nine-point Likert scale, with thorough instructions provided prior to rating. Higher scores on this scale consistently indicated stronger agreement with the item in question. For odor characteristics, we assessed two key dimensions: intensity and pleasantness. Based on prior research that utilized preference and attractiveness to evaluate perceptual changes in self-faces[50], we adopted these same two metrics for our self-face ratings. Thus, participants rated both the preference and attractiveness of their own faces.

EEG recording and data analysis

Both EEG and electrooculographic (EOG) data were acquired using an Active Two Biosemi EEG amplifier and Actiview software (Amsterdam, Netherlands), sampling at a rate of 2048 Hz. A 64-channel EEG cap (Biosemi) was utilized, with electrode placement adhering to the international 10–20 system. Our recording montage included the common-mode-sensor (CMS) and driven-right-leg (DRL) electrodes as active references. Throughout the recording, electrode impedance was maintained below 15 kΩ.

EEG data analysis was performed using MATLAB R2022b (MathWorks, Natick, MA) and the EEGLAB toolbox (version 2021.1.b)[51]. Raw data were down-sampled from 2048 Hz to 512 Hz and re-referenced to the average of all scalp channels. Continuous EEG data underwent bandpass filtering between 2 and 35 Hz prior to epoch extraction. Epochs were extracted from 300 ms pre-stimulus to 1000 ms post-stimulus, relative to the self-face stimulus marker (0 s), and then baseline-corrected. Subsequently, epochs for each participant were averaged across the three experimental conditions: "Air," "Lavender" [L], and "Isovaleric Acid" [IVA].

Following pre-processing, an average of over 25 trials of EEG data per odor condition were retained for each participant, resulting in three distinct ERP datasets per individual ("Air," "L," and "IVA"). In line with previous studies[52], we identified Positive Potential (PP) and Negative Potential (NP) peaks as the most prominent positive and negative deflections within six distinct time windows between 50 ms and 1000 ms (50–120 ms, 120–200 ms,

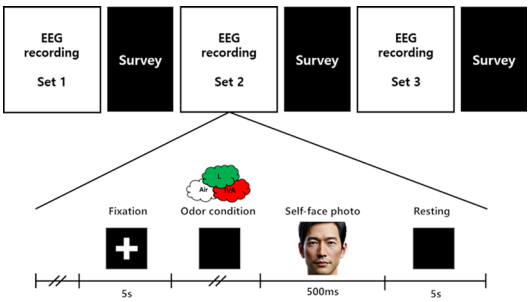

Fig. 1. Experimental and EEG recording scheme.

200–300 ms, 300–600 ms, 600–800 ms, and 800–1000 ms). The time windows for ERP analysis were selected based on previous studies on face and self-face processing. To examine the P1 component, a time window of 50–120 ms was used. For the N170 component, the window was set to 120–200 ms. The 200–300 ms window was selected to analyze the P200 and N250 components, while the 300–600 ms window was used to examine the P300 and N400 components. Finally, the 600–800 ms and 800–1000 ms windows were used to analyze the Middle-LPP and Late-LPP components, respectively.

For grand average analyses, individual participant ERPs were selected based on these positive and negative peaks within each odor condition and time window. The latency points of individual PPs or NPs were then fitted to the mean latency of all participants' PPs and NPs for each odor condition and time window. Ultimately, 28 participants were included in the final analysis to examine changes in ERP amplitude and latency in response to self-face stimuli across the different odor conditions.

Statistical analysis

Statistical analyses were performed using GraphPad Prism 5 (GraphPad Software, Inc., La Jolla, CA, USA) and MATLAB R2022b. All results are presented as the mean ± Standard Error of the Mean (SEM). We defined statistical significance as $p < .05$ (*), $p < .01$ (**), and $p < .005$ (***).

To analyze the ratings for both odor characteristics and self-face perception, we employed one-way repeated-measures ANOVA (RM-ANOVA) with odor condition ("Air," "L," and "IVA") as a within-subject factor.

For each predefined time window (50–120, 120–200, 200–300, 300–600, 600–800, 800–1000 ms) and electrode, we ran an RM-ANOVA with odor condition as a within-subject factor on peak amplitude and latency. When sphericity was violated, Greenhouse–Geisser corrections were applied; we report F with degrees of freedom, corrected p, and partial eta-squared ($p\eta^2$). Whenever the main effect of odor was significant, Bonferroni-corrected post-hoc tests (Air vs. L, Air vs. IVA, and L vs. IVA) were conducted, and the significant pairwise differences are described in the Results section.

Results

Odor characteristic ratings

We first evaluated the differences in odor intensity and pleasantness across the odor conditions: "Air", "L", and "IVA", following both odor and self-face presentations. RM-ANOVA revealed a significant main effect for odor intensity ($F = 48.62$, $p\eta^2 = 0.62$, $p < .001$; Fig. 2B). Post-hoc comparisons showed that both "L" ($t = 7.04$, $p < .001$; Bonferroni-corrected) and "IVA" conditions ($t = 9.50$, $p < .001$; Bonferroni-corrected) were rated as significantly more intense than the "Air" condition. However, we observed no significant difference in intensity between "L" and "IVA" conditions ($t = 2.46$, $p = .051$; Bonferroni-corrected).

Similarly, we found a significant main effect for odor pleasantness ($F = 49.74$, $p\eta^2 = 0.62$, $p < .001$; Fig. 2B). Post-hoc comparisons indicated no significant difference in pleasantness between "Air" and "L" conditions ($t = 1.76$, $p = .251$; Bonferroni-corrected). However, the "IVA" condition was rated as significantly less pleasant compared to both "Air" ($t = 7.62$, $p < .001$; Bonferroni-corrected) and "L" conditions ($t = 9.38$, $p < .001$; Bonferroni-corrected).

Self-face evaluation ratings

Participants rated their own faces in terms of preference and attractiveness after exposure to each odor. RM-ANOVA revealed significant effects of odor on both self-face preference ($F = 9.24$, $p\eta^2 = 0.24$, $p < .001$; Fig. 3A)

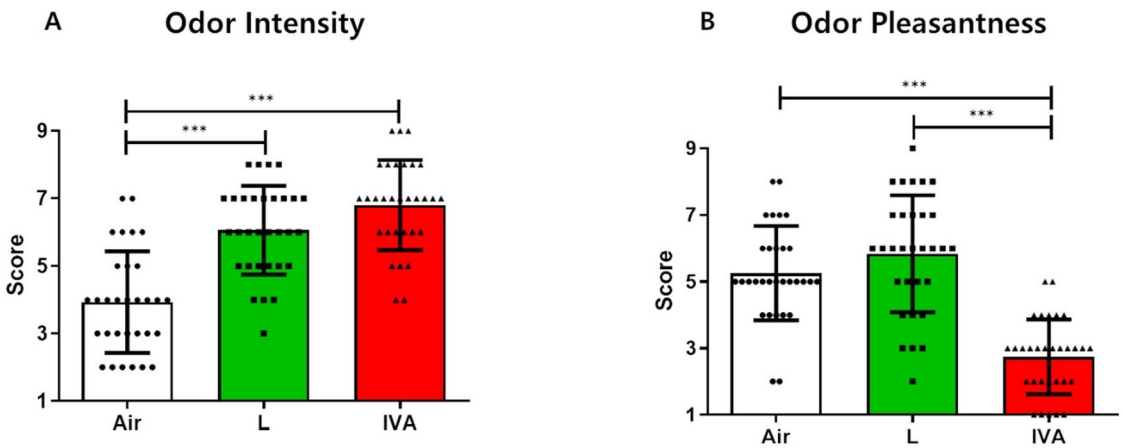

Fig. 2. Bar graph of odor intensity and pleasantness ratings under odor conditions. The y-axes display the odor intensity and pleasantness scores for each odor condition, as rated using a 9-point Likert scale survey. (**A**) Odor Intensity, (**B**) Odor Pleasantness. There was no significant difference in odor intensity between the "L" and "IVA" conditions. However, the pleasantness of the "IVA" condition was significantly lower than that of the "Air" and "L" conditions. Post-hoc comparisons results marked with * were significant at $p < .05$, those marked with ** were significant at $p < .01$, and those marked with *** were significant at $p < .005$.

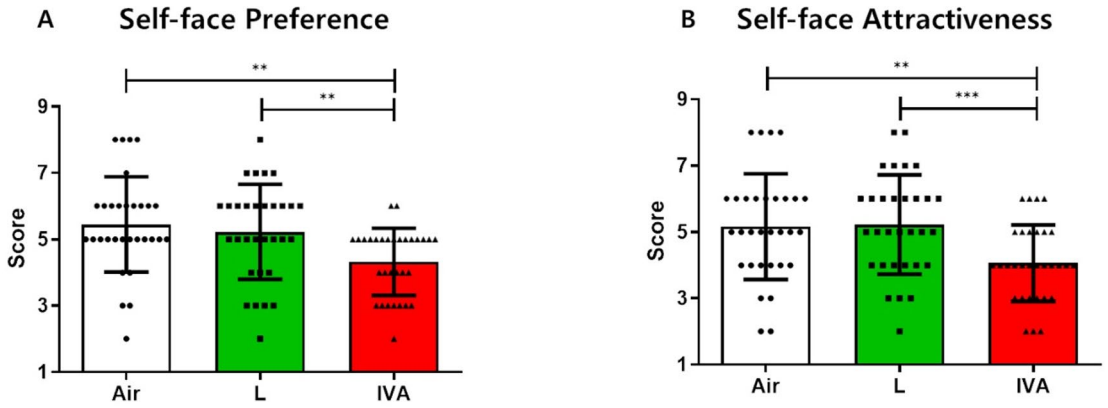

Fig. 3. Bar graph of self-face preference and attractiveness ratings under odor conditions. The y-axes represent the self-face preference and attractiveness scores for each odor condition, rated using a 9-point Likert scale survey. (**A**) Self-face Preference, (**B**) Self-face Attractiveness. There was no significant difference between the "Air" and "L" conditions. However, the self-face preference and Attractiveness of the "IVA" condition were significantly lower than those of the "Air" and "L" conditions. Post-hoc comparisons results marked with * were significant at $p < .05$, those marked with ** were significant at $p < .01$, and those marked with *** were significant at $p < .005$.

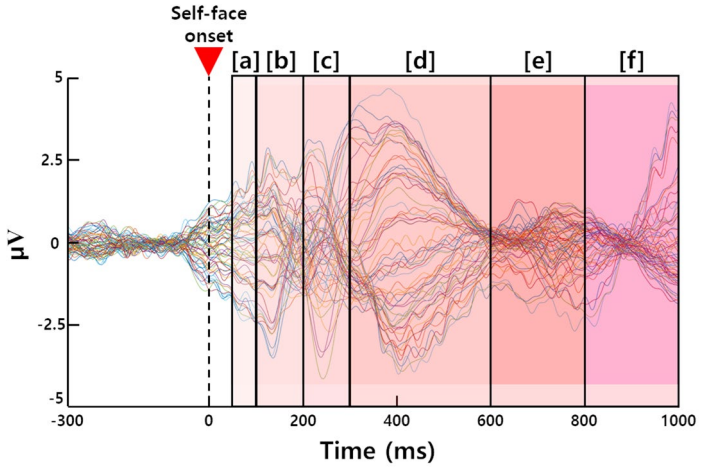

Fig. 4. Butterfly plot of the grand average ERP response to self-face. This figure presents the grand average of Event-Related Potentials (ERPs) from 64 electrodes, based on the responses of 28 participants under the "Air" condition. The onset of the self-face visual stimulus was set to 0 ms. The depicted time windows are: [a] 50–120 ms, [b] 120–200 ms, [c] 200–300 ms, [d] 300–600 ms, [e] 600–800 ms, and [f] 800–1000 ms.

and attractiveness ($F = 9.48$, $p\eta^2 = 0.24$, $p < .001$; Fig. 3B). In self-face preference, post-hoc comparisons revealed that ratings under "IVA" were significantly lower than under "Air" ($t = 4.06$, $p < .001$; Bonferroni-corrected) and "L" conditions ($t = 3.25$, $p = .006$; Bonferroni-corrected). However, we observed no significant difference in self-face preference between "Air" and "L" conditions ($t = 0.81$, $p > .999$; Bonferroni-corrected).

In self-face attractiveness, post-hoc comparisons revealed that ratings under "IVA" were significantly lower than under "Air" ($t = 3.66$, $p = .002$; Bonferroni-corrected) and "L" conditions ($t = 3.87$, $p < .001$; Bonferroni-corrected). However, we observed no significant difference in attractiveness between the "Air" and "L" conditions ($t = 0.22$, $p > .999$; Bonferroni-corrected).

Significant changes in amplitude and latency of ERP

EEG signals were analyzed to identify ERP responses during self-face perception across different odor conditions. ERP waveforms were segmented into six specific time windows: 50–120 ms, 120–200 ms, 200–300 ms, 300–600 ms, 600–800 ms, and 800–1000 ms following stimulus onset (Fig. 4).

To examine how the odor conditions ("Air," "L," and "IVA") modulated ERP amplitudes and latencies elicited by self-face stimuli, we conducted repeated-measures ANOVAs (RM-ANOVAs) with odor as a within-subject factor for each predefined time window and electrode. A separate RM-ANOVA was performed for each electrode (e.g., CP4, FT8, PO8) within six time windows (50–120, 120–200, 200–300, 300–600, 600–800, and 800–1000

ERP Component	Channel	Amplitude			RM-ANOVA				Latency (ms_			RM-ANOVA			
		Air	L	IVA	*df*	F	*p*	η_p^2	Air	l	IVA	*df*	F	*p*	η_p^2
A															
Positive potential (50–120)	**Right hemisphere**														
	TP8	0.9 ± 0.2	0.5 ± 0.1	1.1 ± 0.2 •	2, 27	4.75	**0.013** *	0.15	78 ± 4	85 ± 5	78 ± 5	2, 27	0.71	0.476	0.03
	Left hemisphere														
	C3	0.8 ± 0.1	0.8 ± 0.1	0.9 ± 0.1	2, 27	0.53	0.571	0.02	83 ± 4	82 ± 4	99 ± 3 † •	2, 27	6.30	**0.004** **	0.19
	C5	1.0 ± 0.1	1.0 ± 0.1	0.9 ± 0.1	2, 27	0.23	0.788	0.01	82 ± 4	78 ± 3	92 ± 4 •	2, 27	3.68	**0.035** *	0.12
B															
Negative potential (50–120)	**Right hemisphere**														
	P10	−1.8 ± 0.2	−1.8 ± 0.2	−2.0 ± 0.2	2, 27	0.72	0.479	0.03	90 ± 5	84 ± 4	100 ± 3 •	2, 27	3.61	**0.041** *	0.12

Table 1. Effects of odor conditions ("Air," "L," and "IVA") on ERP responses to self-face stimuli in the 50–120 Ms time window.

ERP Component	Channel	Amplitude			RM-ANOVA				Latency (ms_			RM-ANOVA			
		Air	L	IVA	*df*	F	*p*	η_p^2	Air	L	IVA	*df*	F	*p*	η_p^2
A															
Positive potential (120–200)	**Right hemisphere**														
	FT8	2.0 ± 0.2	2.0 ± 0.2	2.0 ± 0.3	2, 27	0.07	0.916	< 0.01	140 ± 4	155 ± 6	159 ± 5 †	2, 27	4.99	**0.012** *	0.16
	PO8	2.0 ± 0.4 †	1.6 ± 0.5	1.2 ± 0.4	2, 27	4.02	**0.031** *	0.13	172 ± 5	173 ± 4	173 ± 4	2, 27	0.02	0.963	< 0.01
	Left hemisphere														
	C3	0.8 ± 0.1	0.6 ± 0.1	1.0 ± 0.1 •	2, 27	3.24	**0.049** *	0.11	143 ± 3	148 ± 5	148 ± 6	2, 27	0.42	0.654	0.02
	CP3	0.1 ± 0.1	0.1 ± 0.1	0.5 ± 0.1 †	2, 27	4.15	**0.022** *	0.13	145 ± 5	154 ± 5	153 ± 6	2, 27	1.11	0.336	0.04
	F3	2.5 ± 0.2 ‡	1.8 ± 0.2	2.1 ± 0.2	2, 27	4.85	**0.013** *	0.15	146 ± 4	150 ± 5	148 ± 6	2, 27	0.25	0.866	< 0.01
	Central position														
	CPz	0.0 ± 0.1	0.4 ± 0.2	0.4 ± 0.1 †	2, 27	3.74	**0.037** *	0.12	145 ± 5	156 ± 6	147 ± 6	2, 27	1.62	0.208	0.06

Table 2. Effects of odor conditions ("Air," "L," and "IVA") on ERP responses to self-face stimuli in the 120–200 Ms time window.

ms). Significant main effects of odor were followed by Bonferroni-corrected post-hoc comparisons (Air vs. L, Air vs. IVA, L vs. IVA). All effects were tested using Greenhouse–Geisser corrections where appropriate. Complete statistical results (df, F, corrected p, and $p\eta^2$), along with post-hoc comparison outcomes, are summarized in Tables 1, 2, 3, 4, 5 and 6. In the tables, symbols denote significant post-hoc comparisons: ‡ for Air vs. L, † for Air vs. IVA, and • for L vs. IVA. Each symbol is positioned next to the value representing the condition with the larger absolute response.

Post-hoc analyses revealed distinct pairwise effects across hemispheric and central regions, indicating temporally dynamic modulation of ERP responses by odor conditions.

In the 50–120 ms window (Table 1), significant differences emerged in both PP and NP components. PP amplitude at the right hemisphere (TP8) was higher under IVA than L. PP latencies at left hemisphere (C3, C5) were longer under IVA than L, with C3 also showing longer latency under IVA than Air. NP components also showed significant differences, NP latency at the right hemisphere (P10) was longer under IVA than L.

In the 120–200 ms window (Table 2), significant differences emerged in PP components. PP amplitude at the right hemisphere (PO8) was higher under Air than IVA, whereas amplitudes at left hemisphere (CP3) and central-position (CPz) were higher under IVA than Air. PP amplitude at left hemisphere (C3) was higher under IVA than L. PP amplitude at left hemisphere (F3) was higher under Air than L. PP latency at right hemisphere (FT8) was longer under IVA than Air.

In the 200–300 ms window (Table 3), significant differences emerged in both PP and NP components. PP amplitude at left hemisphere (P9) was higher under Air than IVA. PP latency at right hemisphere (P10) was longer under IVA than Air. PP latencies at left hemisphere were longer under Air than L (FC5) or IVA (C1). PP latency at left hemisphere (Fp1) was longer under L than IVA. NP components also showed significant differences, NP amplitude at left hemisphere (FC1) was higher under Air than IVA, whereas amplitude at left hemisphere (CP5) was higher under IVA than Air. NP latencies at right (FC2), left hemisphere (F1, C3, and P1) and central position (Cz) were longer under IVA than Air, whereas latency at right hemisphere (P10) was longer under Air than IVA. NP latencies at right (CP4) and left hemisphere (C3, CP3, and P1) were longer under L than Air.

In the 300–600 ms window (Table 4), significant differences emerged in both PP and NP components. PP amplitudes at right hemisphere were higher under IVA than Air (F8 and FT8) or L (F8 and CP4). PP amplitude at left hemisphere (FT7) was higher under IVA than L. NP components also showed significant differences, NP

ERP Component	Channel	Amplitude			RM-ANOVA				Latency (ms_			RM-ANOVA			
		Air	L	IVA	df	F	p	η_p^2	Air	L	IVA	df	F	p	η_p^2
A															
Positive potential (200–300)	**Right hemisphere**														
	F8	1.1 ± 0.2	1.3 ± 0.2	1.8 ± 0.2 † •	2, 27	9.30	**< 0.001** ***	0.26	520 ± 19	515 ± 21	524 ± 18	2, 27	0.15	0.808	0.01
	Left hemisphere														
	Fp1	4.4 ± 0.5	4.5 ± 0.7	4.1 ± 0.5	2, 27	0.45	0.613	0.02	232 ± 5	240 ± 5 •	228 ± 5	2, 27	4.28	**0.027** *	0.14
	C1	1.2 ± 0.2	1.0 ± 0.2	1.2 ± 0.2	2, 27	1.29	0.283	0.05	254 ± 5 †	243 ± 5	239 ± 5	2, 27	5.70	**0.008** **	0.17
	P9	2.7 ± 0.4 †	2.3 ± 0.4	2.0 ± 0.4	2, 27	3.81	**0.034** *	0.12	248 ± 9	254 ± 9	247 ± 8	2, 27	0.55	0.581	0.02
	FC5	1.2 ± 0.2	1.0 ± 0.2	1.3 ± 0.2	2, 27	1.00	0.374	0.04	240 ± 5 ‡	223 ± 3	228 ± 6	2, 27	5.35	**0.012** *	0.17
B															
Negative potential (200–300)	**Right hemisphere**														
	FC2	−2.2 ± 0.3	−2.3 ± 0.3	−2.0 ± 0.3	2, 27	1.65	0.206	0.06	264 ± 8	275 ± 7	279 ± 6 †	2, 27	3.88	**0.043** *	0.13
	P10	−5.8 ± 0.6	−5.8 ± 0.6	−5.7 ± 0.7	2, 27	0.02	0.972	< 0.01	249 ± 5 †	243 ± 4	238 ± 4	2, 27	6.67	**0.005** **	0.20
	CP4	−2.1 ± 0.2	−1.9 ± 0.2	−2.1 ± 0.3	2, 27	0.83	0.444	0.03	232 ± 3	248 ± 5 ‡	238 ± 5	2, 27	4.72	**0.013** *	0.15
	Left hemisphere														
	F1	−1.7 ± 0.3	−1.7 ± 0.3	−1.5 ± 0.3	2, 27	1.05	0.354	0.04	258 ± 8	268 ± 8	281 ± 6 †	2, 27	4.09	**0.025** *	0.13
	FC1	−1.9 ± 0.3 †	−1.8 ± 0.3	−1.5 ± 0.3	2, 27	4.71	**0.013** *	0.15	258 ± 8	271 ± 8	276 ± 7	2, 27	3.07	0.059	0.10
	C3	−1.8 ± 0.2	−1.7 ± 0.2	−1.5 ± 0.2	2, 27	1.16	0.313	0.04	239 ± 8	258 ± 8 ‡	260 ± 8 †	2, 27	6.08	**0.004** **	0.18
	CP3	−1.2 ± 0.1	−1.4 ± 0.2	−1.3 ± 0.2	2, 27	1.17	0.319	0.04	226 ± 6	247 ± 8 ‡	238 ± 7	2, 27	4.12	**0.022** *	0.13
	CP5	−1.4 ± 0.2	−1.8 ± 0.2	−1.8 ± 0.2 †	2, 27	4.98	**0.013** *	0.16	248 ± 6	249 ± 6	245 ± 6	2, 27	0.17	0.831	0.01
	P1	−1.4 ± 0.2	−1.7 ± 0.3	−1.3 ± 0.2	2, 27	3.09	0.055	0.10	208 ± 3	224 ± 6 ‡	226 ± 6 †	2, 27	5.92	**0.005** **	0.18
	Central position														
	Cz	−2.1 ± 0.3	−2.2 ± 0.3	−2.1 ± 0.3	2, 27	1.01	0.364	0.04	253 ± 9	270 ± 8	271 ± 8 †	2, 27	4.37	**0.018** *	0.14

Table 3. Effects of odor conditions (“Air,” “L,” and “IVA”) on ERP responses to self-face stimuli in the 200–300 Ms time window.

amplitudes at right (PO4) and left hemisphere (FC5, C5, CP3, CP1, and P1) were higher under IVA than Air, whereas amplitude at right hemisphere (P10) was higher under Air than IVA. NP amplitude at left hemisphere (P1) was higher under L than Air. NP latencies were longer under IVA than Air (Right hemisphere site: FT8; Central position site: POz) or L (Right hemisphere site: F2, CP2, and P6; Left hemisphere site: T7). NP latency at left hemisphere (C3) was longer under Air than IVA.

In the 600–800 ms window (Table 5), significant differences emerged in PP components. PP amplitude at right hemisphere (FT8) was higher under IVA than L. PP amplitude at left hemisphere (FC5) was higher under Air than L. PP latency at left hemisphere (F3) was longer under Air than IVA, and latency at central position (Fz) was longer under L than IVA.

In the 800–1000 ms window (Table 6), significant differences emerged in both PP and NP components. PP amplitudes at left hemisphere (FT7 and T7) were higher under Air than IVA. PP latency at left hemisphere (FC5) was longer under L than Air. NP components also showed significant differences, NP amplitudes at right hemisphere (C6 and T8) were higher under Air than L. NP amplitude at left hemisphere (FT7) was higher under IVA than Air. NP latency at right hemisphere (C6) was longer under L than Air. NP latency at left hemisphere (F5) was longer under IVA than L.

Collectively, these results demonstrate that odor conditions significantly modulate ERP amplitudes and latencies across multiple time windows and scalp regions, confirming temporally dynamic and region-specific effects of olfactory context on self-face processing.

This table summarizes the electrode- and time-specific effects that reached statistical significance in the RM-ANOVA. Reported statistics are df, F, corrected p, and partial eta squared ($p\eta^2$). Results marked with * were significant at $p<.05$, ** at $p<.01$, and *** at $p<.005$. When a significant main effect of odor was observed, Bonferroni-corrected post-hoc tests were conducted to identify pairwise differences among conditions. Significant post-hoc effects are indicated by symbols in the table: ‡ for Air vs. L, † for Air vs. IVA, and • for L vs. IVA, which are positioned next to the values representing the condition with the larger absolute response. The following post-hoc results came to significance:

a. (**A**) Effects of odor condition on PP (50–120 ms). Amplitude at TP8 was higher under IVA than L ($t=2.90$, $p=.022$). Latencies at C3 and C5 were longer under IVA than L (C3: $t=2.82$, $p=.027$; C5: $t=3.03$, $p=.016$). Latency at C3 was longer under IVA than Air ($t=3.33$, $p=.008$).
b. (**B**) Effects of odor condition on NP (50–120 ms). Latency at P10 was longer under IVA than L ($t=3.24$, $p=.010$).

This table summarizes the electrode- and time-specific effects that reached statistical significance in the RM-ANOVA. Reported statistics are df, F, corrected p, and partial eta squared ($p\eta^2$). Results marked with * were significant at $p<.05$, ** at $p<.01$, and *** at $p<.005$. When a significant main effect of odor was observed, Bonferroni-corrected post-hoc tests were conducted to identify pairwise differences among conditions. Significant post-hoc effects are indicated by symbols in the table: ‡ for Air vs. L, † for Air vs. IVA, and • for L vs. IVA, which are positioned next to the values representing the condition with the larger absolute response. The following post-hoc results came to significance:

(**A**) Effects of odor conditions on PP (120–200 ms). Amplitude at PO8 was higher under Air than IVA ($t=3.07$, $p=.015$), whereas CP3 and CPz showed the reverse pattern with higher amplitude under IVA than Air (CP3: $t=2.56$, $p=.049$; CPz: $t=3.18$, $p=.011$). Amplitude at F3 was higher under Air than L ($t=3.07$, $p=.015$). Amplitude at C3 was higher under IVA than L ($t=2.52$, $p=.044$). In addition, latency at FT8 was longer under IVA than Air ($t=2.85$, $p=.025$).

No significant NP differences were found in this time window.

This table summarizes the electrode- and time-specific effects that reached statistical significance in the RM-ANOVA. Reported statistics are df, F, corrected p, and partial eta squared ($p\eta^2$). Results marked with * were significant at $p<.05$, ** at $p<.01$, and *** at $p<.005$. When a significant main effect of odor was observed, Bonferroni-corrected post-hoc tests were conducted to identify pairwise differences among conditions. Significant post-hoc effects are indicated by symbols in the table: ‡ for Air vs. L, † for Air vs. IVA, and • for L vs. IVA, which are positioned next to the values representing the condition with the larger absolute response. The following post-hoc results came to significance:

iii. (**A**) Effects of odor conditions on PP (200–300 ms). Amplitude at P9 was higher under Air than IVA ($t=2.75$, $p=.024$). Latency at P10 was longer under IVA than Air ($t=3.39$, $p=.006$). Latency at C1 was longer under Air than IVA ($t=3.27$, $p=.006$). Latency at Fp1 was longer under L than IVA ($t=2.84$, $p=.019$). Latency at FC5 was longer under Air than L ($t=3.19$, $p=.007$).
iv. (**B**) Effects of odor conditions on NP (200–300 ms). Amplitude at FC1 was higher under Air than IVA ($t=2.96$, $p=.019$), whereas CP5 showed the reverse pattern with higher amplitude under IVA than Air ($t=2.80$, $p=.028$). Latencies at FC2, F1, C3, P1, and Cz were longer under IVA than Air (FC2: $t=2.68$, $p=.029$; F1: $t=2.95$, $p=.020$; C3: $t=3.11$, $p=.013$; P1: $t=3.13$, $p=.013$; Cz: $t=2.64$, $p=.041$), whereas P10 showed the reverse pattern with longer latency under Air than IVA ($t=3.05$, $p=.015$). Latencies at CP4, C3, CP3, and P1 were longer under L than Air (CP4: $t=3.05$, $p=.011$; C3: $t=2.98$, $p=.018$; CP3: $t=3.08$, $p=.014$; P1: $t=2.95$, $p=.020$).

This table summarizes the electrode- and time-specific effects that reached statistical significance in the RM-ANOVA. Reported statistics are df, F, corrected p, and partial eta squared ($p\eta^2$). Results marked with * were significant at $p<.05$, ** at $p<.01$, and *** at $p<.005$. When a significant main effect of odor was observed, Bonferroni-corrected post-hoc tests were conducted to identify pairwise differences among conditions.

ERP Component	Channel	Amplitude			RM-ANOVA				Latency (ms_			RM-ANOVA			
		Air	L	IVA	df	F	p	η_p^2	Air	L	IVA	df	F	p	η_p^2
A															
Positive potential (300–600)	**Right hemisphere**														
	F8	1.1 ± 0.2	1.3 ± 0.2	1.8 ± 0.2 † •	2, 27	9.30	**< 0.001** ***	0.26	520 ± 19	515 ± 21	524 ± 18	2, 27	0.15	0.808	0.01
	FT8	1.5 ± 0.2	1.6 ± 0.2	1.9 ± 0.2 †	2, 27	3.76	**0.031** *	0.12	544 ± 11	557 ± 10	547 ± 13	2, 27	0.49	0.573	0.02
	CP4	2.1 ± 0.1	1.9 ± 0.1	2.2 ± 0.1 •	2, 27	4.02	**0.025** *	0.13	437 ± 14	446 ± 15	435 ± 15	2, 27	0.21	0.802	0.01
	Left hemisphere														
	FT7	1.6 ± 0.2	1.4 ± 0.2	1.5 ± 0.2	2, 27	0.27	0.753	0.01	494 ± 19	481 ± 20	536 ± 16 •	2, 27	3.81	**0.029** *	0.12
B															
Negative potential (300–600)	**Right hemisphere**														
	F2	−4.0 ± 0.3	−4.0 ± 0.3	−3.9 ± 0.3	2, 27	0.23	0.792	0.01	409 ± 13	398 ± 12	427 ± 15 •	2, 27	3.35	**0.049** *	0.11
	FT8	−3.5 ± 0.3	−3.7 ± 0.3	−3.7 ± 0.3	2, 27	0.60	0.531	0.02	363 ± 12	372 ± 12	408 ± 13 †	2, 27	5.10	**0.011** *	0.16
	CP2	−1.2 ± 0.2	−1.5 ± 0.2	−1.3 ± 0.2	2, 27	1.43	0.249	0.05	374 ± 18	344 ± 14	423 ± 21 •	2, 27	6.25	**0.005** **	0.19
	P6	−0.7 ± 0.1	−0.6 ± 0.2	−0.7 ± 0.1	2, 27	0.14	0.836	0.01	470 ± 26	446 ± 26	515 ± 21 •	2, 27	3.89	**0.032** *	0.13
	P10	−2.2 ± 0.3 †	−1.8 ± 0.2	−1.6 ± 0.3	2, 27	3.74	**0.034** *	0.12	429 ± 25	444 ± 26	465 ± 25	2, 27	1.88	0.164	0.06
	PO4	−0.3 ± 0.2	−0.5 ± 0.2	−0.8 ± 0.2 †	2, 27	3.64	**0.036** *	0.12	503 ± 21	534 ± 18	534 ± 18	2, 27	2.55	0.091	0.09
	Left hemisphere														
	FC5	−2.8 ± 0.2	−2.9 ± 0.2	−3.1 ± 0.2 †	2, 27	3.56	**0.037** *	0.12	393 ± 11	397 ± 14	374 ± 11	2, 27	1.53	0.227	0.05
	C3	−1.8 ± 0.2	−1.9 ± 0.2	−2.1 ± 0.2	2, 27	2.93	0.066	0.10	404 ± 18 †	381 ± 13	364 ± 12	2, 27	3.24	**0.049** *	0.11
	C5	−1.9 ± 0.1	−2.1 ± 0.2	−2.2 ± 0.2 †	2, 27	3.54	**0.048** *	0.12	370 ± 11	390 ± 16	382 ± 15	2, 27	0.55	0.569	0.02
	T7	−2.7 ± 0.2	−2.9 ± 0.2	−3.1 ± 0.2	2, 27	1.68	0.196	0.06	365 ± 11	347 ± 8	384 ± 12 •	2, 27	3.90	**0.035** *	0.13
	CP3	−0.9 ± 0.1	−1.0 ± 0.1	−1.2 ± 0.1 †	2, 27	3.24	**0.049** *	0.11	424 ± 21	421 ± 21	427 ± 23	2, 27	0.02	0.976	< 0.01
	CP1	−1.0 ± 0.2	−1.3 ± 0.2	−1.4 ± 0.2 †	2, 27	5.21	**0.013** *	0.16	419 ± 21	386 ± 19	405 ± 21	2, 27	1.24	0.296	0.04
	P1	−0.4 ± 0.1	−0.8 ± 0.2 ‡	−0.8 ± 0.1 †	2, 27	6.47	**0.004** **	0.19	436 ± 22	472 ± 24	488 ± 21	2, 27	2.29	0.112	0.08
	Central position														
	POz	−0.5 ± 0.1	−0.6 ± 0.2	−0.7 ± 0.2	2, 27	1.42	0.252	0.05	485 ± 22	527 ± 20	537 ± 18 †	2, 27	3.66	**0.034** *	0.12

Table 4. Effects of odor conditions ("Air," "L," and "IVA") on ERP responses to self-face stimuli in the 300–600 Ms time window.

Significant post-hoc effects are indicated by symbols in the table: ‡ for Air vs. L, † for Air vs. IVA, and • for L vs. IVA, which are positioned next to the values representing the condition with the larger absolute response. The following post-hoc results came to significance:

e. (**A**) Effects of odor conditions on PP (300–600 ms). Amplitudes at F8 and FT8 were higher under IVA than Air (F8: t = 4.00, p = .001; FT8: t = 2.71, p = .027). Amplitude at F8 and CP4 were higher under IVA than L (F8; t = 2.95, p = .019; t = 2.62, p = .042). Latency at FT7 was longer under IVA than L (t = 2.64, p = .033).
f. (**B**) Effects of odor conditions on NP (300–600 ms). Amplitude at PO4, FC5, C5, CP3, CP1, and P1 were higher under IVA than Air (PO4: t = 2.63, p = .034; FC5: t = 2.60, p = .045; C5: t = 2.66, p = .031; CP3: t = 2.54, p = .042; CP1: t = 3.11, p = .009; P1: t = 3.61, p = .004), whereas P10 showed the reverse pattern with higher amplitude under Air than IVA (t = 2.66, p = .039). Amplitude at P1 was higher under L than Air (t = 2.66, p = .039). Latencies at F2, CP2, P6, and T7 were longer under IVA than L (F2: t = 2.61, p = .044; CP2: t = 3.60, p = .004; P6: t = 3.13, p = .012; T7: t = 2.62, p = .043). Latencies at FT8 and POz were longer under IVA than Air (FT8: t = 2.73, p = .033; POz: t = 2.54, p = .042), whereas C3 showed the reversed pattern with longer latency under Air than IVA (t = 2.76, p = .031).

This table summarizes the electrode- and time-specific effects that reached statistical significance in the RM-ANOVA. Reported statistics are df, F, corrected p, and partial eta squared ($p\eta^2$). Results marked with * were significant at p < .05, ** at p < .01, and *** at p < .005. When a significant main effect of odor was observed, Bonferroni-corrected post-hoc tests were conducted to identify pairwise differences among conditions. Significant post-hoc effects are indicated by symbols in the table: ‡ for Air vs. L, † for Air vs. IVA, and • for L vs. IVA, which are positioned next to the values representing the condition with the larger absolute response. The following post-hoc results came to significance:

(**A**) Effects of odor conditions on PP (600–800 ms). Amplitude at FT8 was higher under IVA than L (FT8: t = 2.84, p = .026). Amplitude at FC5 was higher under Air than L (FC5: t = 2.93, p = .015). Latency at F3 was longer under Air than IVA (t = 2.56, p = .050). Latency at Fz was longer under L than IVA (t = 2.62, p = .043).

No significant NP differences were found in this time window.

This table summarizes the electrode- and time-specific effects that reached statistical significance in the RM-ANOVA. Reported statistics are df, F, corrected p, and partial eta squared ($p\eta^2$). Results marked with * were significant at p < .05, ** at p < .01, and *** at p < .005. When a significant main effect of odor was observed, Bonferroni-corrected post-hoc tests were conducted to identify pairwise differences among conditions. Significant post-hoc effects are indicated by symbols in the table: ‡ for Air vs. L, † for Air vs. IVA, and • for L vs. IVA, which are positioned next to the values representing the condition with the larger absolute response. The following post-hoc results came to significance:

g. (**A**) Effects of odor conditions on PP (800–1000 ms). Amplitude at FT7 and T7 were higher under Air than IVA (FT7: t = 2.50, p = .046; T7: t = 2.58, p = .047). Latency at FC5 was longer under L than Air (t = 2.59, p = .037).
h. (**B**) Effects of odor conditions on NP (800–1000 ms). Amplitude at C6 and T8 were higher under Air than L (C6: t = 2.64, p = .041; T8: t = 2.82, p = .027). Amplitude at FT7 was higher under IVA than Air (t = 4.05, p = .001). Latency at C6 was longer under L than Air (t = 4.36, p < .001). Latency at F5 was longer under IVA than L (t = 3.08, p = .014).

Associations between odor-condition–dependent ERP changes and self-face ratings

To link ERP effects to behavior, we examined correlations between ERP peak amplitude/latency and self-face ratings (preference and attractiveness). Correlation tests were restricted to the time-window × channel combinations where post-hoc comparisons showed that the "IVA" condition differed from "Air" and/or "L" (Tables 1, 2, 3, 4, 5 and 6); this restriction ensured that the behavioral–neural associations were evaluated at sites showing a reliable odor effect. Within the 300–600 ms window, PP amplitude at CP4 was positively associated with self-face preference (r = .23, p = .039) and attractiveness (r = .23, p = .037) (Fig. 5). These associations suggest that a more pronounced positive potential at these sites is associated with higher self-face ratings within odor-sensitive windows.

Discussion

Our study demonstrates that odor stimuli modulate self-face perception, particularly through differences in perceived pleasantness. Unlike previous research that has primarily focused on other-face perception, this study emphasizes self-face evaluation. Consistent with prior literature, the self-face is processed more rapidly and associated with increased attentional activation than other-face stimuli[30,31,53,54]. Our findings extend this understanding by showing that differences in odor pleasantness alter self-perceived attractiveness and preference, consistent with prior studies that report odor pleasantness affects evaluations of other faces[16,19].

ERP analyses revealed significant odor-related modulations of ERP amplitude and latency between 50 and 1000 ms following self-face presentation across odor conditions. Amplitudes in the 300–600 ms interval correlated with subjective ratings of self-face attractiveness and preference, indicating that this time window is critical for affective self-evaluation. Previous studies have consistently associated the P300 component within this interval with attention and attractiveness judgments, and they have typically reported larger amplitudes for self-faces compared with other-faces. Interestingly, P300 amplitudes in response to self-face stimuli were modulated by the pleasantness of the odor, with stronger responses observed under less pleasant odor conditions. This pattern suggests that odor-induced emotional context influences affective self-evaluation[19,20,55].

ERP Component	Channel	Amplitude			RM-ANOVA				Latency (ms_			RM-ANOVA			
		Air	L	IVA	df	F	p	η_p^2	Air	L	IVA	df	F	p	η_p^2
A															
Positive potential (600–800)	**Right hemisphere**														
	FT8	1.8 ± 0.1	1.7 ± 0.1	2.2 ± 0.2 •	2, 27	3.93	**0.029** *	0.12	669 ± 11	665 ± 10	655 ± 10	2, 27	0.69	0.499	0.03
	Left hemisphere														
	F3	1.9 ± 0.2	1.7 ± 0.2	1.8 ± 0.2	2, 27	0.51	0.579	0.02	739 ± 8 †	734 ± 8	711 ± 11	2, 27	3.97	**0.025** *	0.13
	FC5	1.9 ± 0.2 ‡	1.5 ± 0.1	1.8 ± 0.2	2, 27	4.42	**0.017** *	0.14	740 ± 7	722 ± 9	720 ± 8	2, 27	2.09	0.133	0.07
	Central position														
	Fz	1.7 ± 0.3	1.6 ± 0.2	1.8 ± 0.2	2, 27	0.58	0.550	0.02	735 ± 9	743 ± 8 •	714 ± 12	2, 27	3.62	**0.037** *	0.12

Table 5. Effects of odor conditions (“Air,” “L,” and “IVA”) on ERP responses to self-face stimuli in the 600–800 Ms time window.

Although our correlations were observed in the 300–600 ms window, earlier (50–300 ms) and later (600–1000 ms) intervals also play important roles in self-face perception. Early components such as P1 (50–120 ms) reflect the initial visual encoding of face stimuli, primarily occurring in the occipital visual cortex[34,36]. The subsequent components, including N170 and N200 (120–300 ms), are generated in the fusiform gyrus and fusiform face area, regions responsible for the structural encoding of facial features. Prior studies have demonstrated that these components exhibit distinct patterns depending on whether the stimulus is self-face or another-face[38]. Later time windows, such as 600–1000 ms, are associated with higher-order emotional and evaluative processing of facial stimuli. Together, these findings indicate that odor pleasantness modulates both perceptual and evaluative stages of self-face processing[16,44,45].

The frontal cortex, particularly regions such as the mPFC and OFC, may contribute to the ERP modulations observed in this study. These regions are involved in emotional and evaluative processes related to self-face perception[33,56,57] and odor-face integration[18,25,26]. Given the OFC's key role in processing facial attractiveness and reward[28,29], the observed ERP changes likely indicate the modulatory influence of odor pleasantness on affective self-assessment circuits.

While previous studies have typically highlighted right hemisphere dominance in self-face processing[33,56,58], our findings predominantly revealed effects in the left frontal region. Several factors may explain this discrepancy. First, bilateral frontal engagement in self-related processing has also been reported, suggesting that hemisphere-specific effects may be context-dependent[59,60]. Moreover, our experimental design presented odors immediately prior to self-face stimuli, potentially priming evaluative neural pathways differently from previous studies.

Several methodological considerations should be acknowledged. While our findings robustly demonstrate odor-induced changes in self-face perception, direct comparisons between self-face and other-face evaluations under various odor conditions would be necessary to better delineate the unique neural mechanisms. Future research should explicitly contrast these conditions to clarify odor-specific effects on self-related processing.

Odor characteristic ratings indicated no significant difference between the Air and Lavender conditions. However, previous studies had reported that lavender is generally perceived as a pleasant odor, which can influence behavioral results[61,62]. We measured odor pleasantness on a scale of 1 to 9, and 20 out of 31 people rated lavender as highly pleasant (score > 5). Among them, 11 out of 31 people rated it as more pleasant (score > 6). Because of the high variance caused by the 11 people who rated lavender as less unpleasant, no statistically significant difference was observed ($t = 1.76$, $p = .251$) between air and lavender (Fig. 2). We conducted a correlation analysis to compare response patterns between participants who rated lavender as pleasant (score > 5) and those who rated it as neutral or unpleasant (score ≤ 5). This was done to examine whether the emotional value of the odor affected self-face processing. We computed two-tailed Pearson correlation coefficients between odor pleasantness ratings and self-face attractiveness and preference ratings within each odor condition (Supplement Fig. 1). Significant positive correlations were found between odor pleasantness and self-face preference ($r = .59$, $p < .001$) as well as between odor pleasantness and attractiveness ($r = .49$, $p < .001$). These results confirm that self-face processing is modulated in a value-dependent manner, linking self-face perception with evaluations of odor pleasantness.

In this study, IVA was used to examine the effects of less pleasant odors on self-face perception. Previous research has shown that IVA induces strong arousal responses[63], whereas lavender—used as a neutral odor in the present study—has been associated with low arousal levels[64]. However, we did not directly assess odor-induced arousal, and therefore, differences in arousal among the three odor conditions (Air, Lavender, and IVA) could not be confirmed. Nonetheless, prior studies have reported that P300 amplitudes are typically lower in low- than in high-arousal conditions, regardless of odor pleasantness. This pattern is consistent with our findings in the CP4 channel, where P300 amplitude was lower in the lavender condition (1.9 ± 0.1 μV) than in the IVA condition (2.2 ± 0.1 μV). These results suggest that the observed modulation of P300 may reflect differences in odor-induced arousal rather than odor pleasantness alone. Although our study primarily focused on the effects of odor pleasantness on self-face perception, it remains unclear whether the changes in P300 amplitude are driven by odor pleasantness, arousal, or their interaction. To address this limitation, future research should incorporate a subjective arousal rating scale and include odor conditions that vary systematically in both pleasantness and arousal. Replacing the neutral odor condition with clearly pleasant and unpleasant odors may provide a more comprehensive understanding of how odor-related emotional factors influence self-face processing.

In conclusion, our results provide evidence that odor pleasantness modulates self-face perception and is associated with neural responses linked to attractiveness and preference evaluations. These findings have practical implications, suggesting that everyday olfactory environments, such as personal hygiene contexts or social preparation activities, may play a modest role in shape self-perception. Taken together, this underscores the broader social and psychological relevance of olfactory influences on self-assessment.

ERP Component	Channel	Amplitude			RM-ANOVA				Latency (ms_			RM-ANOVA			
		Air	L	IVA	df	F	p	η_p^2	Air	L	IVA	df	F	p	η_p^2
A															
Positive potential (800–1000)	**Right hemisphere**														
	FT7	2.0 ± 0.2 †	1.7 ± 0.1	1.5 ± 0.2	2, 27	3.25	**0.047** *	0.11	893 ± 13	911 ± 12	880 ± 13	2, 27	1.68	0.197	0.06
	T7	2.2 ± 0.2 †	1.7 ± 0.2	1.6 ± 0.1	2, 27	4.50	**0.018** *	0.14	890 ± 14	894 ± 14	873 ± 14	2, 27	0.83	0.441	0.03
	FC5	1.6 ± 0.1	1.3 ± 0.1	1.3 ± 0.1	2, 27	2.41	0.099	0.08	878 ± 13	918 ± 12 ‡	897 ± 13	2, 27	3.36	**0.042** *	0.11
B															
Negative potential (800–1000)	**Right hemisphere**														
	C6	−1.8 ± 0.2 ‡	−1.2 ± 0.2	−1.4 ± 0.1	2, 27	3.77	**0.003** *	0.12	863 ± 12	921 ± 12 ‡	889 ± 13	2, 27	9.54	**<0.001** ***	0.26
	T8	−2.5 ± 0.3 ‡	−1.8 ± 0.2	−2.2 ± 0.2	2, 27	4.45	**0.019** *	0.14	885 ± 14	882 ± 14	871 ± 14	2, 27	0.42	0.658	0.02
	Left hemisphere														
	F5	−1.7 ± 0.3	−1.8 ± 0.2	−1.8 ± 0.2	2, 27	0.19	0.799	0.01	872 ± 12	859 ± 10	897 ± 12 •	2, 27	3.39	**0.046** *	0.11
	FT7	−1.3 ± 0.2	−1.6 ± 0.1	−2.0 ± 0.2 †	2, 27	7.64	**0.001** **	0.22	905 ± 12	909 ± 10	923 ± 12	2, 27	0.98	0.380	0.04

Table 6. Effects of odor conditions (“Air,” “L,” and “IVA”) on ERP responses to self-face stimuli in the 800–1000 Ms time window.

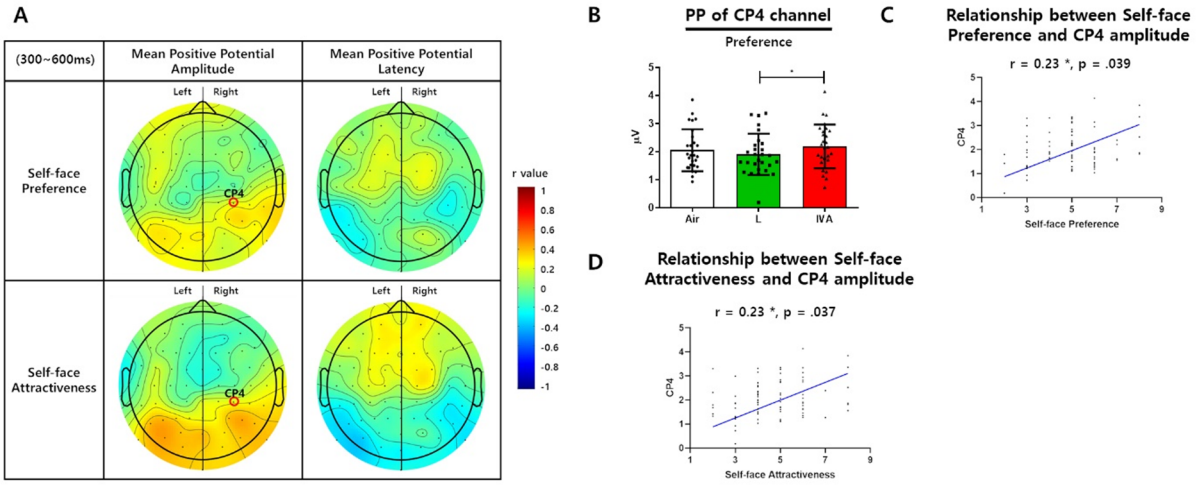

Fig. 5. Topography of correlation between ERPs and self-face perceptions (Preference and Attractiveness) on 300 ~ 600ms. This figure displays the topography patterns of correlation between PPs amplitude and self-face perceptions from 300 to 600ms. (**A**) The circled CP4 channel exhibited a statistically significant correlation between PP amplitude and both self-face preference and attractiveness. (**B**) In the RM-ANOVA with Bonferroni-corrected post-hoc tests, CP4 showed a higher PP amplitude under "IVA" than under "L" in the right hemisphere ($t = 1.55$, $p = .042$). (**C**, **D**) Pearson's two-tailed correlations between CP4 PP amplitude and self-face perceptions with linear regression overlays (95% confidence bands for the best-fit line). The correlations at CP4 were positive (**C**: preference, $r = .23$, $p = .039$; **D**: attractiveness, $r = .23$, $p = .037$). In the post-hoc comparisons, results marked with * were significant at $p < .05$, those marked with ** were significant at $p < .01$, and those marked with *** were significant at $p < .005$.

Data availability

The raw data and datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

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Author contributions
SM, KK, and CM conceived and designed the study. SM and KK performed the experiments. SY, SM, JB, and KK analyzed and interpreted the data, and drafted the article and figures. CM critically revised the article and supervised all experiments and analyses.

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Declarations

Competing interests
The authors declare no competing interests.

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